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ABSTRACT

We ask whether regulation can usefully supplement litigation in a model of optimal social control of harmful externalities. In our model, firms choose activity levels in addition to precautions. In contrast to the usual analysis, we assume that social returns to activity are higher than private returns before taking harmful externalities into account. We also assume that both courts and regulators make errors in assessing whether it is efficient for a given firm to take precautions. We show that regulation can, in some circumstances, improve resource allocation. Regulatory preemption of litigation may be efficient when social returns to activity exceed the expected harm that could result from a firm taking too few precautions. The optimal structure of law enforcement is influenced by the divergence between private and social returns to activity as well as the competence of regulators and courts.

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1. Introduction

When would a benevolent government regulate economic activity in a world where 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.

In this paper, we describe some circumstances under which, despite court enforcement of tort and contract claims, there is room for regulation, and examine the form such regulation might take. Following Shavell (1984a,b), we define regulation as *ex ante* determination of which firms are risky and hence should undertake precautions. Under litigation, in contrast, such determinations are made *ex post*. Our theory follows the general approach of Becker (1968), Calabresi (1970), and Posner (1972) on the relative desirability from the efficiency perspective of alternative methods of controlling harmful behavior, but introduces some new aspects of the problem.

In our model, the benefits of regulation in part come from the generation of additional information useful for providing correct incentives to firms, but also in part from generating this information *ex ante*, so that firms can make choices with some knowledge of where they stand vis a vis authorities. We use the model to examine the crucial policy question of whether regulation should preempt subsequent litigation through safe-harbor provisions for firms that comply with regulatory standards. Such provisions exist in many situations: individuals who take a course in CPR and obtain certification are exempt from negligence liability when they administer it unsuccessfully, judges are exempt from negligence claims when they make bad decisions, and, as we discuss below, the U.S. Supreme Court is in the process of deciding whether FDA approval protects pharmaceutical firms from tort liability for unanticipated side effects.

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. We make three substantive assumptions, some of which have already been considered by law and economics scholarship but in different contexts.

First, in our model the structure of penalties affects not just precautions, but also the level of activity. A firm chooses not only its level of precautions, but also whether or not to operate (or to pursue a particular project). Shavell (1980) and Polinsky (1980) have considered activity levels in assessing the optimal liability rules, but not regulation. Viscusi and Moore (1993) theoretically and empirically explore how liability costs may decrease the incentive for firms to innovate.

Second, models of optimal enforcement analyze the case where, absent the harmful externalities, the private and social returns to activity are the same, so that, with the externality, private returns to activity are higher than social ones. We relax this assumption and assume instead that activity generates greater social than private benefits before taking harmful externalities into account. The obvious example is of an entrepreneur or an innovator, whose activity improves a technology, the returns from which he does not fully capture. This assumption is critical to making the case that combining regulation with litigation can increase welfare through encouraging greater activity. Our analysis provides an analytical foundation for the commonly made argument that there is room for regulation when litigation drives firms out of business or discourages the introduction of new products (Viscusi 1991a).

By themselves, the above two assumptions are not sufficient to make the case for regulation: in our model negligence does as well as any combined regime. However, introducing regulation may increase welfare under an additional third assumption, namely that both regulators and judges make errors in deciding whether a firm should efficiently take precautions. The idea of law enforcers making errors is also not new; 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.

We develop the implications of the above three assumptions in a fairly standard model of optimal law enforcement. In our model, the optimal liability rule that involves courts alone is negligence, whereby a firm has to pay damages if the court finds that it did not take precautions but should have taken them. The optimal rule that combines regulation with litigation depends on whether the social benefits of the activity exceed the expected harm that may result when firms take inefficiently few precautions (i.e., when they do not take proper care). When the social benefit to activity is sufficiently high, the optimal rule is "complete safe harbor" regulation, whereby a firm that is initially found not to need to take precautions by the regulator is exempt from damages even if an accident occurs (Viscusi 1991b). Regulation preempts litigation. 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. Regulation does not preempt litigation. 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.

A simple example illustrates our central argument. 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 radition 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.

The question of regulatory preemption of litigation has acquired recent policy relevance because of two Supreme Court cases. In the first, *Riegel v. Medtronic*, the Court ruled that FDA approval preempts tort claims against manufacturers of medical devices. In the second, still pending a decision, *Wyeth v. Levine*, the same issue is raised with respect to drugs. A recent literature has discussed some of the relevant legal and economic issues (Kessler and Vladeck 2008, Curfman et al 2008, Glantz et al 2008, Philipson et al 2008). However, these articles do not examine the conditions under which preemption is efficient in a model of optimal social control of harmful externalities. 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 errors are explicitly present in Calabresi's quote, and the level of activity is also considered, at least implicitly. Our paper presents a formal model in which, with errors by law enforcers, high penalties resulting from efficient negligence rules might unnecessarily discourage highly socially desirable activity.

Section 2 presents the basic model of litigation and regulation. Section 3 presents a preliminary discussion of efficiency. Section 4 describes firm behavior under the efficient liability rule, which in this model is negligence. Second 5 describes the circumstances under which the addition of regulation improves resource allocation, and characterizes efficient regimes, including preemption. Section 6 briefly considers firm behavior under two important, but not optimal regimes: strict liabilty and negligence when damages are restricted to equal harm. Section 7 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
- Whether to warn physicians of a potential side-effect of taking the drug where
    - 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
- 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
- $e \sim U[0, \bar{e}]$ ($\bar{e} \leq b$) 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[2]

(1) positive externalities (e.g., nuclear power or R&D)

(2) asymmetric information or moral hazard (e.g., a monopolist will not fully internalize the social surplus if it cannot completely price discriminate; a firm will face greater private than social costs if it needs to pay efficiency wages)

(3) consumers cannot afford to pay their valuations (e.g., hospital beds).

