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All-or-Nothing versus Proportionate Damages

Shmuel Leshem* and Geoffrey P. Miller**

ABSTRACT

This paper considers the choice between an all-or-nothing rule (AON) and a proportionate damages rule (PD) in civil litigation. Under AON, a prevailing plaintiff receives a judgment equal to his entire damages. Under PD, damages are reduced to reflect uncertainty. For example, if the trier of fact found that there was a seventy-five percent chance that the defendant is liable, the judgment would equal seventy-five percent of the plaintiff's damages. Using a moral hazard model that takes into account defendants' decisions to comply with legal rules, evidentiary uncertainty, and settlement, we show that AON usually maximizes the rate of compliance, although it may result in a higher level of litigation. This, in turn, provides an efficiency rationale for the ubiquity of AON in the legal system.

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*Justice Brandeis is said to have remarked once that “To be effective in this world you have to decide which side is probably right; and once you decide, you must act as if it were one hundred percent right.”**

1. Introduction

This paper considers the choice of the optimal decision rule to be used by courts in awarding damages in the presence of evidentiary uncertainty. Under the traditional all-or-nothing rule (AON), coupled with a preponderance-of-the-evidence standard of proof, the defendant is required to pay the plaintiff’s *entire* damages if it is more likely than not that the defendant is liable. In contrast, under the proportionate damages rule (PD), the defendant is required to pay a *portion* of the plaintiff’s damages equal to the probability that the defendant is liable. The court award is thus higher under an all-or-nothing rule than it would be under a proportional rule if the plaintiff’s claim is supported by the preponderance of the evidence. For example, if the likelihood that the defendant is liable were seventy-five percent, the court award would be equal to the plaintiff’s entire damages under AON, but only seventy-five percent of the plaintiff’s damages under PD. In contrast, the court award is higher under a proportional rule than it would be under an all-or-nothing rule if the plaintiff’s claim is not corroborated by the preponderance of the evidence. For example, if the likelihood that the defendant is liable were twenty-five percent, the court award would be equal to twenty-five percent of the plaintiff’s damages under PD, but no damages would be ordered under AON.

Commentators have long argued that a proportionate damages rule would improve the accuracy, fairness, and legitimacy of adjudication, and also reduce litigation (Allen et al., 1964). This raises the question of why the legal system almost uniformly follows the harsh all-or-nothing rule in civil litigation, rather than the more finely tuned proportional rule. As emphasized by Levmore (1990), this question is “central to the understanding of any civil law system.” The dominance of AON in civil litigation is even more puzzling when one considers that private settlements and arbitration decisions often result in compromised outcomes, a fact that suggests that “[T]he ‘fair’ decision promoted in

* Coons (1980), at p. 260.

private is one unattainable by law” (Coons 1964, at p. 751). Despite the importance of the subject, only a few scholars have considered the choice between AON and PD. As pointed out by Abramovitz (2001), “[a]side from one article thirty-five years ago and a burst of interest twenty years ago, scholars have paid almost no attention to the possibility of replacing the preponderance-of-the-evidence [all-or-nothing] rule with an alternative that is not ‘winner take-all.’”

This paper provides insight into the prevalence of AON by considering the effects of different decision rules on the incentives to comply with the legal standard and on settlement negotiations. It differs from previous analyses that compared AON and PD in that it considers the interplay between different decision rules, the rate of compliance, and the level of litigation. The analysis here identifies factors that affect the choice between AON and PD and thereby provides an efficiency rationale for the ubiquity of AON in the legal system. Specifically, we show that when the parties are able to settle the case before trial AON usually maximizes the rate of compliance with the legal standard, although it may result in more litigation. In addition, our results highlight the importance of settlement negotiations for the superiority of AON over PD in inducing compliance.

