NBER WORKING PAPER SERIES

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Working Paper 14752
http://www.nber.org/papers/w14752

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
February 2009

We thank Gary Becker, Georgy Egorov, Edward Glaeser, Oliver Hart, Louis Kaplow, Richard Posner, Jesse Shapiro, Steven Shavell, and Lucy White for helpful comments. Schwartzstein acknowledges financial support from an NBER pre-doctoral fellowship in health and aging. The views expressed herein are those of the author(s) and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 14752
February 2009, Revised October 2010
JEL No. D62,K13,K40,L51

ABSTRACT

We propose an activity-generating theory of regulation. When courts make errors, tort litigation becomes unpredictable and as such imposes risk on firms, thereby discouraging entry, innovation, and other socially desirable activity. When social returns to innovation are higher than private returns, it may pay the society to generate some information ex ante about how risky firms are, and to impose safety standards based on that information. In some situations, compliance with such standards should entirely preempt tort liability; in others, it should merely reduce penalties. By reducing litigation risk, this type of regulation can raise welfare.

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1. INTRODUCTION

When would a benevolent government regulate economic activity if courts both enforce contracts and adjudicate tort claims? Not very often, according to standard law and economics arguments. As shown by Coase (1960), so long as people whose behavior might affect each other's welfare can sign enforceable contracts, they will agree to efficient conduct. Even if contracting is costly, efficient tort rules would generally keep harmful acts down to efficient levels and restore efficiency. And these rules are not too complex. For example, when harmful conduct by one party can affect another, strict liability in many cases creates incentives for efficient behavior (Becker 1968, Posner 1973, Spence 1977, Shavell 1980). There is no need for regulation. Despite this logic, regulation is pervasive in many spheres, such as drug, workplace, or product safety, where contracting is extensive and tort law is extremely well developed. The question is why?

In this paper, we propose an activity-generating theory of regulation. The basic idea is that, when courts make errors, tort litigation becomes unpredictable and as such imposes risk on firms. This risk can discourage firm entry, innovation, or more generally activity. In the circumstances where social returns to activity are higher than private returns, perhaps because firms are involved in innovative activity or perhaps because there are frictions in the labor market, it pays the society to encourage activity by reducing litigation risks. One way to do that is to generate some information ex ante about how risky firms are and appropriate standards for precautions they should take. Compliance with such standards need not insulate firms from subsequent tort liability completely if an accident occurs, but can be taken into account by courts. Following Shavell (1984a, b), we think of such ex ante information gathering and standards for precautions as a kind of regulation. By reducing litigation risk firms face, regulation can encourage activity and raise welfare.

Our analysis provides an analytical foundation for the commonly made argument that there is room for regulation when litigation drives firms out of business and discourages the introduction of new products (Viscusi 1991a, Viscusi and Moore 1993). Perhaps the closest to our analysis is the observation by Calabresi (1970, p. 270): "Too large a fine or criminal penalty in an area where errors are likely may, as we have already seen, result in individuals abstaining from conduct we do not wish to affect, such as driving in general, for fear that if they drive at all they may occasionally be incorrectly condemned and penalized." Note that court errors are explicit in Calabresi's quote, and the level of activity, namely driving, is also considered. Our paper presents a formal model in which, when law enforcers make errors, high penalties resulting from efficient negligence rules unnecessarily discourage highly socially desirable activity.

Our analysis also allows an analytical evaluation of the so-called preemption doctrine, which holds that compliance with regulatory requirements should provide "safe harbor" against litigation risks. The U.S. Supreme Court has struggled with this doctrine in the area of medical safety, deciding, on subtle jurisdictional grounds, that FDA approval should preempt tort liability for medical devices (Riegel v Medtronic) but not for drugs (Wyeth v Levine). Although several recent articles examined the doctrine of preemption (Kessler and Vladeck, 2008, Curfman et al. 2008, Glanz et al. 2008, Philipson et al 2009), our paper is the first to examine the conditions under which preemption is efficient in a model of optimal social control of harmful externalities. We show that when social benefits to activity are sufficiently high, the optimal rule is complete safe harbor regulation, whereby a firm that is initially found by the regulator not to need to take precautions is exempt from damages when an accident occurs. Regulatory compliance preempts tort liability. In contrast, if the social benefits of activity are not so large, the optimal policy allows for negligence claims even against firms that comply with regulations but the magnitude of damage awards is lower for such firms. Regulatory compliance does not preempt liability. Under our theory, the preemption doctrine as applied to private common law tort actions might be efficient in governing the safety of vaccines or other pharmaceuticals, but not that of airplanes.

To illustrate how the theory works, consider a simple example. Suppose that a company is considering the construction of a nuclear power plant, and that the design can be either relatively safe or relatively unsafe as captured by the likelihood of an accident allowing radiation to escape. In the latter case, it is first best efficient for the company to invest in additional safety precautions; in the former it is not. Suppose that the social benefits of constructing the plant exceed the private benefits (e.g., national interest in energy independence, reduced pollution), but the plant cannot be subsidized. Nonetheless, if unsafe designs can be perfectly identified, it is conditionally efficient to incentivize companies with such designs to take precautions: The social loss from some such companies avoiding costs by not building is outweighed by the gain from incentivizing those that enter to take precautions. Suppose finally that, if an accident occurs and radiation escapes, the court determines without error whether precautions had been taken, but possibly with error whether the design is unsafe and therefore precautions should have been taken.

In this example, without court errors, a negligence rule can achieve efficient precautions by all firms, and conditionally efficient entry given the constraint that firms cannot be subsidized. With court errors, however, a negligence regime has the unintended consequence that companies with safe designs also face the risk that they will be held liable in the case of an accident for failure to take precautions and, as a result, some may (inefficiently) choose not to operate. Regulators have the ability to encourage entry by making an ex ante determination of whether a design is safe or unsafe and limiting liability costs for companies with designs determined to be safe, even if regulators also make errors. The benefit of introducing such regulation depends on the degree to which it is targeted: It limits liability costs for and only for companies with safe designs. It also depends on the degree to which entry needs to be encouraged, an increasing function of the shortfall of the private benefits of constructing the plant from the social ones.

If introducing such regulation is welfare enhancing, should a regulatory finding that a design is safe eliminate future liability under negligence or merely reduce the damages? If regulators never mistakenly classify an unsafe design as safe then it is unambiguous that liability costs should be eliminated. On the other hand, if regulators make mistakes then some companies with unsafe designs are affected by the regulation. In this case, the answer depends on whether the construction of nuclear plants with unsafe designs is socially beneficial even when precautions are not taken. If yes, then liability costs should still be eliminated. If no, then it is desirable to set low damages (expected damages $<$ cost of precautions) which deter the construction of some plants with unsafe designs without affecting the construction of plants with safe designs.

Our paper is related to several strands of research in law and economics. Becker (1968), Calabresi (1970), and Posner (1972) initiated the research on alternative methods of controlling harmful behavior, and in particular on comparing regulation and litigation. Shavell (1980) and Polinsky (1980) have considered activity levels in assessing the optimal liability rules, but not regulation.

Immordino, Pagano, and Polo (2009) analyze the performance of different methods of controlling harmful externalities when innovation may be discouraged. Png (1986), Kostad, Ulen, and Johnson (1990), and Polinsky and Shavell (2000) examine the implications of errors in enforcement for optimal fines. Kaplow and Shavell (1996) provide a general analysis of the effects of accuracy in the assessment of damages. Gennaioli and Shleifer (2008) endogenize court errors as the result of judicial policy preferences. Essentially, the assumption of errors in law enforcement implies that rules governing the behavior of safe firms also affect unsafe firms, and vice versa.

There is also some research on when regulation might be preferred to litigation. One previously examined case for regulation is based on the judgment-proof problem. If, with liability, damages might be so high that the liable firm or individual would be unable to pay them, regulation might be optimal (Shavell 1984a,b, 1993, Summers 1983). The judgment-proof problem is particularly applicable to small firms with limited resources. However, it is often the large corporations, with considerable resources as well as access to insurance, that are being regulated. Another economic argument for regulation includes the greater expertise of regulators than of judges (Landis 1938, Glaeser, Johnson, and Shleifer 2001); our model allows some results bearing on the question of expertise. Still another idea is that pure liability regimes are more vulnerable to persuasion and bribery because they entail greater ex post fines (Becker and Stigler 1974, Glaeser and Shleifer 2003). In this paper, we abstract from the judgment proof problem or the incentives of law enforcers. Instead, our paper examines the case for regulation under three substantive assumptions: that the structure of penalties affects not just precautions but the level of activity, that private returns to activity are lower than social returns, and that both courts and regulators make errors.

Section 2 presents the basic model of litigation and regulation. Section 3 considers outcomes and social welfare under the efficient liability regime implemented by courts alone, and demonstrates that the activity-generating case for regulation rests on private returns to activity being lower than social returns. Section 4 describes the circumstances under which the addition of regulation improves resource allocation, characterizes efficient regimes, and addresses the question of when preemption is optimal. Section 5 briefly considers firm behavior under two important, but not optimal regimes: strict liabilty and negligence when damages are restricted to equal harm. Section 6 concludes. Before presenting the analysis, we mention two examples to keep in mind.

Example 1. *Drugs*

A drug company decides whether to bring a drug to market and whether to warn physicians of a potential side-effect of taking the drug. For some drugs, the side effect is unlikely given the information known to the drug company. For others, the side effect is likely given the information known to the drug company.

If the enforcement method involves regulators, then prior to a drug's release a regulator decides whether to require the drug company to warn physicians of a potential side-effect in the process of marketing the drug. After an accident occurs, a judge or jury decides whether or not the drug company did and should have warned physicians of a potential side-effect. A plaintiff is awarded damages as a function of these findings, taking into account the regulatory standard as well.

Example 2. *Nuclear power*

A company which is considering whether to construct a nuclear power plant decides whether to build and whether to make additional safety investments. Given the (relatively unsafe) design of some plants, the likelihood that radiation will escape is large and making additional safety investments reduces that likelihood. Given the (relatively safe) design of others, the likelihood that radiation will escape is low and making additional safety investments does not reduce that likelihood.