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 very high.[3] Another way to justify why subsidies are not given is that they would invite line of firms outside government offices arguing for positive externalities from 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.*

[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]Note that 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.

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. Measure 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.

Measure 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. **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 precaution as well as a noisy signal σ_J of firm safety $\theta \in \{S, U\}$, where

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

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).

[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.

2.3. **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 firm safety θ, where

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

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 $\sigma_R = \hat{U}_R$). 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* $r = \hat{S}_R$ *or* $\hat{U}_R$ *and* $j = \hat{S}_J$ *or* $\hat{U}_J$.

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 $t(\hat{\theta}, \hat{e}, \hat{\theta}_R, \hat{\theta}_J) \geq 0$ 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

- 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. Preliminaries

In this section we present some useful benchmarks to consider in analyzing firm behavior under different enforcement regimes.

3.1. **First best.** To solve for the first best, we 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

$$W^{FB} = \underbrace{(b - \pi_S h)}_{W_S^{FB}} + \underbrace{(b - c - \pi_U^L h)}_{W_U^{FB}} \tag{5}$$

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

$$(b - e - cp)y \tag{6}$$

and Tirole (1991, page 257). Suppose allocation $(p(\theta, e, \sigma_R), y(\theta, e, \sigma_R))$ is implementable through transfer function $t = t(\theta, e, \sigma_R, \sigma_J)$. Then the following damage award function implements the same allocation:

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

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

$$W^{LF} = \underbrace{(b - \pi_S h)}_{W_S^{LF}} + \underbrace{(b - \pi_U h)}_{W_U^{LF}} \tag{7}$$

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

3.3. **Upper bound.** With the enforcement regimes we consider, welfare cannot be higher than under a hypothetical benevolent social planner who can directly observe whether a firm is safe or unsafe and choose its level of precautions but not its level of activity.[7] [8] Outcomes under this hypothetical planner serve as a relevant benchmark for assessing the performance of alternative enforcement methods. We label the planner's choice *conditionally efficient*.

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 unsafe firms taking precautions is positive (taking into account the impact on both the likelihood of an accident and activity):

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

When Assumption 6 does not hold, laissez-faire is necessarily optimal.[9]

The benevolent planner would dictate that safe firms not take precautions and that unsafe firms take precautions (the latter as a consequence of Assumption 6). As a result, safe firms would

[7] In principle, while these enforcement methods cannot incentivize firms to increase activity beyond the level chosen under this hypothetical planner, they can incentivize firms to decrease activity below this amount through penalties. However, such a decrease in activity is inefficient conditional on unsafe firms taking precautions by Assumption 2, so outcomes under this hypothetical planner are the relevant benchmark.

[8] Outcomes under this planner correspond to outcomes under the optimal combined regime when courts or regulators can perfectly determine whether a firm is safe.

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

engage in activity as would all unsafe firms with $e \leq b - c$. Welfare equals

$$W^{UB} = \underbrace{(b - \pi_S h)}_{W_S^{UB}} + \underbrace{\min\left\{\frac{b-c}{\bar{e}}, 1\right\}(b - c - \pi_U^L h)}_{W_U^{UB}} \tag{8}$$

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

$$W^{FB} - W^{UB} = \left(1 - \min\left\{\frac{b-c}{\bar{e}}, 1\right\}\right)(b - c - \pi_U^L h), \tag{9}$$

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 conditionally efficient outcome. We maintain Assumptions 0-6 throughout the paper, except in our statement of Proposition 4 where we relax Assumption 6.

4. Negligence

We first establish when the conditionally efficient outcome can be achieved with courts alone ($D = D(p, \sigma_J)$). For any enforcement regime only involving 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.

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 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	$\hat{S}_J$	$\hat{U}_J$
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 ($\sigma_J \in \{\hat{S}_J, \hat{U}_J\}$).

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 can achieve the conditionally efficient outcome. This outcome can be achieved through a negligence regime if and only if it can be achieved when damages are the minimum necessary to incentivize unsafe firms to take precautions.

Label such damages $\bar{d}$, so:

$$\underbrace{c}_{\text{cost of precautions}} = \underbrace{\pi_U(1-\epsilon_{S|U})\bar{d}}_{\text{expected liability cost for an unsafe firm if no precautions}} \Rightarrow \tag{10}$$

$$\overline{d} = \frac{c}{(1-\epsilon_{S|U})\pi_U} \tag{11}$$

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:

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

where the inequality follows from (10).

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

$$b - e - c \geq 0 \tag{13}$$

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

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

which is conditionally efficient and equals the first best level if and only if

$$\bar{e} \leq b - c \tag{15}$$

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

$$b - e - \pi_S\epsilon_{U|S}\overline{d} \geq 0 \tag{16}$$

Inequality (16) implies that the activity level of safe firms is

$$\min\left\{\frac{b-\pi_S\epsilon_{U|S}\overline{d}}{\bar{e}},1\right\} \tag{17}$$

which is conditionally efficient if and only if

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

Aggregate welfare under negligence with damages $\overline{d}$ is then given by

$$W^N=\min\left\{\frac{b-\pi_S\epsilon_{U|S}\overline{d}}{\bar{e}},1\right\}(b-\pi_S h)+\min\left\{\frac{b-c}{\bar{e}},1\right\}(b-c-\pi_U^L h) \tag{19}$$

We have proved the following:

Proposition 1. *Negligence alone can achieve the conditionally efficient outcome if and only if*

$$\bar{e}\leq b-\pi_S\epsilon_{U|S}\overline{d}\equiv\widetilde{e}^{UB} \tag{20}$$

Corollary 1. *If either $\epsilon_{U|S}=0$ or $\bar{e}=0$, then negligence alone can achieve the conditionally efficient outcome.*

Corollary 2. *Negligence alone can achieve the first best if and only if $\bar{e}\leq b-c\equiv\widetilde{e}^{FB}$.*

Proposition 1 establishes a sufficient condition for there to be no room for regulation. There is no room for regulation so long as the level of activity of safe firms is unaffected in a negligence regime in which damages are the minimum necessary to incentivize unsafe firms to take precautions. Proposition 1 provides a general condition for this to be the case. In particular, the conditionally efficient outcome is achieved so long as safe firms capture enough of the social surplus generated by their activity (e.g., the level of positive externalities is sufficiently small) relative to expected liability costs under this negligence regime.