To examine the effect of different decision rules on the rate of compliance and the level of litigation, we employ the following stylized framework. We consider a potential defendant who must decide whether to comply with a legal standard. We assume that compliance is costly and that a potential plaintiff is more likely to suffer damages if the defendant does not comply with the legal standard. If the plaintiff suffered damages, a settlement negotiation takes place in which the plaintiff makes a take-it-or-leave-it settlement offer to the defendant. If the defendant declines the offer, the case proceeds to trial. We assume that, when adjudicating the plaintiff’s damages claim, the court may make two types of errors: it may find for the plaintiff even if the defendant complied with the legal standard (Type I error) or it may find for the defendant even if the defendant did not comply with the legal standard (Type II error). Given that the adjudication process is

relatively efficient,¹ we show that the plaintiff's expected recovery at trial is higher under AON than under PD if the defendant complied with the legal standard, but is lower under AON than under PD if the defendant did not comply with the legal standard.

Consider first the effect of different decision rules on the defendant's incentive to comply with the legal standard when the plaintiff's litigation cost or the defendant's cost of compliance is sufficiently high. In such cases, only AON induces the defendant to comply with the legal standard. To see this, assume first that the plaintiff's litigation cost is sufficiently high. Then, since the plaintiff's expected recovery at trial is higher under AON than under PD given that the defendant did not comply with the legal standard, only AON supports the plaintiff's threat to go to trial. This implies that the defendant always violates the legal standard under PD, but complies (at least probabilistically) with the legal standard under AON. Assume next that the defendant's cost of compliance is sufficiently high. Then, since the difference between the defendant's expected payment from compliance and from noncompliance is greater under AON than under PD, only AON provides the defendant with an incentive to comply with the legal standard, even if the plaintiff always makes a high settlement demand. This implies that the defendant always violates the legal standard under PD, but complies (probabilistically) with the legal standard under AON.

Next, consider the case in which the plaintiff's litigation cost and the defendant's cost of compliance are such that, under both AON and PD, the defendant will not find it optimal to always violate the legal standard. Then, if the plaintiff suffered damages, the plaintiff would make a take-it-or-leave-it settlement offer which is either high (inducing only non-compliant defendants to settle) or low (inducing all defendants to settle). The defendant's expected recovery is higher under an all-or-nothing rule if the defendant violated the legal standard, but higher under a proportional rule if the defendant complied with the legal standard. Accordingly, a high settlement demand is higher and a low settlement demand is lower under AON than under PD, which in turn entails that the difference between a low settlement demand and a high settlement demand is greater under AON.

¹ By *relatively* efficient we mean that that Type I and Type II errors are sufficiently low and the difference between the error rates is sufficiently small.

As a result, the plaintiff's opportunity cost from making a low settlement demand is higher under AON than under PD. The plaintiff thus has a greater incentive to make a high settlement demand under AON than he would have under PD. The plaintiff's greater incentive to make a high settlement demand results, in turn, in a higher rate of compliance under AON than under PD. It should be stressed that this result depends on the presence of settlement; if the parties may not settle the case before trial, the advantage of AON over PD in inducing compliance no longer holds.

Although the rate of compliance is usually higher under AON, the level of litigation *may* be lower under PD. The reason is twofold. First, *given* that the plaintiff suffered damages, the defendant is more likely to have complied with the legal standard under AON than under PD; as a result, the defendant is more likely to decline a high settlement offer under AON. Second, the plaintiff's *equilibrium* probability of making a high settlement demand may be higher under AON than under PD.² Therefore, *given* that the defendant complied with the legal standard, he is more likely to decline the plaintiff's settlement offer under AON than under PD.

Since social cost is likely to be dominated by the expected cost of the primary activity (rather than litigation cost), this analysis provides an efficiency rationale for the prevalence of AON in civil litigation. We also identify factors that affect the choice between AON and PD by evaluating the social cost under each rule. In particular, we show that the advantage of AON over PD in inducing compliance increases in the plaintiff's litigation cost, but decreases in the defendant's cost of compliance.