If the enforcement method involves regulators, then prior to the operator's decision of whether to build, a regulator decides whether to require that additional safety investments be made in the event that the plant is built. After an accident occurs, a judge or jury decides whether or not proper safety investments were made. A plaintiff is awarded damages as a function of these findings, taking into account the regulatory requirement as well.

2. MODEL

2.1. **Setup.** A firm decides whether or not to engage in an activity, $y \in \{0, 1\}$ (whether to bring a drug to market, to build a nuclear power plant). If it does not engage in activity ($y = 0$), it receives a payoff of 0. If it engages in activity, it receives private gross payoff $b - e$, where

- b is the gross social return to firm activity, which is constant across firms, and
- $e \sim U[0, \bar{e}]$ ($\bar{e} < b$) is a firm specific parameter that measures the shorfall of the private gross benefit of an activity from the social one. In most models of law enforcement, $e = 0$ for all firms ($\bar{e} = 0$), but here we focus on the more general, and perhaps more interesting, case.[1]

Our assumption that $e \geq 0$ applies to any industry where, before taking harmful externalities into account, firms do not fully internalize the social surplus generated by their activity. This could be true because of positive externalities (e.g., nuclear power or R&D), asymmetric information or moral hazard (e.g., a monopolist does not fully internalize the social surplus if it cannot completely price discriminate; a firm faces greater private than social costs if it needs to pay efficiency wages), or consumers being unable to afford to pay their valuations (e.g., hospital beds).[2]

Crucially, we make the fairly standard assumption that firms cannot be subsidized, which is important given that firms may not capture the full social benefit from their activity. One way to justify this assumption is that subsidies are costly, and the government has to raise distortionary taxes to finance subsidies. With many competing claims on public funds, the marginal social cost of providing subsidies could be high.[3] Another way to justify why subsidies are not given is that they would invite a line of firms outside government offices arguing for positive externalities from

[1]In our model, firms vary in their ability to appropriate social benefits. Another interpretation is that there is a single, representative, firm but courts and regulators are uncertain about that firm's ability to appropriate social benefits. We obtain similar but messier results under the alternative assumption that firms vary in the social returns from their activity (b) and private returns equal αb ($0 \leq \alpha \leq 1$).

[2]Our model does not apply to perfectly competitive markets in the absence of market failures (even though there are zero profits), since, at the margin, firms face the private gross benefit of price = marginal cost = valuation of marginal consumer.

[3]A more general model could allow for subsidies conditional on a firm engaging in activity, but specify that raising 1 dollar to subsidize firms costs society $(1 + \lambda)$, where $\lambda > 0$ represents the exogneously given shadow cost of public funds (as in Laffont and Tirole, 1993). We do not believe that generalizing the model in this manner would lead to qualitatively different insights, but it would complicate the analysis.

their activity (Banerjee 1997). Firms would alter their lines of activity to seek public funds. The government would then need to evaluate all these potential beneficiaries, a socially costly endeavor especially when the government makes mistakes or is vulnerable to inappropriate influence.

Assumption 0. *Transfers to firms are not possible.*

If a firm engages in the activity, it also decides on its level of precautions $p \in \{0, 1\}$ (whether or not to warn physicians of a potential side-effect of taking a drug, to make additional safety investments). Not taking precautions ($p = 0$) is costless. Taking precautions ($p = 1$) costs the firm c and may decrease the probability of an accident. The accident imposes a social cost h, which is assumed to be the same for all accidents.

The payoff to the firm if it engages in activity is

$$(b - e - cp - L), \tag{1}$$

where L stands for expected liability costs given the firm's type and its level of precautions.

The firm's problem is to choose its level of precautions $p \in \{0, 1\}$ and activity $y \in \{0, 1\}$ to maximize

$$(b - e - cp - L)y. \tag{2}$$

The social payoff that results from a given firm choosing precautions p and activity y equals

$$(b - cp - H)y, \tag{3}$$

where H stands for expected harm given the firm's type and level of precautions.

For each firm, activity is a 0, 1 decision. The *activity level* of firms that face expected costs $cp + L$ if they choose to operate equals the count of the number of firms for which this cost is less than the private benefit of activity, $b - e$. Equivalently, the activity level equals the number of firms for which $e \leq b - cp - L$. By the assumption that $e \sim U[0, \bar{e}]$, this level equals

$$\min\left\{\frac{b - cp - L}{\bar{e}}, 1\right\}. \tag{4}$$

Firms differ in whether or not taking precautions is efficient. Denote this aspect of the firm's type by θ, which is independent of e. Fraction $\alpha < 1$ of firms are safe, $\theta = S$. For a safe firm, the probability of an accident is independent of the level of precautions and equals $\pi_S(p) \equiv \pi_S > 0$. Hence it is socially inefficient for the safe firm to take precautions.

Fraction $1 - \alpha < 1$ of firms are unsafe, $\theta = U$. For an unsafe firm, the probability of an accident depends on whether or not it takes precautions. If it fails to take precautions, the probability of an accident is $\pi_U(0) \equiv \pi_U > \pi_S$. If it takes precautions, the probability of an accident is $\pi_U(1) \equiv \pi_U^L < \pi_U$.

We assume that it is socially efficient for unsafe firms to take precautions conditional on engaging in activity:

Assumption 1. $(\pi_U - \pi_U^L)h > c$.

We also assume that unsafe firms generate positive social returns to activity so long as they take precautions (guaranteeing that it is never optimal to shut down a firm) but do not restrict whether they generate positive returns if they fail to take precautions. Additionally, we assume that safe firms generate positive social returns to activity.

Assumption 2. $b > \max\{c + \pi_U^L h, \pi_S h\}$.

2.2. **First best.** Before introducing courts and regulators, briefly consider the market failure. To solve for the first best, maximize social payoff (3) with respect to activity y and precautions p for each firm. Under our assumptions, it is clear that, in the first best, safe firms do not take precautions, unsafe firms take precautions, and all firms engage in activity. Welfare in the first best is:

(5) $$W^{FB} = \alpha(b - \pi_S h) + (1 - \alpha)(b - c - \pi_U^L h).$$

2.3. **Laissez-faire.** In the absence of liability rules, each firm maximizes

(6) $$(b - e - cp)y,$$

since each firm faces zero liability costs ($L = 0$). As a consequence, all firms engage in activity (since $\bar{e} < b$ by assumption) and no firm takes precautions since $c > 0$. Welfare under laissez-faire is

$$W^{LF} = \alpha(b - \pi_S h) + (1 - \alpha)(b - \pi_U h). \tag{7}$$

The difference in welfare between the first best and laissez-faire is given by $W^{FB} - W^{LF} = (1 - \alpha)[(\pi_U - \pi_U^L)h - c]$, which is the social loss from unsafe firms taking inefficiently few precautions (this loss is positive by Assumption 1).

Courts and regulators can help bring outcomes more in line with the first best.

2.4. **Courts.** A case is brought against a firm if and only if it causes an accident.[4] If a case is brought, the court can observe whether the firm took precautions as well as a noisy signal σ_J of firm safety $\theta \in \{S, U\}$, where

$$\begin{aligned} \text{Prob}[\sigma_J = \hat{S} | \theta = U, e = e'] &= \epsilon_{S|U} \\ \text{Prob}[\sigma_J = \hat{U} | \theta = S, e = e'] &= \epsilon_{U|S} \end{aligned}$$

for all $e' \in [0, \bar{e}]$. Here $\epsilon_{S|U}$ and $\epsilon_{U|S}$ represent court errors in determining whether a firm is safe. We assume that errors cannot be "too large" or, equivalently, that court signals are informative:

Assumption 3. $0 \leq \epsilon_{S|U} < 1/2,\ 0 \leq \epsilon_{U|S} < 1/2.$

The court imposes damages $D \geq 0$, where D is a function of whether the firm took precautions, as well as available information regarding firm safety. While the court verifies the firm's type with error, it is able to perfectly verify whether precautions had been taken (it can verify whether safety investments were made, inspections conducted, or doctors warned).

2.5. **Regulators.** If the enforcement method involves regulators as well then, prior to a firm's choice of precautions and activity, a regulator generates a public signal σ_R which is correlated with

[4]Setting the probability of a lawsuit to equal one is without loss of generality since damages are not capped. For the same reason, we do not need to consider court injunctions to activity.

firm safety θ, where

$$\text{Prob}[\sigma_R = \hat{S} | \theta = U, e = e'] = \delta_{S|U}$$

$$\text{Prob}[\sigma_R = \hat{U} | \theta = S, e = e'] = \delta_{U|S}$$

for all $e' \in [0, \bar{e}]$. The public signal is interpreted as reflecting the regulator's *ex ante* determination of whether the firm is unsafe and should take precautions (i.e., the firm is determined to be unsafe if and only if $\sigma_R = \hat{U}$). Then $\delta_{S|U}$ and $\delta_{U|S}$ are regulatory errors in firm classification. We assume that these errors cannot be "too large" or, equivalently, that the regulatory signals are informative.

Assumption 4. $0 \leq \delta_{S|U} < 1/2, \ 0 \leq \delta_{U|S} < 1/2.$

For simplicity, we assume that regulators and courts observe independent signals conditional on a firm's type:

Assumption 5. *Prob*$[\sigma_R = r, \sigma_J = j|$*firm's type*$]$ = *Prob*$[\sigma_R = r|$*firm's type*$] *$ *Prob*$[\sigma_J = j|$*firm's type*$]$ *for all* $r = \hat{S}$ *or* $\hat{U}$ *and* $j = \hat{S}$ *or* $\hat{U}$.