Corollary 1 highlights the simple fact that negligence always achieves the conditionally efficient outcome when $\epsilon_{U|S}=0$ because, in this case, courts never mistake safe firms for unsafe, so safe firms face zero expected liability costs and their activity is unaffected (independent of the level of damages). Court errors are essential for making the case for regulation. Negligence also always achieves the conditionally efficient outcome in the conventionally studied case where there is no difference between private and social benefits of activity.

To illustrate this Corollary, 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 Corollary 1 says that there is no welfare benefit from having the FDA make an *ex ante* determination of whether a drug company should issue such a warning. Likewise, suppose that, absent the harmful externalities controlled by the negligence rule, the private and social returns to introducing the drug are the same. In this case, there are no additional benefits of regulation either, since negligence assures correct incentives. Matters may be different if judges and juries do not have sufficient expertise or if the social benefits of drug introduction exceed the private ones.

Corollary 2 says that when firms are able to capture a sufficient fraction of the surplus generated by their activity then negligence even achieves the first best.

5. ADDING REGULATORS

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 $(d_{\hat{S}_R}, d_{\hat{U}_R})$, where $d_{\sigma_R} \geq 0$ is the the level of damages a firm *ex ante* classified as type $\sigma_R \in \{\hat{S}_R, \hat{U}_R\}$ must pay in the case of an accident if it is found to have not taken precautions and to be unsafe. Since we allow $d_{\hat{S}_R} = d_{\hat{U}_R}$, 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}.

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

p \ σ_J	$\hat{S}_J$	$\hat{U}_J$
0	0	d_{σ_R}
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 ($\sigma_J \in \{\hat{S}_J, \hat{U}_J\}$), and the regulatory classification ($\sigma_R \in \{\hat{S}_R, \hat{U}_R\}$).

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

Proposition 2 addresses the question of which combinations of $d_{\hat{S}_R}$ and $d_{\hat{U}_R}$ can be optimal when there is room for regulation ($\bar{e} > \tilde{e}^{UB}$). To break indifference, we suppose that the information available to regulators is imperfect ($\delta_{S|U} > 0, \delta_{U|S} > 0$) and that there is an arbitrarily small positive cost to administering damage awards (i.e., to setting $d_{\sigma_R} > 0$ for $\sigma_R \in \{\hat{S}_R, \hat{U}_R\}$).

Prior to stating the proposition, define $\underline{d} \equiv \frac{b-\bar{e}}{\pi_S \epsilon_{U|S}}$. $\underline{d}$ is the maximum damage award that does not affect the activity level of safe firms.

Proposition 2. *Suppose $\bar{e} > \widetilde{e}^{UB}$, $\delta_{S|U} > 0$, $\delta_{U|S} > 0$, and there is an arbitrarily small positive cost to setting $d_{\sigma_R} > 0$ for $\sigma_R \in \{\hat{S}_R, \hat{U}_R\}$.*

(1) *If $b > \pi_U h$ then there are parameter values under which $(d_{\hat{S}_R}, d_{\hat{U}_R})$ is optimal only if: (i) $d_{\hat{S}_R} = d_{\hat{U}_R} = \overline{d}$, (ii) $d_{\hat{S}_R} = 0$, $d_{\hat{U}_R} = \overline{d}$, or (iii) $d_{\hat{S}_R} = d_{\hat{U}_R} = 0$.*

(2) *If $b < \pi_U h$ then there are parameter values under which $(d_{\hat{S}_R}, d_{\hat{U}_R})$ is optimal only if: (i) $d_{\hat{S}_R} = d_{\hat{U}_R} = \overline{d}$, (ii) $d_{\hat{S}_R} = \underline{d}$, $d_{\hat{U}_R} = \overline{d}$, or (iii) $d_{\hat{S}_R} = d_{\hat{U}_R} = \underline{d}$.*

Proposition 2 generates an important Corollary that makes use of the following definition.

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

Corollary 3. *Suppose the conditions of Proposition 2 continue to hold.*

(1) *If $b > \pi_U h$ then whenever the optimal regime includes regulation, $d^*_{\hat{S}_R} = 0$ and $d^*_{\hat{U}_R} = \overline{d}$*

(2) *If $b < \pi_U h$ then whenever the optimal regime includes regulation, $d^*_{\hat{S}_R} = \underline{d}$ and $d^*_{\hat{U}_R} = \overline{d}$*

Corollary 3 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 conditionally efficient precautions for all firms and conditionally efficient activity for unsafe firms. Consequently, the addition of regulators can only improve matters when the activity level of safe firms is less than conditionally efficient 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