The analysis here differs from previous works that compare AON to PD in three respects. First, our model emphasizes the interplay between the rate of deterrence and settlement negotiations. Specifically, we show that a greater incentive to make a high settlement demand results in a higher rate of compliance. Second, the source of evidentiary uncertainty in our model is the imperfection of the evidentiary process rather than casual indeterminacy. Third, the cause for litigation here is the information asymmetry

² The plaintiff's equilibrium probability of making a high settlement demand depends on the defendant's *incentive* to comply with the legal standard, as distinct from the defendant's *equilibrium* probability of compliance.

regarding the defendant's choice of action rather than, as in some previous analyses, divergent expectations of the litigants as to the trial outcome.

Our analysis also sheds light on the choice between litigation and arbitration. Arbitration is often characterized by the flexibility of its procedures; this flexibility results in a considerable amount of discretion given to the arbitrator to resolve the disagreement. Accordingly, arbitrators are often perceived as deviating from a strict adherence to the parties' legal rights, applying instead a split-the-difference, or proportional, approach. Another consequence of the flexibility of arbitration procedures is that arbitration is usually more expeditious and less costly than litigation. Given the advantages of arbitration over litigation, one might predict that private parties would have incentives to resolve their dispute through arbitration. However, recent empirical evidence has shown that sophisticated contractual parties seldom choose to include arbitration clauses in their agreements (Eisenberg and Miller, 2006). Our results provide an explanation for the observed preference for litigation over arbitration: although litigation is more costly than arbitration and may result in a lower frequency of settlement, it is nevertheless more effective in inducing compliance.

The rest of the paper proceeds as follows. Section 2 reviews the relevant literature. Section 3 sets up a model and compares the actual court award and the expected court award under AON and under PD. Section 4 presents the equilibrium strategies and the equilibrium outcomes. Section 5 compares social welfare under AON and under PD. Section 6 briefly considers the case of non-settlement. Section 7 concludes.

2. Related Literature

As stated above, only a few studies have considered the choice between AON and PD.³ Kaye (1982) shows that AON minimizes the expected cost of error as measured by the probability of a wrongful judgment multiplied by the amount erroneously paid to (or

³ For an exhaustive summary of the literature see Abramowicz (2001).

withheld from) the plaintiff.⁴ Kaye also showed that AON is superior to all other decision rules in minimizing the expected cost of error. Orloff and Stedinger (1983) refine Kaye's analysis by emphasizing that minimizing the costs of error need not be the singular objective of a decision rule. They show that PD may be superior to AON in minimizing the costs of large errors as well as in avoiding bias in the distribution of errors between plaintiffs and defendants. Neither of these studies consider the effect of different decision rules on the incentives to engage in the primary activity or on settlement negotiations.

Shavell (1985) examines the deterrence effects of AON and PD by considering a potential injurer's decision to engage in a risky activity. Shavell's analysis concludes that under PD, but not under AON, the injurer fully internalizes the expected costs of harm in his decision whether to engage in or abstain from the activity. In Shavell's analysis, which is restricted to uncertainty relating to causal indeterminacy, a potential injurer faces a binary choice of whether or not to engage in the regulated activity: if the potential injurer does not engage in the activity he escapes liability, whereas if he engages in the activity his liability depends on the adjudication rule. Here, by contrast, we consider the *rate* of compliance among a population of injurers by allowing a potential injurer to randomize between complying and not complying with the legal standard. We thus reach an opposite conclusion from Shavell's.

Our paper is related to several papers that considered the optimal *standard of proof* (or evidence) in civil litigation given an all-or-nothing rule of recovery. Lando (2002) shows that a preponderance-of-the-evidence standard (as distinct from, for example, clear and convincing evidence) maximizes deterrence and is efficient if sanctions are costless. Demougina and Fluet (2006) likewise show that a preponderance-of-the-evidence standard maximizes the incentive to take care. Neither of these papers, however, consider the deterrence effects of a proportionate-damages rule. In addition, in contrast to Lando's and Demougina and Fluet's models, in our model the advantage of AON over PD hinges on the presence of settlement. In particular, in the absence of settlement no longer is AON always superior to PD in inducing compliance.