The regulatory classification can be considered by the court in setting damages. It is not important that the court (rather than the regulator) imposes a penalty in the case of an accident. It is important, however, that the penalty can be set taking into account the regulatory classification together with the court's signal.[5]

Summarizing the timing of the model:[6]

[5]A "command and control" regulatory regime is suboptimal in our model, where "command and control" here means that a regulator may penalize a firm for failure to take precautions regardless of whether there is an accident. The intuition is that it is desirable to make all liability costs contingent on whether accident occurs as well as the court's signal in order to minimize safe firms' exposure to such costs.

[6]We assume that each firm faces an indirect incentive scheme $D(p, \sigma_R, \sigma_J)$ in choosing its precautions p and activity y in period 2. Our analysis would remain the same if we instead assumed that, after σ_R is generated, society offers a direct mechanism $\{t(\theta, e, \sigma_R, \sigma_J), p(\theta, e, \sigma_R), y(\theta, e, \sigma_R)\}$ and each firm decides whether to accept the mechanism and, if so, makes an announcement of its type $(\hat{\theta}, \hat{e})$, where $t(\hat{\theta}, \hat{e}, \sigma_R, \sigma_J) \geq 0$ represents the size of the transfer from the firm in the event of an accident given the announcement of its type and information about its safety (analyzing the performance of such direct revelation mechanisms in studying regulation is quite popular - e.g., Laffont and Tirole 1993). The argument for why this would not change the analysis is simple and closely follows Fudenberg and Tirole (1991, page 257). Suppose allocation $(p(\theta, e, \sigma_R), y(\theta, e, \sigma_R))$ is implementable through transfer function

- Period 0: Each firm learns its true type (θ, e). The damage award function $D(\cdot) \geq 0$ is announced, where $D = D(p, \sigma_J)$ if the enforcement method only involves courts and $D = D(p, \sigma_J, \sigma_R)$ if the method also involves regulators.
- Period 1: If the enforcement method involves regulators, then, for each firm, the regulator generates a public signal σ_R which is correlated with firm safety θ.
- Period 2: Each firm decides whether to engage in activity ($y \in \{0, 1\}$) and whether to take precautions ($p \in \{0, 1\}$).
- Period 3: If a firm causes an accident then the court generates a signal σ_J which is correlated with firm safety θ and imposes damages D in accordance with the previously announced damage award function $D(\cdot)$.

3. Courts Alone

We first consider the performance of courts alone ($D = D(p, \sigma_J)$). For any enforcement regime involving only courts (as described by $D(p, \sigma_J)$), each firm chooses its level of precautions and activity to maximize (2). Denote the maximum level of social welfare achievable by an enforcement regime only involving courts by W^C.

3.1. **Special case: No Positive Externalities to Firm Activity.**

Consider the special case where, before taking harmful externalities into account, firms fully internalize the social surplus generated by their activity: $\bar{e} = 0$. For simplicity, we refer to this case as one with no positive externalities to firm activity.

In this special case, courts alone can implement the first best. Consider a strict liability regime with damages equal to harm (i.e., a firm pays h whenever it causes an accident). Under this regime, each firm chooses precautions p and activity y to maximize

$$(b - e - cp - H)y = (b - cp - H)y, \tag{8}$$

$t = t(\theta, e, \sigma_R, \sigma_J)$. Then the following damage award function implements the same allocation:

$$D(p, \sigma_R, \sigma_J) = \begin{cases} t & \text{if there exists } (\hat{\theta}, \hat{e}) \text{ such that } t = t(\hat{\theta}, \hat{e}, \sigma_R, \sigma_J), p = p(\hat{\theta}, \hat{e}, \sigma_R), \text{ and } 1 = y(\hat{\theta}, \hat{e}, \sigma_R) \\ & \text{(if there are several such } (\hat{\theta}, \hat{e}) \text{, pick one)} \\ -\infty & \text{otherwise.} \end{cases}$$

where the equality follows from $0 \leq e \leq \bar{e} = 0$ (recall that H stands for expected harm given the firm's type and level of precautions). Since the right hand side of (8) is exactly the social payoff that results from a given firm choosing precautions p and activity y (i.e., it is equivalent to (3)), we have the following proposition.

Proposition 1. *With no positive externalities to firm activity ($\bar{e} = 0$), courts alone can implement the first best through a regime of strict liability with damages equal to harm.*

Proposition 1 establishes that, absent positive externalities to firm activity, there is no role for regulation. Strict liability with damages equal to harm ensures that precautions and activity levels are first best. In particular, generating additional information about firm safety cannot be helpful in this, standard, scenario. In fact, there is no need to collect *any* information about firm safety to create incentives for efficient precuations without distorting activity.[7]

However, there may be room for regulation when there are positive externalities to firm activity ($\bar{e} > 0$). To develop a useful necessary condition for when regulation can help in this, more general, case, we first establish a tighter bound on what is achievable by regimes involving both courts and regulators.

3.2. **General case.**

3.2.1. *Full Information Benchmark.* With the enforcement regimes we consider, welfare cannot be higher than when damages are made directly contingent on whether a firm is safe or unsafe (i.e., $D = D(p, \theta)$) and are set to maximize social surplus. We use this *full information benchmark* to assess the performance of alternative enforcement methods.

To limit the number of cases considered and to keep the problem interesting, we assume that, absent subsidies, the net effect on social welfare of mandating that unsafe firms take precautions is positive (taking into account the impact on both the likelihood of an accident and activity):

Assumption 6. $\min\left\{\frac{b-c}{\bar{e}}, 1\right\}(b - c - \pi_U^L h) > b - \pi_U h.$

[7]Absent positive externalities, the results of the next subsection (Subsection 3.2) imply that a properly designed negligence regime can also implement the first best: court errors do not matter. If there is limited liability, generating information about firm safety can help create incentives for firms to take efficient *precautions* (e.g., Glaeser and Shleifer 2003).

When Assumption 6 does not hold, laissez-faire is necessarily optimal.[8]

When damages can be made contingent on firm safety, it is clear that the damage schedule for unsafe firms should be set to create incentives for these firms to take precautions (by Assumption 6) while not exposing these firms to damages when they *do* take precautions (by Assumption 2).[9] It is also clear that it is (weakly) optimal to never expose safe firms to damages (by Assumption 2). Under any damage schedule satisfying these conditions, unsafe firms take precautions and engage in activity so long as $e \leq b - c$, while safe firms do not take precautions and all engage in activity. Welfare equals

$$W^{FI} = \alpha(b - \pi_S h) + (1 - \alpha) \min\left\{\frac{b - c}{\bar{e}}, 1\right\}(b - c - \pi_U^L h). \tag{10}$$

Comparing this upper bound on welfare with welfare under the first best, we have

$$W^{FB} - W^{FI} = (1 - \alpha)\left(1 - \min\left\{\frac{b - c}{\bar{e}}, 1\right\}\right)(b - c - \pi_U^L h), \tag{11}$$

which is the loss from some unsafe firms choosing not to operate given the costs of precautions (recall that $e \sim U[0, \bar{e}]$). If $\bar{e} \leq b - c$ then this loss is zero, reflecting the fact that if positive externalities are sufficiently low then no loss results from the inability to directly control firm activity (or from the inability to subsidize firms).

In the remainder of the paper, we analyze and compare firm behavior under enforcement regimes implemented by courts alone or regulators together with courts, and consider when adding regulators gets closer to the full information benchmark. We maintain Assumptions 0-6 throughout the paper, except in our statement of Proposition 5 where we relax Assumption 6.

3.2.2. *Negligence.* Consider negligence regimes, in which damages are zero whenever a firm takes precautions or is found to be safe. As illustrated in Figure 1, any negligence regime can be described by $d \geq 0$, the level of damages a firm must pay in the case of an accident if it is found

[8]One simple condition that implies Assumption 6 is $(\pi_U - \pi_U^L)h > 2c$.

[9]For example, the planner could set

$$D(p, U) = \begin{cases} \frac{c}{\pi_U} & \text{if } p = 0 \\ 0 & \text{if } p = 1. \end{cases} \tag{9}$$

to have not taken precautions and to be unsafe. Negligence regimes are a subset of all enforcement regimes involving only courts. Denote the maximum level of social welfare achievable by a negligence regime by W^N.

p \ σ_J	$\hat{S}$	$\hat{U}$
0	0	d
1	0	0

FIGURE 1. Damages under negligence, where damages are a function of the level of precautions ($p \in \{0, 1\}$) and the court's signal ($\sigma_J \in \{\hat{S}, \hat{U}\}$).

To illustrate, take the drug example. Under negligence, after an accident occurs, a judge or jury decides both whether the drug company did and whether it should have warned physicians of a potential side-effect. A plaintiff is awarded damages if the court decides (possibly incorrectly) that the drug company should have warned but failed to do so.

Lemma 1. $W^N = W^C$.

By Lemma 1 we only need to consider negligence regimes to establish what is achievable through enforcement methods that only involve courts. The intuition for why negligence regimes are optimal is that, by using the maximal amount of information regarding a firm's type and whether precautions have been taken, such regimes minimize safe firms' exposure to liability costs (fixing desired behavior on the part of unsafe firms) and eliminate unsafe firms' exposure conditional on taking precautions. We next ask when negligence, and thus courts alone, can implement the full information benchmark. This outcome can be achieved through a negligence regime if and only if it can be achieved when damages are the minimum necessary to create incentives for unsafe firms to take precautions. Label such damages $\bar{d}$, so:

$$\underbrace{c}_{\text{cost of precautions}} = \underbrace{\pi_U(1-\epsilon_{S|U})\bar{d}}_{\text{expected liability cost for an unsafe firm if no precautions}} \Rightarrow$$

$$\overline{d} = \frac{c}{(1-\epsilon_{S|U})\pi_U}.$$

When $d = \overline{d}$, a safe firm optimally chooses *not* to take precautions since such firms are less likely than unsafe firms to cause an accident and to be found unsafe:

(12) $$\underbrace{c}_{\text{cost of precautions}} > \underbrace{\pi_S \epsilon_{U|S}\overline{d}.}_{\text{expected liability cost for a safe firm if no precautions}}$$

Now we consider firm activity when $d = \bar{d}$. Because damages $\bar{d}$ are such that unsafe firms take precautions, these firms are not exposed to liability costs. As a result, a given unsafe firm engages in activity if

(13) $$b - e - c \geq 0.$$

Inequality (13) implies that the activity level of unsafe firms is

(14) $$\min\left\{\frac{b-c}{\bar{e}}, 1\right\},$$

which is the full information benchmark level.