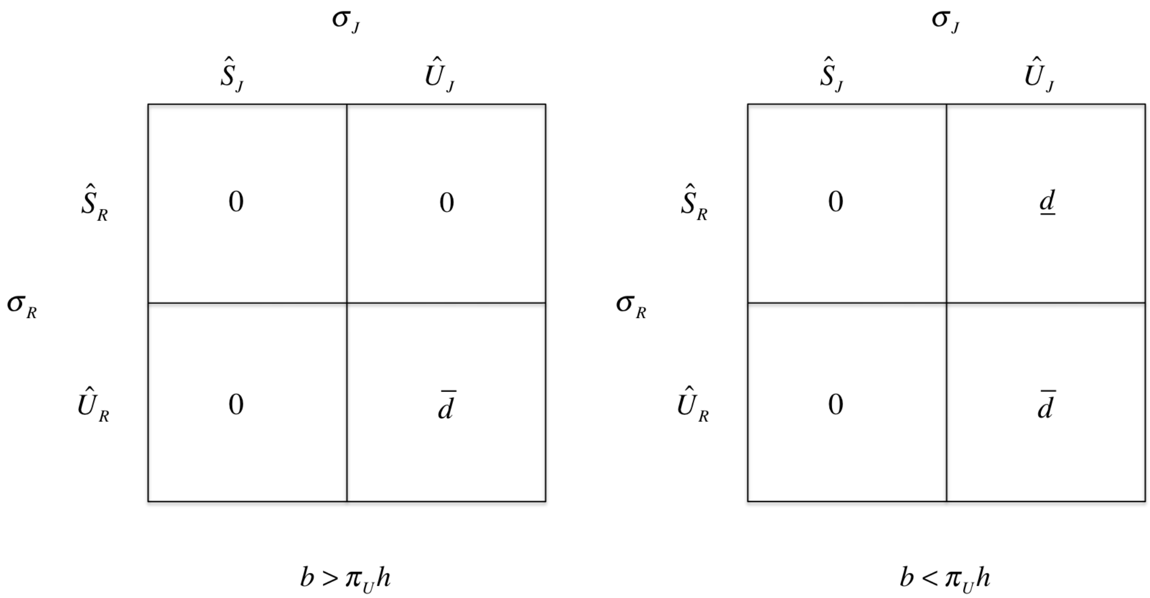

FIGURE 3. Damages under the optimal regime whenever it includes regulation. Damages are a function of the regulatory classification ($\sigma_R \in \{\hat{S}_R, \hat{U}_R\}$), the court's signal ($\sigma_J \in \{\hat{S}_J, \hat{U}_J\}$), and the social returns from firm activity (b) as compared to expected 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). Fixing σ_R, $\bar{d} = \frac{c}{(1-\epsilon_{S|U})\pi_U}$ is the minimum level of damages necessary to incentivize unsafe firms to take precautions and $\underline{d} = \frac{b-\bar{e}}{\pi_S \epsilon_{U|S}}$ is the maximum damage award that does not affect the activity level of safe firms, where $\underline{d} < \bar{d}$ whenever the conditions of Proposition 2 hold.

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.

5.1. **Why regulation can help.** When safe firms capture an insufficient amount of the social surplus generated by their activity relative to expected liability costs under negligence with damages $\bar{d}$ ($\bar{e} > \widetilde{e}^{UB}$), 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 be beneficial because of two key features which allow regulation to encourage more safe firms to engage in activity through limiting their expected liability costs.

First, regulation provides society with more information about firm safety which reduces the information asymmetry at the root of the problem. To illustrate, consider the extreme case where regulators perfectly classify firms ($\delta_{U|S} = \delta_{S|U} = 0$), and compare negligence with damages $\overline{d}$ to 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 ($d_{\hat{S}_R} = 0$) while firms are subject to a negligence claim with damages $\overline{d}$ in the case of an accident if they are *ex ante* classified as unsafe by the regulator ($d_{\hat{U}_R} = \overline{d}$). Welfare under this regime is given by

$$(b - \pi_S h) + \frac{b-c}{\bar{e}}(b - c - \pi_U^L h) \tag{21}$$

while welfare under negligence with damages $\overline{d}$ is given by

$$\frac{\widetilde{e}^{UB}}{\bar{e}}(b - \pi_S h) + \frac{b-c}{\bar{e}}(b - c - \pi_U^L h) \tag{22}$$

Subtracting (22) from (21) we obtain

$$(b - \pi_S h)\left(1 - \frac{\widetilde{e}^{UB}}{\bar{e}}\right) > 0 \tag{23}$$

which captures the increase in welfare from eliminating the informational asymmetry regarding firm safety.

Second, regulators generate and reveal their information *ex ante* (prior to a firm's choice of precautions and activity) which allows each firm to respond to its regulatory classification. While this feature has an associated cost of removing the incentives for some unsafe firms to take precautions, it also limits expected liability costs of safe firms on average. To illustrate, suppose courts are unable to distinguish safe from unsafe firms themselves ($\epsilon_{U|S} = \epsilon_{S|U} = 1/2$), but now have access to an additional signal $\hat{\sigma} \in \{\hat{S}, \hat{U}\}$ ($\Pr[\hat{\sigma} = \hat{S}|\theta = U] = \hat{\delta}_{S|U} < 1/2, \Pr[\hat{\sigma} = \hat{U}|\theta = S] = \hat{\delta}_{U|S} < 1/2$) which it can take into account in its calculation of damages. We can compare average expected liability costs (given optimal damages) under the assumption that $\hat{\sigma}$ is assumed to be generated and revealed *ex ante* to average expected liability costs when $\hat{\sigma}$ is instead assumed to be generated and revealed *ex post*. To simplify this discussion, assume $b > \pi_U h$ and that $\bar{e}$ is large.