⁴ A similar argument is made by Kaplan (1968).

Our paper is also related to previous works that examined the effects of legal error on the rate of deterrence and the level of litigation. Polinsky and Shavell (1989) examine the effect of legal error on the decision to bring suit and the incentive to obey the law, but do not consider the interrelation between these effects. Hylton (1990) considers the interrelation between legal error, the rate of compliance, and the probability of suit but is primarily concerned with the effect of legal error on the equilibrium rate of compliance. Gutierrez (2003) examines the equilibrium rates of performance and litigation in a model closely related to ours. Her analysis, however, focuses on the effects of private contracting on social welfare rather than on the incentive effects of decision rules.

3. Model

3.1 The Game

- **The Activity Stage.** A risk-neutral party (the “injurer”) engages in a risky but socially valuable activity. The injurer must choose between taking care and not taking care. Let $a \in \{L, H\}$ denote the injurer’s level of care. Assume that not taking care (L) is costless, but taking care (H) costs e . After the injurer has chosen whether to take care, an accident may occur. The accident causes harm to a risk-neutral party (the “victim”). Without loss of generality, we normalize the victim’s harm from an accident to one. Let p_L and p_H denote the probability of accident as a function of the injurer’s choice of care. Assume that $p_L > p_H$; that is, the probability that an accident occurs is higher when the injurer does not take care. We exclude from consideration cases in which both the injurer and the victim may take actions to reduce the probability of accident. Finally, we assume that taking care is socially efficient; that is:

$$p_L > p_H + e. \tag{1}$$

- **The Settlement Stage.** If an accident occurs, a settlement stage takes place wherein the victim may present a settlement demand to the injurer. If the injurer accepts the settlement demand, the game ends. If the injurer rejects the settlement demand, the case goes to trial. To simplify the presentation, we assume that the victim can commit to go to

trial if the case fails to settle. As we later show, relaxing this assumption does not change our main results. We further assume that if the injurer is indifferent between accepting and rejecting the settlement demand, he will rather settle than go to trial. If the case goes to trial, the victim has to incur a litigation cost of k . For simplicity, we assume that the injurer does not incur costs if the case reaches trial. This assumption as well does not affect the substance of our results.

▪ **The Trial Stage.** If the case reaches trial, the court observes a signal, $s \in \{l, h\}$, indicating whether the injurer took care or not. Let q_L denote the probability that the court observes a low signal given that the injurer did *not* take care ($\Pr(s = l | i = L) = q_L$) and q_H denote the probability that the court observes a low signal given that the injurer *took* care ($\Pr(s = l | i = H) = q_H$). Assume that $q_L > 0.5 > q_H$; i.e., the signal is informative, but imperfect. Thus, the probability of a Type I error (a false positive) is q_H and the probability of a Type II error (a false negative) is $1 - q_L$. Legal error may result from the insufficiency of the evidence presented at trial or the court's limited competence to correctly assess the evidence.^{5, 6}

The following table summarizes the probability that the court observes a low or a high signal conditional on the injurer's choice of care:

TABLE 1: LIKELIHOOD MATRIX OF THE EVIDENCE

Effort → Signal ↓	Careless (L)	Careful (H)
l	q_L	q_H
h	$1 - q_L$	$1 - q_H$

⁵ For a similar technique to abstract the evidentiary process see Polinsky and Shavell (1989) and Hylton (1990).

⁶ Although we consider a negligence model, our model also captures a setting in which a contract between a principal and an agent specifies that the agent is to exert high effort in managing a project and the agent's choice of effort is unobservable to the principal, but costly and imperfectly verifiable by a court.