Because damages $\overline{d}$ are such that safe firms do not take precautions, they are exposed to liability costs due to court errors. As a result, a given safe firm engages in activity if

(15) $$b - e - \pi_S \epsilon_{U|S}\overline{d} \geq 0.$$

Inequality (15) implies that the activity level of safe firms is

(16) $$\min\left\{\frac{b - \pi_S \epsilon_{U|S}\overline{d}}{\bar{e}}, 1\right\},$$

which is the full information benchmark level if and only if

$$\bar{e} \leq b - \pi_S \epsilon_{U|S} \overline{d}. \tag{17}$$

We have proved the following:

Proposition 2. *Courts alone can implement the full information benchmark if and only if*

$$\bar{e} \leq b - \pi_S \epsilon_{U|S} \overline{d} \equiv \tilde{e}. \tag{18}$$

Proposition 2 establishes a necessary and sufficient condition for courts alone to implement the full information benchmark and there to be no room for regulation. There is no room for regulation when inequality (18) holds, which is the condition for it to be possible for a negligence regime to create incentives for unsafe firms to take precautions without deterring safe firms from participating in the market. In particular, courts alone can implement the full information benchmark whenever positive externalities are sufficiently small or courts mistake safe firms as unsafe with sufficiently low probability: Inequality (18) is satisfied whenever $\bar{e}$ is sufficiently small (fixing $\epsilon_{U|S}$) or $\epsilon_{U|S}$ is sufficiently small (fixing $\bar{e}$).

To illustrate, suppose that, absent the harmful externalities controlled by the negligence rule, the private and social returns to introducing a drug are similar. Then Proposition 2 says that there is no welfare benefit from having the FDA make an *ex ante* determination of whether a drug company should issue a warning of a potential side effect. Likewise, suppose judges (or juries) have sufficient expertise that they only find that a drug company should have warned physicians of a potential side-effect when issuing such a warning would have in fact been socially efficient. If judges and juries really have such expertise, then there are no additional benefits of regulation either, since negligence assures correct incentives. Matters may be different if the social benefits of drug introduction greatly exceed the private ones, and judges and juries do not have sufficient expertise.

When inequality (18) does not hold, the addition of regulators may be beneficial. Before turning to this issue, it will be helpful to derive optimal damages under courts alone. When any negligence regime that creates incentives for unsafe firms to take precautions deters safe firms from participating in the market ($\bar{e} > \tilde{e}$), it may be optimal to set damages below the level that incentivizes precautions ($\bar{d}$). If unsafe firms generate positive social returns in the absence of precautions ($b \geq \pi_U h$), a damage award of zero is the obvious candidate among damage awards in this range since lowering the award encourages greater (and more efficient) activity while bringing out the same level of precautions. On the other hand, if unsafe firms generate negative social returns in the absence of precautions ($b < \pi_U h$), a damage award of zero cannot be optimal because it is possible to set a small but positive award that efficiently lowers the activity level of unsafe firms while not affecting the activity level of safe firms (recall that unsafe firms are more likely to cause harm and be held liable if an accident occurs). The obvious candidate in this case is $\frac{b-\bar{e}}{\pi_S \epsilon_{U|S}}$, which is the maximum damage award that does not affect the activity level of safe firms. Define

$$\underline{d} = \begin{cases} \frac{b-\bar{e}}{\pi_S \epsilon_{U|S}} & \text{if } b < \pi_U h \\ 0 & \text{if } b \geq \pi_U h. \end{cases} \tag{19}$$

When $\bar{e} > \tilde{e}$, damages should be set by comparing the benefit of creating incentives for unsafe firms to take precautions with the cost of discouraging safe firms from engaging in activity. Let

$$G_S = \left[1 - \left(\frac{b - \pi_S \epsilon_{U|S} \bar{d}}{\bar{e}}\right)\right](b - \pi_S h) \tag{20}$$

represent the expected gain from increasing a given safe firm's incentive to engage in activity by reducing damages from $\bar{d}$ to $\underline{d}$. Further, let

$$L_U = \frac{b-c}{\bar{e}}(b - c - \pi_U^L h) - \min\left\{\frac{b - \pi_U(1 - \epsilon_{S|U})\underline{d}}{\bar{e}}, 1\right\}(b - \pi_U h) \tag{21}$$

represent the expected loss from eliminating a given unsafe firm's incentive to take precautions by reducing damages from $\bar{d}$ to $\underline{d}$.

Letting $W(d)$ equal social welfare as a function of the level of damages under negligence and defining d^* to equal the smallest maximizer of $W(d)$ – i.e., $d^* = \min \arg\max_{d \geq 0} W(d)$ – we have the following result:

Proposition 3. *If $\bar{e} > \tilde{e}$, then optimal damages under negligence are given by*

$$d^* = \begin{cases} \bar{d} & \text{if } \alpha < \frac{L_U}{L_U+G_S} \\ \underline{d} & \text{if } \alpha \geq \frac{L_U}{L_U+G_S}. \end{cases} \tag{22}$$

Proposition 3 characterizes the optimal negligence regime when positive externalities and court errors are sufficiently large that negligence cannot implement the full information benchmark. Proposition 3 says that damages should be high enough to create incentives for unsafe firms to take precautions if and only if the proportion of safe firms (α) is sufficiently low. The intuition is that the cost of setting large damages is the loss from detering safe firms from participating in the market due to court errors; this loss is proportional to the number of safe firms that are affected.

4. ADDING REGULATORS

When safe firms capture an insufficient amount of the social surplus generated by their activity and courts mistake safe firms as unsafe with sufficiently large probability ($\bar{e} > \tilde{e}$), then any negligence regime that encourages unsafe firms to take precautions necessarily lowers the activity level of safe firms. In this situation, the addition of regulators may help by reducing safe firms' exposure to liability costs while maintaining incentives for at least some unsafe firms to take precautions.

To illustrate most simply, first consider the extreme case where regulators perfectly classify firms ($\delta_{U|S} = \delta_{S|U} = 0$), and consider the following "safe harbor" regime involving regulators: firms are immune from liability in the case of an accident if they are *ex ante* classified as being safe by the regulator while firms are subject to a negligence claim with damages $\bar{d}$ in the case of an accident if they are *ex ante* classified as unsafe by the regulator. It is clear that this combined regime implements the full information benchmark, thus improving on the court-only outcome when $\bar{e} > \tilde{e}$.

More generally ($\delta_{U|S} \geq 0, \delta_{S|U} \geq 0$), consider enforcement methods involving courts and regulators of the following form: In the case of an accident, a firm is subject to a negligence claim, and the magnitude of damages if found liable may depend on the regulatory classification. As illustrated in Figure 2, any enforcement method involving both regulators and courts of this form is described by $(d_{\hat{S}}, d_{\hat{U}})$, where $d_{\hat{\theta}} \geq 0$ is the the level of damages a firm *ex ante* classified as type $\hat{\theta} \in \{\hat{S}, \hat{U}\}$ must pay in the case of an accident if it is found to have not taken precautions and to be unsafe. Since we allow $d_{\hat{S}} = d_{\hat{U}}$, mixed regimes of this type nest pure negligence. Denote the maximum level of social welfare achievable by such an enforcement method by W^{N+R}

		σ_J: $\hat{S}$	σ_J: $\hat{U}$
p	0	0	$d_{\hat{\theta}}$
	1	0	0

FIGURE 2. Damages under negligence combined with regulation, where damages are a function of the level of precautions ($p \in \{0, 1\}$), the court's signal ($\sigma_J \in \{\hat{S}, \hat{U}\}$), and the regulatory classification ($\sigma_R \in \{\hat{S}, \hat{U}\}$).

To illustrate, return to the drug example. Prior to a drug's release, a regulator determines whether the drug company should warn physicians of a potential side-effect in the process of marketing the drug. If an accident occurs, a case against the drug company is brought to court. A judge or jury then determines whether or not the drug company did and should have warned physicians of a potential side-effect. A plaintiff is awarded damages if the court decides (possibly incorrectly) that the drug company should have warned but failed to do so. The magnitude of damages may depend on the regulator's previous classification.

We can restrict attention to such mixed regimes by the following Lemma, where W^{C+R} denotes the maximum level of social welfare achievable by an enforcement regime involving both courts and regulators. The intuition is the same as for why we can restrict attention to negligence regimes among those that only involve courts.

Lemma 2. $W^{C+R} = W^{N+R}$.

What is the optimal combination of $(d_{\hat{S}}, d_{\hat{U}})$? Proposition 3 indicates that the optimal combination will depend on the proportion of safe firms among those classified as safe and unsafe. Let

$$\alpha_{\hat{S}} = \text{Prob}(S|\sigma_R = \hat{S}) = \frac{(1-\delta_{U|S})\alpha}{(1-\delta_{U|S})\alpha + \delta_{S|U}(1-\alpha)}$$

denote the fraction of safe firms among those classified by the regulator as safe and

$$\alpha_{\hat{U}} = \text{Prob}(S|\sigma_R = \hat{U}) = \frac{\delta_{U|S}\alpha}{\delta_{U|S}\alpha + (1-\delta_{S|U})(1-\alpha)}$$

denote the fraction of safe firms among those classified by the regulator as unsafe.