When $\hat{\sigma}$ is generated *ex ante*, we can limit attention to enforcement methods described by $(d_{\hat{S}}, d_{\hat{U}})$, where $d_{\hat{\theta}} \geq 0$ is 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. The interesting case is when, at the optimum, $d_{\hat{S}} < d_{\hat{U}}$. Then, $d^*_{\hat{S}} = 0$ and $d^*_{\hat{U}} = \frac{c}{\pi_U}$ and, under this regime, $(1 - \hat{\delta}_{U|S})$ safe firms face zero liability costs while $\hat{\delta}_{U|S}$ safe firms face expected liability costs of $\pi_S \frac{c}{\pi_U}$. On average, safe firms then face expected liability costs of

$$\mathcal{L_S}^{ea} = \hat{\delta}_{U|S} \pi_S \frac{c}{\pi_U} \tag{24}$$

When $\hat{\sigma}$ is generated *ex post*, we can limit attention to enforcement methods described by d, where d 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 $\hat{\sigma} = \hat{U}$. The interesting case is when, at the optimum, $d > 0$. Then $d^* = \frac{c}{(1-\hat{\delta}_{S|U})\pi_U}$ and, under this regime, all safe firms face expected liability costs of

$$\mathcal{L_S}^{ep} = \hat{\delta}_{U|S} \pi_S \frac{c}{(1 - \hat{\delta}_{S|U})\pi_U} \tag{25}$$

Comparing $\mathcal{L}_S^{ea}$ and $\mathcal{L}_S^{ep}$, we see that safe firms face lower average expected liability costs when $\hat{\sigma}$ is revealed to firms *ex ante* ($\mathcal{L}_S^{ea} = (1-\hat{\delta}_{S|U})\mathcal{L}_S^{ep}$).[10] This is a consequence of the fact that, when $\hat{\sigma}$ is assumed to be 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 $(1-\hat{\delta}_{S|U})$ if $\hat{\sigma}$ is instead generated *ex post*. As a consequence, damages can be lower by a factor of $(1-\hat{\delta}_{S|U})$ while still creating incentives for those firms to take precautions, which in turn limits average expected liability costs for safe firms.

5.2. **Comparing enforcement regimes.** The analysis so far has established necessary conditions for the optimal enforcement regime to include regulation and has described what such a regime would look like if optimal. This subsection shows when the optimal enforcement regime does in fact require the use of regulators.

The optimal regime includes regulation if and only if (i) it is optimal for a regulator to limit liability costs for a firm when the regulator's information indicates that the firm is safe (otherwise, negligence with damages $\bar{d}$ is optimal) but (ii) it is not optimal for a regulator to limit liability costs for a firm when the regulator's information indicates that the firm is unsafe (otherwise, negligence with damages $d \in \{0, \underline{d}\}$ is optimal). The condition for (i) is

$$(26) \qquad (1-\delta_{U|S}) \underbrace{\left[1 - \left(\frac{b - \pi_S \epsilon_{U|S} \bar{d}}{\bar{e}}\right)\right](b - \pi_S h)}_{G_S} \geq$$

$$(27) \qquad \delta_{S|U} \underbrace{\left[\frac{b-c}{\bar{e}}(b - c - \pi_U^L h) - \min\left\{\frac{b - \pi_U(1-\epsilon_{S|U})d^R}{\bar{e}}, 1\right\}(b - \pi_U h)\right]}_{L_U}$$

where

$$d^R = \begin{cases} \underline{d} & \text{if } b < \pi_U h \\ 0 & \text{if } b > \pi_U h. \end{cases}$$

[10]When $\bar{e} > b - \mathcal{L}_S^{ep} \frac{\hat{\delta}_{S|U}}{1-\hat{\delta}_{U|S}}$ such lower average expected liability costs result in an increase in average activity.

To interpret (26),[11] the left hand side equals $(1-\delta_{U|S})G_S \propto \Pr(\theta = S|\sigma_R = \hat{S}_R)G_S$, the likelihood that a firm is safe given regulatory signal $\hat{S}_R$ multiplied by the expected welfare gain from correctly granting a safe firm safe-harbor from large future damages and increasing its incentive to engage in activity. The right hand side equals $\delta_{S|U}L_U \propto \Pr(\theta = U|\sigma_R = \hat{S}_R)L_U$, the likelihood that a firm is unsafe given regulatory signal $\hat{S}_R$ multiplied by the expected welfare loss from mistakenly granting an unsafe firm safe-harbor from large future damage awards, which eliminates its incentive to take precautions. Inequality (26) says that it is optimal to limit liability costs for a firm given regulatory signal $\hat{S}_R$ when the first term dominates the second.

For (ii) to also hold (i.e., for it to be optimal to not limit liability costs for a firm given $\sigma_R = \hat{U}_R$), we must have

$$\Pr(\theta = U|\sigma_R = \hat{U}_R)L_U \geq \Pr(\theta = S|\sigma_R = \hat{U}_R)G_S \iff \tag{30}$$

$$(1-\delta_{S|U})L_U \geq \delta_{U|S}G_S \tag{31}$$

Combining (26) and (31) yields Proposition 3.

Proposition 3. *Let $\bar{e} > \tilde{e}^{UB}$. The optimal regime includes regulation if and only if regulators are sufficiently good at distinguishing safe from unsafe firms: $d^*_{\hat{S}_R} \neq d^*_{\hat{U}_R}$ if and only if*

$$\delta_{S|U} + \delta_{U|S}\frac{G_S}{L_U} \leq \min\left\{\frac{G_S}{L_U}, 1\right\} \tag{32}$$

Proposition 3 provides a necessary and sufficient condition for the addition of regulators to raise welfare when litigation alone fails to achieve the conditionally efficient outcome because of court errors and positive externalities to activity. Regulators increase welfare if and only if

[11] To derive (26), note that, if the regulator limits liability costs for a firm, then, in expectation, the firm generates social surplus

$$\Pr(S|\sigma_R)(b-\pi_S h) + (1-\Pr(S|\sigma_R))\min\left\{\frac{b-\pi_U(1-\epsilon_{S|U})d^R}{\bar{e}}, 1\right\}(b-\pi_U h) \tag{28}$$