In the model's evidentiary process, the court does not consider the injurer's prior probability of carelessness or the conditional probability of an accident in deciding the injurer's liability. The court thus assumes that the prior probability of carelessness, given that an accident has occurred, is one-half.⁷ We motivate this assumption on several grounds. As Posner (1999) points out, incorporating the prior probability of carelessness or the conditional probability of an accident into the court's decision would reduce the value of the evidence presented at trial, and would thereby compromise the injurer's ability to affect the trial outcome through his choice of action. In particular, a strong (weak) prior that the injurer is liable would decrease (enhance) the value of exculpatory evidence. Similarly, a strong (weak) prior that the injurer is liable would enhance (decrease) the value of inculpatory evidence. The parties' incentives to provide evidence, as well as the injurer's incentive to take care, would consequently be distorted.⁸ In addition, the prior probability of carelessness may depend on factors such as the litigation cost, the cost of taking care, and the conditional probability of an accident. Information on such factors may not be verifiable. Moreover, even if information on such factors is verifiable, policy reasons may render such information irrelevant or inadmissible. For example, character evidence, which may help to establish the prior probability of carelessness, is inadmissible.⁹ We accordingly assume that the court's decision depends solely on the signal produced at trial.¹⁰

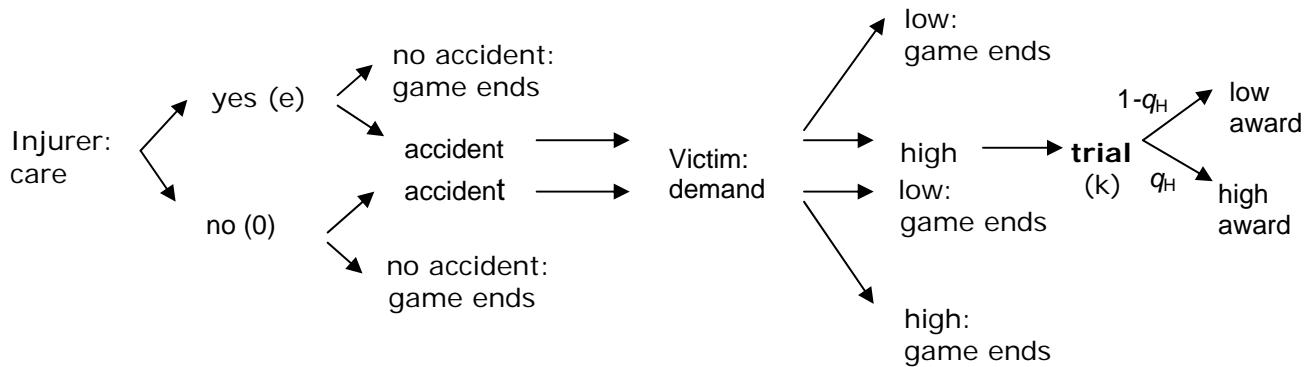
⁷ Posner (1999), for example, argues that rules of evidence allow 'non biased' priors: "Ideally we want the trier of fact to work from prior odds of 1 to 1 that the plaintiff ... has a meritorious case". In a similar vein, Lando (2002) distinguishes between the probability of *guilt* (or negligence), which takes into account ex-ante information, and the standard of *evidence*, which only considers ex-post information.

⁸ See Koehler (2002) for a summary of courts' decisions that conclude that information about a 'base rate' – the relative frequency with which an event occurs or an attribute is present in some reference population – is irrelevant as evidence.

⁹ See Federal Rules of Evidences 404.

¹⁰ See Daughety and Reinganum (2000) for an exhaustive discussion of the justifications for non-Bayesian model of courts' decision-making process. Reinganum and Daughety write (p. 372): "... we model the trial court's assessment of credible evidence in non-Bayesian terms, not because we don't believe in Bayesian decision making, but because we believe that the evidence aggregation process is highly constrained. Whether one models this as 'mostly Bayesian with a few constraints' or 'mostly constrained with a few opportunities for Bayesian updating' is a judgment call."