Define $W(d_{\hat{S}}, d_{\hat{U}})$ to equal social welfare as a function of the level of damages and note that $W(d_{\hat{S}}, d_{\hat{U}})$ can be expressed as $\text{Prob}(\sigma_R = \hat{S})W_{\hat{S}}(d_{\hat{S}}) + \text{Prob}(\sigma_R = \hat{U})W_{\hat{U}}(d_{\hat{U}})$, where $W_{\hat{\theta}}(d_{\hat{\theta}})$ equals expected welfare conditional on a firm being classified as $\hat{\theta}$. Finally, let $d^*_{\hat{\theta}}$ equal the smallest maximizer of $W_{\hat{\theta}}(d_{\hat{\theta}})$; i.e., $d^*_{\hat{\theta}} = \min \arg\max_{d \geq 0} W_{\hat{\theta}}(d)$.

Proposition 4. *Let $\bar{e} > \tilde{e}$, $\delta_{S|U} > 0$, and $\delta_{U|S} > 0$. Then damages in the optimal combined regime are given by*

$$d^*_{\hat{S}} = \begin{cases} \bar{d} & \textit{if } \alpha_{\hat{S}} < \frac{L_U}{L_U + G_S} \\ \underline{d} & \textit{if } \alpha_{\hat{S}} \geq \frac{L_U}{L_U + G_S} \end{cases} \tag{23}$$

$$d^*_{\hat{U}} = \begin{cases} \bar{d} & \textit{if } \alpha_{\hat{U}} < \frac{L_U}{L_U + G_S} \\ \underline{d} & \textit{if } \alpha_{\hat{U}} \geq \frac{L_U}{L_U + G_S}. \end{cases} \tag{24}$$

Proposition 4 characterizes the optimal combined regime when positive externalities and court errors are sufficiently large that negligence alone cannot implement the full information benchmark. This Proposition says that the level of damages faced by firms *ex ante* classified as unsafe (safe) by the regulator should be set high enough to create incentives for unsafe firms to take precautions if and only if the proportion of safe firms among those classified as unsafe (safe) is sufficiently low.

When does the optimal combined regime in fact make use of regulators?

Definition 1. *The optimal regime includes regulation whenever* $d^*_{\hat{S}} \neq d^*_{\hat{U}}$.

Corollary 1. *Suppose the conditions of Proposition 4 hold. Then the optimal regime includes regulation if and only if*

$$\alpha_{\hat{S}} \geq \frac{L_U}{L_U + G_S} > \alpha_{\hat{U}}. \tag{25}$$

By Corollary 1, the optimal regime includes regulation if and only if safe firms comprise a large enough fraction of those firms *ex ante* classified as safe by the regulator *and* unsafe firms comprise a large enough fraction of those firms classified as unsafe. In particular, regulators increase welfare if and only if they are sufficiently good at determining whether a firm should efficiently take precautions. Formally, $\alpha_{\hat{S}}$ is decreasing in regulatory errors, $\delta_{S|U}$ and $\delta_{U|S}$, and tends to 1 as these errors approach zero; $\alpha_{\hat{U}}$ is increasing in these errors and tends to 0 as these errors approach 0. Corollary 1 thus provides some formal support for Landis's (1938) claim that the central benefit of regulators relative to judges is greater expertise.

Corollary 2. *Suppose the conditions of Proposition 4 hold.*

(1) *If* $b \geq \pi_U h$ *then whenever the optimal regime includes regulation,* $(d^*_{\hat{S}}, d^*_{\hat{U}}) = (0, \bar{d})$. *Compliance with regulatory standards exempts firms from liability.*

(2) *If* $b < \pi_U h$ *then whenever the optimal regime includes regulation,* $(d^*_{\hat{S}}, d^*_{\hat{U}}) = \left(\frac{b-\bar{e}}{\pi_S \epsilon_{U|S}}, \bar{d}\right)$. *Compliance with regulatory standards reduces but does not eliminate liability.*

Corollary 2 is illustrated in Figure 3 and says that when the optimal law enforcement regime includes regulation and unsafe firms generate positive social returns even if they fail to take precautions, firms are granted immunity from future liability if they meet the safety standard set by the regulator. On the other hand, when unsafe firms generate negative social returns if they fail to take precautions, firms are subject to negligence claims even if they meet the standard set by the regulator but the magnitude of damage awards is lower for firms which meet that standard.

The intuition behind these results is as follows. A pure negligence regime can always incentivize full information benchmark precautions for all firms and full information benchmark activity for unsafe firms. Consequently, the addition of regulators can only improve matters when the activity

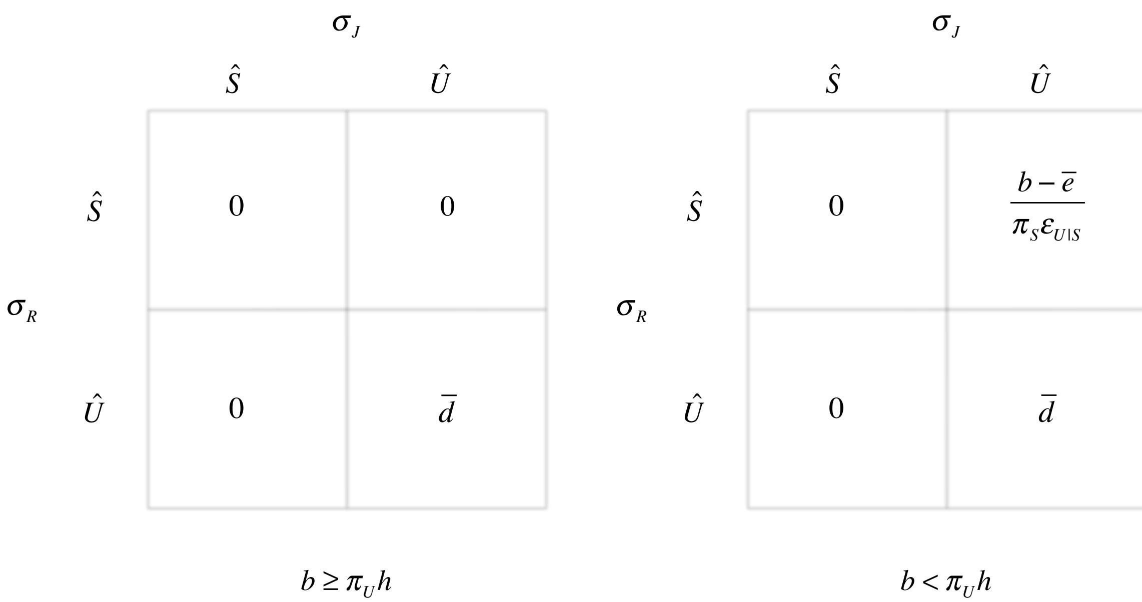

FIGURE 3. Damages under the optimal regime whenever it includes regulation. Damages are a function of the regulatory classification ($\sigma_R \in \{\hat{S}, \hat{U}\}$), the court's signal ($\sigma_J \in \{\hat{S}, \hat{U}\}$), and the social returns from firm activity (b) as compared to expected harm generated by an unsafe firm that does not take precautions ($\pi_U h$). Everything is conditional on a firm not taking precautions (damages are identically 0 otherwise).

level of safe firms is less than the full information benchmark under negligence alone. In this case, regulators have the ability to encourage entry by limiting liability costs for safe firms through setting a damage award for firms classified as safe which is lower than the minimum necessary to incentivize precautions among the unsafe firms mistakenly classified as safe. When unsafe firms generate positive social returns in the absence of precautions, a damage award of zero is clearly optimal among awards in this range, since lowering the award encourages greater (and more efficient) activity while bringing out the same level of precautions. On the other hand, when unsafe firms generate negative social returns in the absence of precautions and unsafe firms are sometimes mistakenly classified as safe, it is no longer optimal to set a damage award of zero. This is because it is possible to set a small but positive award that efficiently lowers the level of activity of unsafe firms mistakenly classified as safe, while not affecting the level of activity of safe firms (recall that unsafe firms are more likely to cause harm and be held liable if an accident occurs).

This result may shed light on the important policy question of whether regulation should preempt subsequent litigation against firms that comply with regulatory rules by providing them with safe harbor from future negligence awards. The answer, according to our analysis, turns on whether the social benefits of activity in the particular sphere exceed expected harm from accidents even when firms do not take proper care. For example, for medical innovations, such as vaccines, drugs, or medical instruments, one might think that there is indeed a case for preemption, and one based on efficiency rather than jurisdictional grounds. On the other hand, in situations such as airplane safety maintenance, where it is difficult to argue that the social benefits of an activity outweigh expected harm when proper care is not taken, our analysis provides no justification for preemption. Rather, the efficient enforcement regime combines regulation with negligence.

4.1. **Benefits and Costs of Revealing Information About Firm Safety *Ex ante*.** Regulators are modeled as generating and revealing additional information about firm safety *ex ante* (prior to a firm's choice of precautions and activity), which allows each firm to respond to its regulatory classification. This is how regulation tends to work in practice. It is possible, however, that a more efficient outcome could be achieved if this information was instead revealed *ex post*, for example at the time of a trial. While a formal examination of when it is optimal to reveal information *ex ante* lies outside the scope of our analysis, we briefly sketch the associated benefits and costs.