On the other hand, if the regulator does not limit liability costs for a firm, then, in expectation, the firm generates social surplus

$$\Pr(S|\sigma_R)\frac{b-\pi_S\epsilon_{U|S}\bar{d}}{\bar{e}}(b-\pi_S h) + (1-\Pr(S|\sigma_R))\frac{b-c}{\bar{e}}(b-c-\pi_U^L h) \tag{29}$$

Comparing (28) and (29) and plugging in $\Pr(S|\sigma_R = \hat{S}_R) = \frac{1-\delta_{U|S}}{1-\delta_{U|S}+\delta_{S|U}}$ gives the result.

they are sufficiently good at determining whether a firm should efficiently take precautions. It thus provides some formal support for Landis's (1938) claim that the central benefit of regulators relative to judges is greater expertise.

6. Other regimes

6.1. **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:

$$c + \pi_U^L d^{SL} = \pi_U d^{SL} \Rightarrow \tag{33}$$

$$d^{SL} = \frac{c}{\pi_U - \pi_U^L} \tag{34}$$

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.[12]

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?[13]

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

[13] 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 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

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.

6.2. **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.[14] [15]

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

rules, firms fully internalize the social benefit to activity but not the expected harm from accidents stemming from the activity, decreasing social benefits imply 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 but taking such precautions does not completely eliminate the risk of harm).

[14]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).

[15]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.[16]

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

$$\underbrace{c}_{\text{cost of precautions}} < \underbrace{\pi_U h}_{\text{reduction in expected liability costs by taking precautions}} \tag{35}$$

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

$$b - e > c \tag{36}$$

Hence, the activity level of such firms is

$$\min\left\{\frac{b-c}{\bar{e}}, 1\right\} \tag{37}$$

While unsafe firms take first best precautions under negligence, their activity is inefficiently low whenever $\bar{e} > b - c$ by (37). 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.[17] The

[16]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.

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

formal condition is

$$(\pi_U - \pi_U^L)h - c < \left(1 - \min\left\{\frac{b-c}{\bar{e}}, 1\right\}\right)(b - c - \pi_U^L h) \tag{38}$$

or, equivalently,

$$b > \pi_U h \text{ and } \bar{e} > \frac{(b-c)(b-c-\pi_U^L h)}{b - \pi_U h} \tag{39}$$

Examining (39) 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 (39) is also the necessary and sufficient condition for unsafe firms not to take precautions under the conditionally efficient outcome, we have established the following Proposition.[18]

Proposition 4. *Suppose $\epsilon_{U|S} = \epsilon_{S|U} = 0$, Assumptions 1 and 2 hold, and courts are restricted to setting damages equal to harm. If* (39) *is not satisfied then negligence achieves the conditionally efficient outcome so there is no room for regulation. On the other hand, if* (39) *holds then negligence does not achieve the conditionally efficient outcome and the conditionally efficient outcome can be achieved by introducing regulation which shields all firms from negligence claims.*

Proposition 4 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.

[18] As before, the conditionally efficient outcome refers to the outcome under a benevolent social planner who can directly observe a firm's type and choose its level of precautions and welfare cannot be higher than under this planner given the enforcement methods we consider.

7. 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 many 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

$$\begin{aligned} W^C &= \max_{p_U, y(\theta,e), D(p,\sigma_J)} \mathcal{W} \\ &= \mathbf{E}_e[y(S,e)(b - \pi_S h)] + \mathbf{E}_e[y(U,e)(b - cp_U - \pi_U(p_U)h)] \end{aligned}$$

subject to

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

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

(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_U stands for whether precautions are taken by unsafe firms, $y(\theta,e)$ stands for whether a type (θ,e) firm engages in activity, and constraint (1) reflects the fact that safe firms do not take precautions at the optimum (as easily can be shown).

Fix a solution $D^*(\cdot)$. We first show that if $D^*(0,\hat{S}_J) > 0$ then there is another a solution to the problem, $D(\cdot)$, with $D(0,\hat{S}_J) = 0$. To this end, consider replacing $D^*(0,\hat{S}_J)$ with 0 and raising $D^*(0,\hat{U}_J)$ by $\frac{D^*(0,\hat{S}_J)\epsilon_{S|U}}{1-\epsilon_{S|U}}$. This would have no effect on constraints (2) and (4), but would relax constraints (1) and (3).

For the remainder of the proof, fix a solution $D^*(\cdot)$ with the property that $D^*(0,\hat{S}_J) = 0$. It is left to show that, if $D^*(1,\hat{S}_J) > 0$ or $D^*(1,\hat{U}_J) > 0$, then there is another solution to the problem, $D(\cdot)$, with $D(1,\hat{S}_J) = D(1,\hat{U}_J) = 0$. Suppose first that $D^*(\cdot)$ implements $p_U = 1$ and consider replacing $D^*(1,\hat{U}_J)$ and $D^*(1,\hat{S}_J)$ with $D(1,\hat{U}_J) = D(1,\hat{S}_J) = 0$ while reducing $D^*(0,\hat{U}_J)$ to $\bar{d} = \frac{c}{\pi_U(1-\epsilon_{S|U})}$. Such a change does not affect constraints (1) and (2) but relaxes the others.

Now suppose that $D^*(\cdot)$ implements $p_U = 0$. It is sufficient to demonstrate that constraints (1) and (2) continue to be satisfied if $D^*(1,\hat{S}_J)$ and $D^*(1,\hat{U}_J)$ are replaced with $D(1,\hat{S}_J) = D(1,\hat{U}_J) = 0$. Equivalently, it is sufficient to show that $c > \pi_U(1-\epsilon_{S|U})D^*(0,\hat{U}_J)$ (here we are using the fact that $D^*(0,\hat{S}_J) = 0$).