FIGURE 1 – GAME CHART



3.2 The Court’s Decision Rule

We consider two decision rules by which the court may decide the dispute. First, the court may use an “all-or-nothing” decision as to whether to grant the plaintiff’s claim. Under this rule, the plaintiff recovers his entire damages if the court finds that the probability of carelessness is higher than one half, but obtains nothing if the court finds that the probability of carelessness is lower than one half. We denote the players’ payoffs under this rule by the superscript ‘*A*’ (for all-or-nothing). Second, the court may use a proportionate damages rule, whereby damages are split according to the court’s estimation of the likelihood that the injurer was careless. We denote the players’ payoffs under this rule by the superscript ‘*S*’ (for split-the-difference).

3.2.1 The Court award

Let $d^j(s), j \in \{A, S\}$, denote the *fraction* of damages awarded to the victim as a function of the signal observed by the court under AON (*A*) and under PD (*S*). We assume that the court may not order punitive damages, but our substantive results would not change if the court award could exceed the victim’s damages. We begin by considering the court award under AON. If the court observes l , it rules in favor of the victim and orders the

injurer to pay the victim's entire damages. If the court observes h , it dismisses the victim's claim. The court award under AON is thus:

$$\begin{cases} 1 & \text{if } s = l \\ 0 & \text{if } s = h. \end{cases} \quad (2)$$

Next, consider the court award under PD. Under PD, the court awards the victim a share of his damages equal to the *likelihood* that the injurer was careless. The court award under PD is thus:

$$\begin{cases} \frac{q_L}{q_L + q_H} \equiv d_l & \text{if } s = l \\ \frac{1 - q_L}{2 - q_L - q_H} \equiv d_h & \text{if } s = h. \end{cases} \quad (3)$$

By Bayes rule, d_l is equal to the likelihood that the injurer was careless given that the court observes l , and d_h is equal to the likelihood that the injurer was careless given that the court observes h . It is straightforward to show that $1 > d_l > 0.5 > d_h > 0$. This, in turn, captures an intuitive relation between AON and PD: the court award is higher under AON than under PD when l is observed, while the reverse is true when h is observed. Note also that in the absence of legal error (i.e., $q_L = 1$ and $q_H = 0$), the court award is identical under AON and PD.

3.2.2 The Ex-post Expected Court Award

Let $d_a^j, a \in \{L, H\}, j \in \{A, S\}$, denote the expected court award under AON and PD as a function of the injurer's choice of care *given* that an accident has occurred ("the ex-post expected court award"). As we will show below, the ex-post expected court award given that the injurer took care and the ex-post expected court award given that the injurer did not take care constitute the possible settlement outcomes of the game.

The ex-post expected court award under AON is given by:

$$\begin{cases} q_L \equiv d_L^A & \text{if } a = L \\ q_H \equiv d_H^A & \text{if } a = H. \end{cases} \quad (4)$$

q_L is the ex-post expected court award under AON given that the injurer did not take care. It is equal to the probability that the court observes (correctly) l given that the injurer did not take care, multiplied by the court award under AON when the court observes l (i.e., 1). q_H is the ex-post expected court award given that the injurer took care. It is equal to the probability that the court observes (incorrectly) l given that the injurer took care, multiplied by the court award under AON when the court observes l (i.e., 1). To facilitate the comparison between AON and PD we denote q_L as d_L^A and q_H as d_H^A .

It is straightforward to show that the ex-post expected court award under AON is: (i) higher if the injurer did not take care than if the injurer took care (because $q_L > q_H$), (ii) lower than the actual court award under AON if the injurer did not take care (because $q_L < 1$), and (iii) higher than the actual court award under AON when the injurer took care (because $q_H > 0$).