Simplify by considering the special case where courts alone have no information available to them ($\epsilon_{S|U} = \epsilon_{U|S} = 1/2$) and suppose $b > \pi_U h$. There is an additional signal, $\sigma \in \{\hat{S}, \hat{U}\}$, with associated errors, $\lambda_{S|U} < 1/2$ and $\lambda_{U|S} < 1/2$. This signal can be revealed *ex ante* or *ex post*. When σ is revealed *ex ante*, we are in a situation equivalent to that described in Section 3: we can confine attention to enforcement methods described by d^{EP}, where d^{EP} is the level of damages a firm must pay in the case of an accident if it is found to have not taken precautions and $\sigma = \hat{U}$. Further, the optimal value of d^{EP} lies in $\{0, \bar{d}^{EP}\}$, where

$$\bar{d}^{EP} = \frac{c}{\pi_U(1 - \lambda_{S|U})}.$$

When σ is revealed *ex post* we are in a situation analagous to that described in the previous subsection and can confine attention to enforcement methods described by $(d^{EA}_{\hat{S}}, d^{EA}_{\hat{U}})$, where $d^{EA}_{\hat{\theta}}$

is the level of damages a firm must pay in the case of an accident if it is classified as type θ. The optimal value of $d_{\hat{\theta}}^{EA}$ lies in $\{0, \bar{d}^{EA}\}$, where

$$\bar{d}^{EA} = \frac{c}{\pi_U}.$$

To limit the number of cases, confine attention to regimes that incentivize at least some unsafe firms to take precautions: $\bar{d}^{EP}$, $(\bar{d}^{EA}, \bar{d}^{EA})$, $(0, \overline{d}^{EA})$, and $(\overline{d}^{EA}, 0)$. It is easy to verify that welfare under $\bar{d}^{EP}$ is weakly greater than welfare under $(\bar{d}^{EA}, \bar{d}^{EA})$ and that $(\overline{d}^{EA}, 0)$ is suboptimal. Thus, the interesting comparison is between $\bar{d}^{EP}$ and $(0, \overline{d}^{EA})$. The cost of $(0, \overline{d}^{EA})$ relative to $\bar{d}^{EP}$ is that fewer unsafe firms take precautions: the cost of allowing firms to respond to the signal is the loss associated with removing the incentives of measure $(1-\alpha)\lambda_{S|U}$ of unsafe firms to take precautions. The benefit is that it may be associated with greater activity among safe firms. To see this, compare average expected liability costs for safe firms under $\bar{d}^{EP}$ to that under $(0, \overline{d}^{EA})$. Under $\bar{d}^{EP}$, safe firms face average expected liability costs of

$$\pi_S \lambda_{U|S} \bar{d}^{EP} = \pi_S \lambda_{U|S} \frac{c}{\pi_U (1 - \lambda_{S|U})}, \tag{26}$$

while, under $(0, \overline{d}^{EA})$, safe firms face average expected liability costs of

$$\lambda_{U|S} \pi_S \bar{d}^{EA} = \lambda_{U|S} \pi_S \frac{c}{\pi_U}. \tag{27}$$

Note that (26) is larger than (27): When σ is revealed *ex ante*, some unsafe firms know in advance that they will certainly be held liable in the event of an accident if they fail to take precautions, rather than only with probability $(1-\lambda_{S|U})$ if σ is instead revealed *ex post*. As a consequence, damages can be lower by a factor of $(1-\lambda_{S|U})$ while still creating incentives for those firms to take precautions, which in turn limits average expected liability costs for safe firms. This reduction in average expected liability costs translates into greater activity among safe firms so long as $\bar{e}$ is sufficiently large.[10]

[10] A sufficient condition for safe firms to engage in more activity under $(0, \overline{d}^{EA})$ than $\bar{d}^{EP}$ is for $\bar{e} > \max\left\{b - \pi_S \lambda_{U|S} \bar{d}^{EP}, b - \pi_S \lambda_{U|S} \left(\frac{\bar{d}^{EP} - \bar{d}^{EA}}{1 - \lambda_{U|S}}\right)\right\}$.

In sum, this brief discussion suggests that revealing information *ex ante* – thereby allowing firms to respond to that information – can have the benefit of encouraging greater activity, and the cost of discouraging precautions. Providing conditions for revealing information *ex ante* to be superior is left for future work.

5. Other Regimes

5.1. **Strict Liability.** Other liability regimes, in particular strict liability, cannot achieve higher welfare than negligence in our model by Lemma 1. It is worth explaining in a bit more detail why strict liability, whereby a firm has to pay damages whenever it causes an accident (damages are independent of whether the firm took precautions and the signal of its type), is suboptimal.

To illustrate, consider the case where negligence with damages $d = \bar{d}$ is optimal among negligence regimes and compare the performance of this regime to the performance of strict liability when damages are set at d^{SL}, where d^{SL} is the minimum damage award necessary to incentivize unsafe firms to take precautions:

$$c + \pi_U^L d^{SL} = \pi_U d^{SL} \Rightarrow$$
$$d^{SL} = \frac{c}{\pi_U - \pi_U^L}.$$

Like negligence with damages $d = \bar{d}$, strict liability with damages $d = d^{SL}$ implements first best precautions. However, both safe and unsafe firms face greater expected liability costs than under negligence: Liability costs for unsafe firms are $\pi_U^L d^{SL}$ versus 0; liability costs for safe firms are $\pi_S d^{SL} = \frac{\pi_S c}{\pi_U - \pi_U^L}$ versus $\pi_S \epsilon_{U|S} \bar{d} = \frac{\epsilon_{U|S}}{1-\epsilon_{S|U}} \frac{\pi_S c}{\pi_U}$. As a result, activity tends to be lower which leads to welfare losses by Assumption 2.[11]

Why does negligence perform better than strict liability under the assumptions of our model but not under the assumptions of earlier models of optimal tort rules that incorporate activity (e.g., Shavell 1980, Polinsky 1980), in which strict liability with damages equal to harm always achieves the first best so long as only one party can affect the probability or magnitude of an accident?[12]

[11]It can also easily be shown that strict liability with damages d cannot perform better than negligence with damages $\bar{d}$ for any $d < d^{SL}$.

[12]In fact, under the assumptions of the more standard models that incorporate activity, strict liability performs better than negligence. This is a consequence of the fact that these models assume decreasing social benefits but constant

The answer is that we relax the assumption that firms fully internalize the gross social benefit of activity (i.e., we allow $\bar{e} > 0$). In this case, strict liability with damages equal to harm may lead to suboptimally low activity. When $\bar{e} = 0$, strict liability with damages equal to harm achieves the first best in our model as well, as illustrated in Subsection 3.1.

5.2. **Negligence When Damages Equal Harm.** Additional reasons to introduce regulation obtain when courts adjudicating tort claims are restricted to applying a negligence standard and setting damages equal to harm. Such damages are optimal in some circumstances (e.g., Posner 1972) and standard in many others, perhaps because they "compensate" the plaintiff for harm and "make him whole" (Shavell 2004).

To pursue this issue we first need to be a bit more explicit in defining what a regulator can do. In addition to generating public information about a firm's type *ex ante*, suppose regulators are able to (i) grant firms immunity from tort liability (this decision is allowed to depend on public information regarding a firm's type as well as its level of precautions) and (ii) set and enforce regulatory fines F, where the magnitude of such fines can depend on the regulatory determination of a firm's type as well as on whether the firm takes precautions (i.e., $F = F(p, \sigma_R)$). We assume that a firm needs to pay the fine if and only if it causes an accident.[13] [14]

There are at least two additional reasons why introducing regulation may be beneficial when damages are restricted to equal harm. First, with this requirement, negligence may fail to create incentives for firms to take first best precautions. Introducing regulation can then result in more efficient behavior even absent positive externalities from firm activity. With no positive externalities

costs from firm activity (we instead assume that firms of given safety θ generate constant - across firms - net social returns to activity conditional on a level of precautions). Combined with the assumption that, in the absence of liability rules, firms fully internalize the social benefit to activity but not the expected harm from accidents stemming from the activity, decreasing social benefits implies that firm activity may be inefficiently high under any regime where expected liability costs are lower than expected harm for some firms given that they take privately optimal levels of care (as is the case under a negligence regime where firms face zero expected liability costs so long as they take sufficient precautions to meet the standard of care).

[13]Equivalently, regulators only investigate whether a firm took precautions if it causes an accident. This is without loss of generality since fines are assumed to be unbounded above (e.g., limited liability is not an issue).

[14]Allowing regulators to perform tasks (i) and (ii) is consistent with our earlier analysis since it is always possible to re-write $D(p, \sigma_J, \sigma_R)$ as

$$D(p, \sigma_J, \sigma_R) = \widetilde{\iota}(p, \sigma_R)[\widetilde{F}(p, \sigma_R)] + (1 - \widetilde{\iota}(p, \sigma_R))[\widetilde{F}(p, \sigma_R) + \widetilde{D}(p, \sigma_J, \sigma_R)]$$

where $\widetilde{\iota} \in \{0, 1\}$ represents the regulatory decision of whether to grant a firm immunity from tort liability and $\widetilde{F} \geq 0, \widetilde{D} \geq 0$ are interpreted as regulatory fines and court enforced damages, respectively.

and damages equal to harm, safe firms could inefficiently take precautions if they are often mistakenly found liable or unsafe firms could fail to take precautions if they are often mistakenly found not liable. With either outcome, regulation which replaces tort liability with more efficiently set regulatory fines (i.e., fines that create incentives for first best precautions) is welfare enhancing.[15]

More interestingly, the requirement that courts set damages equal to harm may result in inefficiency because the social loss from some firms avoiding exposure by stopping activity could outweigh the gain from incentivizing those still operating to take precautions. Introducing regulation that shields firms from liability can increase welfare even in the absence of court errors in determining liability. We now develop a necessary and sufficient condition for this to be the case.

Suppose courts do not make errors ($\epsilon_{U|S} = \epsilon_{S|U} = 0$) and that Assumptions 1 and 2 hold. Under negligence with damages equal to harm, the behavior of safe firms is first best since they are never mistakenly held liable. An unsafe firm takes precautions since

$$\underbrace{c}_{\text{cost of precautions}} < \underbrace{\pi_U h}_{\text{reduction in expected liability costs by taking precautions}} \tag{28}$$

and engages in activity if and only if the private benefit of activity exceeds the cost of precautions:

$$b - e > c. \tag{29}$$

Hence, the activity level of such firms is

$$\min\left\{\frac{b-c}{\bar{e}}, 1\right\}. \tag{30}$$

While unsafe firms take first best precautions under negligence, their activity is inefficiently low whenever $\bar{e} > b - c$ by (30). Welfare may actually be lower under negligence than it would be under laissez faire because the welfare benefit from incentivizing unsafe firms to take first best precautions can be outweighed by the resulting cost from a decrease in such firms' activity.[16] The

[15]Under the assumption of no positive externalities from firm activity a regulatory regime in which any given firm is fined $\frac{c}{\pi_U}$ if it causes an accident and failed to take precautions results in the first best. Note, however, that strict liability with damages equal to harm also results in efficient behavior under this assumption.