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 $p_U = 1$:

(40)

$$W(D^*(\cdot)) = \min\left\{1, \frac{b - \pi_U(1-\epsilon_{S|U})D^*(0,\hat{U}_J)}{\bar{e}}\right\}(b - \pi_U h) + \min\left\{1, \frac{b - \pi_S \epsilon_{U|S} D^*(0,\hat{U}_J)}{\bar{e}}\right\}(b - \pi_S h)$$

(41)

$$> \min\left\{1, \frac{b-c}{\bar{e}}\right\}(b - c - \pi_U^L h) + \min\left\{1, \frac{b - \pi_S \epsilon_{U|S}\bar{d}}{\bar{e}}\right\}(b - \pi_S h)$$

Assumptions 1 and 2 imply that a necessary condition for (41) to hold is the following:

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

If (a) then $\frac{b-\pi_U(1-\epsilon_{S|U})D^*(0,\hat{U}_J)}{\bar{e}} > \frac{b-c}{\bar{e}}$; if (b) then $\frac{b-\pi_S\epsilon_{U|S}D^*(0,\hat{U}_J)}{\bar{e}} > \frac{b-\pi_S\epsilon_{U|S}\bar{d}}{\bar{e}}$. Either way, $c > \pi_U(1-\epsilon_{S|U})D^*(0,\hat{U}_J)$.

The proof of Lemma 2 follows identical arguments and hence omitted. ■

The following notation will be useful in presenting the remaining proofs. Denote the net social surplus generated by the behavior of firms classified as safe given damages $d_{\hat{S}_R}$ by $W_{\hat{S}_R}(d_{\hat{S}_R})$ and the net social surplus generated by the behavior of firms classified as unsafe given damages $d_{\hat{U}_R}$ by $W_{\hat{U}_R}(d_{\hat{U}_R})$.

Proof of Proposition 2. Case 1: $\pi_U h < b$. We begin with the case of $\pi_U h < b$ and will proceed by establishing a sequence of claims.

Claim 1. *$d^*_{\hat{S}_R} \leq \bar{d}$ and $d^*_{\hat{U}_R} \leq \bar{d}$.*

Proof. Consider $d_{\hat{S}_R}$. Clearly it cannot be optimal for $d_{\hat{S}_R} > \frac{c}{\pi_S \epsilon_{U|S}}$ because, in that case, safe firms would inefficiently choose to take precautions.

Suppose $\bar{d} < d^*_{\hat{S}_R} \leq \frac{c}{\pi_S\epsilon_{U|S}}$. Then

(42) $$W_{\hat{S}_R}(d^*_{\hat{S}_R}) = (1-\delta_{U|S})\frac{b - \pi_S\epsilon_{U|S}d^*_{\hat{S}_R}}{\bar{e}}(b - \pi_S h) + \delta_{S|U}\frac{b-c}{\bar{e}}(b - c - \pi_U^L h)$$

We could slightly decrease $d^*_{\hat{S}_R}$ without affecting the activity or precautions of unsafe firms, but such a change would increase the activity of safe firms and raise $W_{\hat{S}_R}$ by an amount proportional to $b - \pi_S h$, a contradiction.

We can similarly show that $d^*_{\hat{U}_R} \leq \bar{d}$. $\square$

Claim 2. *If $d^*_{\hat{S}_R} < \bar{d}$ then $d^*_{\hat{S}_R} = 0$. Likewise, if $d^*_{\hat{U}_R} < \bar{d}$ then $d^*_{\hat{U}_R} = 0$.*

Proof. Consider $d_{\hat{S}_R} < \bar{d}$. For $d_{\hat{S}_R}$ in this range

(43)
$$W_{\hat{S}_R}(d_{\hat{S}_R}) = (1 - \delta_{U|S}) \min\left\{\frac{b - \pi_S \epsilon_{U|S} d_{\hat{S}_R}}{\bar{e}}, 1\right\}(b - \pi_S h) + \delta_{S|U} \min\left\{\frac{b - \pi_U(1 - \epsilon_{S|U}) d_{\hat{S}_R}}{\bar{e}}, 1\right\}(b - \pi_U h)$$

(44)
$$\leq (1 - \delta_{U|S})(b - \pi_S h) + \delta_{S|U}(b - \pi_U h) = W_{\hat{S}_R}(0)$$

with equality if and only if $d_{\hat{S}_R} \leq \frac{b - \bar{e}}{\pi_U(1 - \epsilon_{S|U})}$.

If we add an arbitarily small benefit to setting $d_{\hat{S}_R} = 0$ we get the desired result.

We can similarly establish that if $d^*_{\hat{U}_R} < \bar{d}$ then $d^*_{\hat{U}_R} = 0$ $\square$

Claim 3. *If $d^*_{\hat{U}_R} < \bar{d}$ then $d^*_{\hat{S}_R} < \bar{d}$.*

Proof. If $d^*_{\hat{U}_R} < \bar{d}$ then

(45)
$$W_{\hat{U}_R}(0) > W_{\hat{U}_R}(\bar{d}) \Rightarrow$$

(46)
$$\delta_{U|S}(b - \pi_S h) + (1 - \delta_{S|U})(b - \pi_U h) > \delta_{U|S} \frac{b - \pi_S \epsilon_{U|S} \bar{d}}{\bar{e}}(b - \pi_S h) + (1 - \delta_{S|U}) \frac{b - c}{\bar{e}}(b - c - \pi_U^L h)$$

which implies

$$\text{(47)}\quad \delta_{U|S}\left(1-\frac{b-\pi_S\epsilon_{U|S}\bar{d}}{\bar{e}}\right)(b-\pi_S h)>(1-\delta_{S|U})\left[\frac{b-c}{\bar{e}}(b-c-\pi_U^L h)-(b-\pi_U h)\right]\Rightarrow$$