The ex-post expected court award under PD is given by:

$$\begin{cases} q_L d_l + (1 - q_L) d_h \equiv d_L^S & \text{if } a = L \\ q_H d_l + (1 - q_H) d_h \equiv d_H^S & \text{if } a = H. \end{cases} \quad (5)$$

d_L^S is the ex-post expected court award under PD given that the injurer did not take care. It is equal to the sum of (the probability that the court observes (correctly) l given that the injurer did not take care) \times (the court award under PD when the court observes l (i.e., d_l))

+ (the probability that the court observes (incorrectly) h given that the injurer did not take care) \times (the court award under PD when the court observe h (i.e., d_h)).

Likewise, d_H^S is the ex-post expected court award given that the injurer took care. It is equal to the sum of (the probability that the court observes (incorrectly) l given that the injurer took care) \times (the court award under PD when the court observes l (i.e., d_l)) + (the probability that the court observes (correctly) h given that the injurer took care) \times (the court award under PD when the court observes h (i.e., d_h)). It is straightforward to show that the ex-post expected court award under PD is: (i) higher when the injurer did not take care than when he did (because $d_L^S > d_H^S$), (ii) lower than the actual court award under PD if the injurer did not take care (because $d_L < d_l$), and (iii) higher than the actual court award under PD when the injurer took care (because $d_H > d_h$).

We make the following assumption about the ex-post expected award under AON and under PD.

ASSUMPTION 1.

The ex-post expected court award under AON and PD satisfies the following relations:

$$q_L \equiv d_L^A > d_L^S > d_H^S > d_H^A \equiv q_H.$$

Assumption 1 states that the ex-post expected court award is higher under AON than under PD if the injurer did not take care, and is lower under AON than under PD if the injurer took care. As we show in the Appendix, underlying Assumption 1 is a notion about the efficacy of the evidentiary process. Specifically, Assumption 1 holds if the rates of Type I and Type II errors are sufficiently low, and the difference between the error rates is sufficiently small. This, in turn, implies that the legal system is relatively efficient and that the evidentiary signal is not strongly biased in one direction. In

particular, Assumption 1 always holds when Type I and Type II errors are equal ($q_L = 1 - q_H$).

3.2.3 The Ex-ante Expected Court Award

Let $p_a d_a^j$, $a \in \{L, H\}$, $j \in \{A, S\}$, denote the expected court award under AON and under PD as a function of the injurer's choice of care *prior* to the occurrence of an accident (the “ex-ante expected court award”). As we will later show, the *difference* between the ex-ante expected court award when the injurer takes care and when he does not take care affects the injurer's decision of whether or not to take care.

The ex-ante expected court award under AON and PD is given by:

$$\begin{cases} p_L d_L^j & \text{if } i = L \\ p_H d_H^j & \text{if } i = H \end{cases} \quad \text{for } j \in \{A, S\}. \quad (6)$$

$p_L d_L^j$ is the ex-ante expected court award given that the injurer did not take care. It is equal to (the probability of accident given that the injurer does not take care) \times (the corresponding ex-post expected court award under either AON or PD). Similarly, $p_H d_H^j$ is the ex-ante expected damages given that the injurer took care. It is equal to (the probability of accident given that the injurer takes care) \times (the corresponding ex-post expected court award under AON or PD).

We denote the *difference* between the ex-ante expected court award when the injurer takes care and when he does not take care by Δ^A (under AON) and Δ^S (under PD). More specifically, $\Delta^A = p_L d_L^A - p_H d_H^A$ and $\Delta^S = p_L d_L^S - p_H d_H^S$. It is straightforward to show that given $d_L^A - d_H^A > d_L^S - d_H^S$ (by assumption 1), $\Delta^A > \Delta^S$. That is, the difference between the ex-ante expected court award when the injurer does not take care and when he does is greater under AON than under PD.

4. The Equilibrium Strategies and Outcomes

We solve the game backward. We begin by considering the victim's settlement strategy, $\theta_j \in [0,1]$, for $j \in \{A, S\}$. The victim's settlement strategy is the probability that the victim makes a high settlement demand under AON or under PD when the victim has a credible threat to go to trial. We let $\theta_j = w$ denote the case in which the victim lacks a credible threat to go to trial. We then consider the injurer's care strategy, $\lambda_j \in [0,1]$, for $j \in \{A, S\}$. The injurer's care strategy is the probability that the injurer takes care under AON or under PD. We then provide a general solution of the game. In Section 5 we compare the victim's and the injurer's equilibrium strategies under the different decision rules and consider the efficiency implications of our analysis.