[16]Note that we have implicitly relaxed Assumption 6.

formal condition is

$$(\pi_U - \pi_U^L)h - c < \left(1 - \min\left\{\frac{b-c}{\bar{e}}, 1\right\}\right)(b - c - \pi_U^L h) \tag{31}$$

or, equivalently,

$$b > \pi_U h \text{ and } \bar{e} > \frac{(b-c)(b-c-\pi_U^L h)}{b - \pi_U h}. \tag{32}$$

Examining (32) reveals that welfare is higher under laissez faire if and only if both (a) the social benefit to activity exceeds the expected value of any harmful externalities that may result when firms take inefficiently few precautions and (b) the level of positive externalities is sufficiently large. Since (32) is also the necessary and sufficient condition for unsafe firms not to take precautions under the full information benchmark, we have established the following Proposition.[17]

Proposition 5. *Suppose* $\epsilon_{U|S} = \epsilon_{S|U} = 0$*, Assumptions 1 and 2 hold, and courts are restricted to setting damages equal to harm. If* (32) *is not satisfied then negligence implements the full information benchmark so there is no room for regulation. On the other hand, if* (32) *holds then negligence does not implement the full information benchmark and this benchmark can be implemented by introducing regulation which shields all firms from negligence claims.*

Proposition 5 says that when courts implement inefficient precautions once the social loss from some unsafe firms avoiding costs by not operating is taken into account, it is optimal to introduce regulation which shields all firms from tort liability. One interpretation for why courts might implement such inefficient precautions is that, in performing the cost-benefit analysis that leads to a stringent safety standard for firms deemed to be unsafe, courts narrowly define costs: They only consider private costs of taking precautions and ignore the social loss that will result from driving firms out of business given industry conditions.

[17] As before, the full information benchmark refers to the outcome under a benevolent social planner who can set damages contingent on a firm's type.

6. CONCLUSION

As standard law and economics arguments teach us, private contracting and tort liability can accomplish a great deal in controlling social harms. Finding room for socially desirable regulation is not easy, especially for large firms that can afford to pay damages. We have tried to understand the circumstances under which regulation might nonetheless be socially desirable. The central assumptions of our model are the following. First, social control of externalities affects activity levels and not just precautions. Second, aside from the adverse externalities, social returns to activity might exceed private returns. The second assumption in particular has not been explored in this area, even though it is plausible in some circumstances.

For this model, we have reported two principal findings. First, having regulators make an *ex ante* determination of which firms should take particular precautions might be socially desirable, even if the regulators make mistakes. The benefits of regulation depend on the extent to which the social benefits of the activity exceed the private benefits, and on the size of court and regulatory errors. This implies, in particular, that the case for regulation is relatively easier to make when regulatory institutions have expertise, and when the activities in question generate large positive externalities, as might be the case with innovative activities.

The second finding describes the optimal regulatory rule and, specifically, addresses the question of whether regulation should preempt subsequent tort litigation. We have found that if social returns to activity are high enough relative to the harm from insufficient precautions, it is efficient to grant firms complying with regulations safe harbor from subsequent tort liability. If social returns to activity are not so high, it is still desirable to reduce tort liability for complying firms, but not to eliminate it entirely.

These results may have some implications for the analysis of regulatory preemption of tort litigation. The analysis suggests that full preemption might be desirable in situations where social returns to the activity are particularly high relative to the harm from insufficient precautions. This might be the case, for example, with medical innovation, an area in which the US Supreme Court is charting new territory. When the social benefits of the activity are not as high relative to the social costs of insufficient precautions, full preemption is inefficient. For example, it might be inefficient to exempt airlines whose plane maintenance programs are regulated from tort liability. The paper has suggested some ingredients of an efficient regulatory regime; the optimal solution of course depends on the circumstances of each market.

Appendix A. Omitted proofs

Proof of Lemmas 1 and 2. First consider Lemma 1. We can write

$$W^C = \max_{D(p,\sigma_J)} \mathcal{W}$$

(33)
$$= \alpha \underbrace{\mathbf{E}_e[y(S,e)]}_{\equiv \bar{y}_S}(b - cp_S - \pi_S h) + (1-\alpha) \underbrace{\mathbf{E}_e[y(U,e)]}_{\equiv \bar{y}_U}(b - cp_U - \pi_U(p_U)h),$$

subject to

(1) $p_S = 1 \iff c \leq \pi_S\{\mathbf{E}_{\sigma_J}[D(0,\sigma_J)|\theta = S] - \mathbf{E}_{\sigma_J}[D(1,\sigma_J)|\theta = S]\}$

(2) $p_U = 1 \iff c \leq \pi_U \mathbf{E}_{\sigma_J}[D(0,\sigma_J)|\theta = U] - \pi_U^L \mathbf{E}_{\sigma_J}[D(1,\sigma_J)|\theta = U]$

(3) $y(S,e) = 1 \iff e \leq b - p_S c - \pi_S \mathbf{E}_{\sigma_J}[D(p_S,\sigma_J)|\theta = S]$

(4) $y(U,e) = 1 \iff e \leq b - p_U c - \pi_U(p_U)\mathbf{E}_{\sigma_J}[D(p_U,\sigma_J)|\theta = U]$.

p_θ stands for whether precautions are taken by type θ firms and $y(\theta,e)$ stands for whether a type (θ,e) firm engages in activity.

Step 1. At the optimum, $p_S = 0$.

Fix a solution to the problem D^* and suppose that D^* implements $p_S = p_S^* = 1$. Welfare under this schedule is given by

$$W^* = \alpha \bar{y}_S^*(b - c - \pi_S h) + (1-\alpha)\bar{y}_U^*(b - cp_U^* - \pi_U(p_U^*)h), \tag{34}$$

where $\bar{y}_\theta^*$ stands for the activity level among type θ firms under $D^*(\cdot)$.

Now consider the alternative damage schedule $D'(\cdot)$, with $D'(0,\hat{S}) = D'(1,\hat{S}) = D'(1,\hat{U}) = 0$ and $D'(0,\hat{U}) = \frac{c}{(1-\epsilon_{S|U})\pi_U}$. Under this alternative schedule, unsafe firms take precautions and safe firms do not. Welfare is given by

$$W' = \alpha \bar{y}'_S(b - \pi_S h) + (1-\alpha)\bar{y}'_U(b - c - \pi_U^L h). \tag{35}$$

The first term of (35) is larger than the first term of (34) because $\bar{y}'_S \geq \bar{y}_S^*$ and $b - \pi_S h (> 0) > b - c - \pi_S h$. In addition, the second term of (35) is larger than the second term of (34). This is clear when $p_U^* = 1$: in this case, $\bar{y}'_U \geq \bar{y}_U^*$ (since $D'(1,\hat{U}) = D'(1,\hat{S}) = 0$), so $(1-\alpha)\bar{y}'_U(b - c - \pi_U^L h) \geq$

$(1-\alpha)\bar{y}_U^*(b-c-\pi_U^L h)$ by Assumption 2. When $p_U^* = 0$, we need to compare $(1-\alpha)\bar{y}_U'(b-c-\pi_U^L h)$ and $(1-\alpha)\bar{y}_U^*(b-\pi_U h)$. But we know that the first expression exceeds the second by Assumptions 2 and 6.

Since $W' > W^*$, we must have $p_S = 0$ at the optimum.

Step 2. There is always a solution to the problem with $D(0, \hat{S}) = 0$.

Fix a solution $D^*(\cdot)$ and suppose that $D^*(0, \hat{S}) > 0$. Consider alternative schedule $D'(\cdot)$, where $D'(0, \hat{S}) = 0$, $D'(0, \hat{U}) = D^*(0, \hat{U}) + \frac{D^*(0,\hat{S})\epsilon_{S|U}}{1-\epsilon_{S|U}}$ and $D'(1, \sigma_J) \equiv D^*(1, \sigma_J)$. Simple algebra yields $p_U' = p_U^*, \bar{y}_U' = \bar{y}_U^*, p_S' = p_S^* = 0$ (using Step 1), and $\bar{y}_S' \geq \bar{y}_S^*$. Hence, $W' \geq W^*$, implying that D' is also a solution to the problem.

Step 3. There is always a solution to the problem with $D(0, \hat{S}) = D(1, \hat{U}) = D(1, \hat{S}) = 0$.

Fix a solution $D^*(\cdot)$ with the property that $D^*(0, \hat{S}) = 0$. Further, assume that $D^*(1, \hat{U}) > 0$ or $D^*(1, \hat{S}) > 0$. Suppose first that $D^*(\cdot)$ implements $p_U = 1$ (so, in particular, $D^*(0, \hat{U}) \geq \frac{c}{\pi_U(1-\epsilon_{S|U})}$) and consider the alternative schedule $D'(\cdot)$, where $D'(0, \hat{U}) = \frac{c}{\pi_U(1-\epsilon_{S|U})}$ and $D'(0, \hat{S}) = D'(1, \hat{S}) = D'(1, \hat{U}) = 0$. Simple algebra yields $p_U' = p_U^*, p_S' = p_S^*, \bar{y}_U' \geq \bar{y}_U^*$, and $\bar{y}_S' \geq \bar{y}_S^*$. Hence, $W' \geq W^*$, implying that D' is also a solution to the problem.

Now suppose that $D^*(\cdot)$ implements $p_U = 0$. Consider the alternative schedule $D'(\cdot)$, where $D'(1, \hat{S}) = D'(1, \hat{U}) = 0$, $D'(0, \hat{S}) = D^*(0, \hat{S}) = 0$, and $D'(0, \hat{U}) = D^*(0, \hat{U})$. So long as $p_U' = p_S' = 0$, it is easy to see that $\bar{y}_S' = \bar{y}_S^*$ and $\bar{y}_U' = \bar{y}_U^*$, implying that $W' = W^*$ and that $D'(\cdot)$ is also a solution to the problem. It is thus left to show that $p_U' = p_S' = 0$, or $c > \pi_U(1 - \epsilon_{S|U})D'(0, \hat{U}) = \pi_U(1 - \epsilon_{S|U})D^*(0, \hat{U})$.