(48)

$$(1-\delta_{U|S})\left(1-\frac{b-\pi_S\epsilon_{U|S}\bar{d}}{\bar{e}}\right)(b-\pi_S h)>\delta_{S|U}\left[\frac{b-c}{\bar{e}}(b-c-\pi_U^L h)-(b-\pi_U h)\right]\Rightarrow$$

$$\text{(49)}\quad W_{\hat{S}_R}(0)>W_{\hat{S}_R}(\bar{d})$$

□

These three Claims establish that $(d^*_{\hat{S}_R}, d^*_{\hat{U}_R}) \in \{(\bar{d},\bar{d}),(0,\bar{d}),(0,0)\}$ for the case where $b > \pi_U h$.

Case 2: $\pi_U h > b$. We now turn to the case of $\pi_U h > b$ and again proceed by establishing a sequence of claims

Claim 4. *$d^*_{\hat{S}_R} \le \bar{d}$ and $d^*_{\hat{U}_R} \le \bar{d}$*

Proof. Identical to the proof of Claim 1. □

Claim 5. *If $d^*_{\hat{S}_R} < \bar{d}$ then $d^*_{\hat{S}_R} = \underline{d}$. If $d^*_{\hat{U}_R} < \bar{d}$ then $d^*_{\hat{U}_R} = \underline{d}$.*

Proof. Suppose $0 \le d^*_{\hat{S}_R} < \underline{d}$. Then

$$\text{(50)}\quad W_{\hat{S}_R}(d^*_{\hat{S}_R})=(1-\delta_{U|S})(b-\pi_S h)+\delta_{S|U}\min\left\{\frac{b-\pi_U(1-\epsilon_{S|U})d^*_{\hat{S}_R}}{\bar{e}},1\right\}(b-\pi_U h)$$

Consider raising $d^*_{\hat{S}_R}$ to $\underline{d}$. This change would lower the activity of unsafe firms without affecting the behavior of safe firms. But such a change would increase welfare, a contradiction.

Now consider $\underline{d} < d^*_{\hat{S}_R} < \bar{d}$. Then

$$\text{(51)}\quad W_{\hat{S}_R}(d^*_{\hat{S}_R})=(1-\delta_{U|S})\frac{b-\pi_S\epsilon_{U|S}d^*_{\hat{S}_R}}{\bar{e}}(b-\pi_S h)+\delta_{S|U}\frac{b-\pi_U(1-\epsilon_{S|U})d^*_{\hat{S}_R}}{\bar{e}}(b-\pi_U h)$$

By the assumption that it is optimal for $d_{\hat{S}_R} < \bar{d}$,

$$\text{(52)}\quad \frac{\partial W_{\hat{S}_R}}{\partial d_{\hat{S}_R}}(d^*_{\hat{S}_R})=\frac{\delta_{S|U}\pi_U(1-\epsilon_{S|U})}{\bar{e}}(\pi_U h-b)-\frac{(1-\delta_{U|S})\pi_S\epsilon_{U|S}(b-\pi_S h)}{\bar{e}}<0$$

a contradiction.

Can similarly establish that, if $d^*_{\hat{U}_R} < \bar{d}$, then $d^*_{\hat{U}_R} = \underline{d}$. □

Claim 6. *If* $d^*_{\hat{U}_R} < \bar{d}$ *then* $d^*_{\hat{S}_R} < \bar{d}$

Proof. If $d^*_{\hat{U}_R} < \bar{d}$ then $W_{\hat{U}_R}(\underline{d}) > W_{\hat{U}_R}(\bar{d})$ which is true if and only if

$$\delta_{U|S}(b - \pi_S h) - (1 - \delta_{S|U})\frac{b - \pi_U(1 - \epsilon_{S|U})\underline{d}}{\bar{e}}(\pi_U h - b) > \tag{53}$$

$$\delta_{U|S}\frac{b - \pi_S \epsilon_{U|S}\bar{d}}{\bar{e}}(b - \pi_S h) + (1 - \delta_{S|U})\frac{b - c}{\bar{e}}(b - c - \pi_U^L h) \tag{54}$$

which implies

(55)
$$\delta_{U|S}\left(1 - \frac{b - \pi_S \epsilon_{U|S}\bar{d}}{\bar{e}}\right)(b - \pi_S h) > (1 - \delta_{S|U})\left[\frac{b - c}{\bar{e}}(b - c - \pi_U^L h) + \frac{b - \pi_U(1 - \epsilon_{S|U})\underline{d}}{\bar{e}}(\pi_U h - b)\right]$$

so

(56)
$$(1 - \delta_{U|S})\left(1 - \frac{b - \pi_S \epsilon_{U|S}\bar{d}}{\bar{e}}\right)(b - \pi_S h) > \delta_{S|U}\left[\frac{b - c}{\bar{e}}(b - c - \pi_U^L h) + \frac{b - \pi_U(1 - \epsilon_{S|U})\underline{d}}{\bar{e}}(\pi_U h - b)\right] \Rightarrow$$

$$W_{\hat{S}_R}(\underline{d}) > W_{\hat{S}_R}(\bar{d}) \tag{57}$$

□

These claims establish that $(d^*_{\hat{S}_R}, d^*_{\hat{U}_R}) \in \{(\bar{d}, \bar{d}), (\underline{d}, \bar{d}), (\underline{d}, \underline{d})\}$ for the case where $b < \pi_U h$. ■

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