To this end, note that, as a consequence of $D^*(\cdot)$ being optimal, welfare under $D^*(\cdot)$ must be higher than welfare under any damage award function that implements $p_U = 1$:

$$
\begin{aligned}
W^* &= (1-\alpha)\min\left\{1, \frac{b - \pi_U(1-\epsilon_{S|U})D^*(0,\hat{U})}{\bar{e}}\right\}(b - \pi_U h) \\
&\quad + \alpha \min\left\{1, \frac{b - \pi_S \epsilon_{U|S} D^*(0,\hat{U})}{\bar{e}}\right\}(b - \pi_S h) \qquad (36) \\
&\geq (1-\alpha)\min\left\{1, \frac{b-c}{\bar{e}}\right\}(b - c - \pi_U^L h) + \alpha\min\left\{1, \frac{b - \pi_S\epsilon_{U|S}\bar{d}}{\bar{e}}\right\}(b - \pi_S h).
\end{aligned}
$$

By Assumptions 2 and 6, we have that

$$
(1-\alpha)\min\left\{1, \frac{b-c}{\bar{e}}\right\}(b - c - \pi_U^L h) > (1-\alpha)\min\left\{1, \frac{b - \pi_U(1-\epsilon_{S|U})D^*(0,\hat{U})}{\bar{e}}\right\}(b - \pi_U h).
$$

Thus, a necessary condition for (36) to hold is:

$$
\alpha\min\left\{1, \frac{b - \pi_S\epsilon_{U|S}D^*(0,\hat{U})}{\bar{e}}\right\}(b - \pi_S h) > \alpha\min\left\{1, \frac{b - \pi_S\epsilon_{U|S}\bar{d}}{\bar{e}}\right\}(b - \pi_S h),
$$

or $\frac{b-\pi_S\epsilon_{U|S}D^*(0,\hat{U})}{\bar{e}} > \frac{b-\pi_S\epsilon_{U|S}\bar{d}}{\bar{e}}$, which implies that $c > \pi_U(1-\epsilon_{S|U})D^*(0,\hat{U})$.

This completes the proof of Lemma 1. The proof of Lemma 2 is essentially the same: maximizing welfare with respect to $D(p, \sigma_J, \sigma_R)$ is equivalent to, for each $\sigma_R = \hat{\theta}$, setting $D_{\hat{\theta}}(p, \sigma_J)$ to maximize (33), replacing population weights $(\alpha, 1-\alpha)$ with $(\alpha_{\hat{\theta}}, 1-\alpha_{\hat{\theta}})$. ■

To prove Proposition 3, we will make use of the following lemma.

Lemma 3. $d^* \in \{\underline{d}, \bar{d}\}$

Proof. We will prove this Lemma through a sequence of claims.

Claim 1. $d^* \leq \bar{d}$.

Proof of Claim. Clearly $d^* \leq \frac{c}{\pi_S\epsilon_{U|S}}$ because it is inefficient to create incentives for safe firms to take precautions (see the proof of Lemma 1). For $d \in \left[\bar{d}, \frac{c}{\pi_S\epsilon_{U|S}}\right]$, we have

$$
W(d) = \alpha\frac{b - \pi_S\epsilon_{U|S}d}{\bar{e}}(b - \pi_S h) + (1-\alpha)\frac{b-c}{\bar{e}}(b - c - \pi_U^L h).
$$

For any d in $\left(\bar{d}, \frac{c}{\pi_S \epsilon_{U|S}}\right)$,

$$W'(d) = -\frac{\pi_S \epsilon_{U|S}}{\bar{e}}(b - \pi_S h) < 0,$$

so $d^* \notin (\bar{d}, \infty)$. □

Claim 2. *If $d^* < \bar{d}$, then $d^* = \underline{d}$.*

Proof of Claim. Case 1: $b \geq \pi_U h$.

For $d < \bar{d}$, we have

$$\begin{aligned} W(d) &= \alpha \min\left\{\frac{b - \pi_S \epsilon_{U|S} d}{\bar{e}}, 1\right\}(b - \pi_S h) + (1-\alpha)\min\left\{\frac{b - \pi_U(1-\epsilon_{S|U})d}{\bar{e}}, 1\right\}(b - \pi_U h) \\ &\leq \alpha(b - \pi_S h) + (1-\alpha)(b - \pi_U h) \\ &= W(0). \end{aligned}$$

Case 2: $b < \pi_U h$.

For $d \leq \underline{d}$, we have

$$W(d) = \alpha(b - \pi_S h) + (1-\alpha)\min\left\{\frac{b - \pi_U(1-\epsilon_{S|U})d}{\bar{e}}, 1\right\}(b - \pi_U h),$$

which is constant in d for $d < \frac{b - \bar{e}}{\pi_U(1-\epsilon_{S|U})}$ and increasing in d for $\frac{b-\bar{e}}{\pi_U(1-\epsilon_{S|U})} \leq d < \underline{d}$. Thus, $d^* \geq \underline{d}$.

Now consider $d \in [\underline{d}, \bar{d})$. For d in this range,

$$W(d) = \alpha \frac{b - \pi_S \epsilon_{U|S} d}{\bar{e}}(b - \pi_S h) + (1-\alpha)\frac{b - \pi_U(1-\epsilon_{S|U})d}{\bar{e}}(b - \pi_U h).$$

By the assumption that $d^* < \bar{d}$, we have that, for all $d \in (\underline{d}, \bar{d})$,

$$W'(d) = (1-\alpha)\frac{\pi_U(1-\epsilon_{S|U})}{\bar{e}}(\pi_U h - b) - \alpha\frac{\pi_S \epsilon_{U|S}}{\bar{e}}(b - \pi_S h) \leq 0,$$

implying that $d^* = \underline{d}$. □

■

Proof of Proposition 3. By Lemma 3, we only need to compare $W(\bar{d})$ and $W(\underline{d})$ to solve for d^*:

$$\begin{aligned} W(\bar{d}) &= \alpha \frac{b - \pi_S \epsilon_{U|S} \bar{d}}{\bar{e}} (b - \pi_S h) + (1-\alpha) \frac{b-c}{\bar{e}} (b - c - \pi_U^L h) \\ W(\underline{d}) &= \alpha (b - \pi_S h) + (1-\alpha) \min \left\{ \frac{b - \pi_U (1 - \epsilon_{S|U}) \underline{d}}{\bar{e}}, 1 \right\} (b - \pi_U h). \end{aligned} \tag{37}$$

From (37), we have that $W(\bar{d}) > W(\underline{d})$ if and only if $(1-\alpha)L_U > \alpha G_S$, or $\alpha < \frac{L_U}{L_U + G_S}$. ■

Proof of Proposition 4. Note that

$$W(d_{\hat{S}}, d_{\hat{U}}) = \sum_{\hat{\theta}} \text{Prob}(\sigma_R = \hat{\theta}) [\alpha_{\hat{\theta}} \bar{y}_{S|\hat{\theta}} (b - c p_{S|\hat{\theta}} - \pi_S h) + (1 - \alpha_{\hat{\theta}}) \bar{y}_{U|\hat{\theta}} (b - c p_{U|\hat{\theta}} - \pi_U (p_{U|\hat{\theta}}) h)],$$

where

$$p_{\theta|\hat{\theta}} \in \arg\min_p cp + (1-p) \pi_\theta(p) \, \text{Prob}(\sigma_J = \hat{U} | \theta) d_{\hat{\theta}}$$

equals precautions taken by type θ firms given regulatory classification $\hat{\theta}$ and damages $d_{\hat{\theta}}$, and

$$\bar{y}_{\theta|\hat{\theta}} = \min \left\{ \frac{b - c p_{\theta|\hat{\theta}} - (1 - p_{\theta|\hat{\theta}}) \pi_\theta (p_{\theta|\hat{\theta}}) \, \text{Prob}(\sigma_J = \hat{U} | \theta) d_{\hat{\theta}}}{\bar{e}}, 1 \right\}$$

equals the activity level of such firms.

Since $p_{\theta|\hat{\theta}}$ and $\bar{y}_{\theta|\hat{\theta}}$ depend only on $d_{\hat{\theta}}$, $W(d_{\hat{S}}, d_{\hat{U}})$ can be expressed as $\text{Prob}(\sigma_R = \hat{S}) W_{\hat{S}}(d_{\hat{S}}) + \text{Prob}(\sigma_R = \hat{U}) W_{\hat{U}}(d_{\hat{U}})$, where

$$W_{\hat{\theta}}(d_{\hat{\theta}}) \equiv \alpha_{\hat{\theta}} \bar{y}_{S|\hat{\theta}} (b - c p_{S|\hat{\theta}} - \pi_S h) + (1 - \alpha_{\hat{\theta}}) \bar{y}_{U|\hat{\theta}} (b - c p_{U|\hat{\theta}} - \pi_U (p_{U|\hat{\theta}}) h)$$

equals expected welfare conditional on a firm being classified as $\hat{\theta}$. Thus,

$$\max_{d_{\hat{S}}, d_{\hat{U}}} W(d_{\hat{S}}, d_{\hat{U}}) = \text{Prob}(\sigma_R = \hat{S}) \max_{d_{\hat{S}}} W_{\hat{S}}(d_{\hat{S}}) + \text{Prob}(\sigma_R = \hat{U}) \max_{d_{\hat{U}}} W_{\hat{U}}(d_{\hat{U}}).$$

But the problem of finding $d_{\hat{\theta}}$ to maximize $W_{\hat{\theta}}(d_{\hat{\theta}})$ is the same as the problem of finding d to maximize $W(d)$, replacing population proportions α and $1 - \alpha$ with proportions $\alpha_{\hat{\theta}}$ and $1 - \alpha_{\hat{\theta}}$. The result then follows from Proposition 3.

■

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