4.1 The Victim's Settlement Decision

If an accident occurs, the victim may make either a low settlement demand (d_H^j), which both types of injurer will accept, or a high settlement demand (d_L^j), which only the careless injurer will accept (recall the assumption that the injurer will accept a settlement demand if he is indifferent between settling the case and going to trial).¹¹ Note that the injurer will accept a settlement demand if and only if the victim has a credible threat to go to trial; that is, if the victim's litigation cost is lower than his maximum expected payoff from going to trial. This maximum is obtained when the injurer is always careless and it thus equals d_L^j . We assume that if the victim were indifferent between taking the

¹¹ The victim will never make a settlement demand (a) greater than d_L^j , (b) lower than d_L^j and higher than d_H^j , or (c) lower than d_H^j . A settlement demand greater than d_L^j will be rejected by both types of injurers. It is therefore strictly dominated by d_L^j if the probability that the injurer was careless is positive, and is dominated by d_H^j if the injurer is always careful. A settlement demand which is lower than d_L^j and higher than d_H^j will be accepted by the careless injurer, but not by the careful one. It is therefore strictly dominated by d_L^j if the probability that the injurer is careless is positive, and is dominated by d_H^j if the injurer is always careful. Finally, a settlement demand lower than d_H^j will be accepted by both types of injurers, but so too is d_H^j . A settlement demand lower than d_H^j is therefore strictly dominated by d_H^j .

case to trial and dropping the case, the victim would rather drop the case. Thus, the victim has a credible threat to go to trial if and only if his litigation cost is lower than d_L^j ($k < d_L^j$).

If the victim has a credible threat to go to trial, then his settlement decision depends on his belief about the injurer's choice of care. Let $\hat{\lambda}_j$ denote the victim's *updated* belief about the injurer's choice of care. Then, by Bayes's rule:

$$\hat{\lambda}_j = \frac{\lambda_j p_L}{\lambda_j p_L + (1 - \lambda_j) p_H}. \quad (7)$$

Next we solve for the cut-off probability of carelessness under which the victim is indifferent between making a low settlement demand or a high settlement demand. The victim's expected payoff from making a low settlement demand, which both types of injurers will accept, is d_H^j . The victim's expected payoff from making a high settlement demand, which only the careless injurer will accept, is

$$\hat{\lambda}_j d_L^j + (1 - \hat{\lambda}_j)(d_H^j - k_j). \quad (8)$$

The first term is the victim's expected payoff if the injurer did not take care and therefore accepts a high settlement demand. The second term is the victim's expected payoff if the injurer took care. In the latter case, the injurer rejects a high settlement demand and the case proceeds to trial, costing the victim k in litigation cost.

The victim is indifferent between making a low and a high settlement demand if

$$\hat{\lambda}_j d_L^j + (1 - \hat{\lambda}_j)(d_H^j - k) = d_H^j. \quad (9)$$

The left-hand side is the victim's expected payoff from a high settlement demand. The right-hand side is the victim's expected payoff from a low settlement demand.

Plugging in the expression for $\hat{\lambda}_j$ from (7) and rearranging yields:

$$\bar{\lambda}_j = \frac{p_H k}{p_L(d_L^j - d_H^j) + p_H k}. \quad (10)$$

The interpretation of $\bar{\lambda}_j$ is as follows. The victim is indifferent between making a low settlement demand and a high settlement demand if the injurer's probability of carelessness is $\bar{\lambda}_j$. The victim strictly prefers to make a high settlement demand if the injurer's probability of carelessness is higher than $\bar{\lambda}_j$, and strictly prefers to make a low settlement demand if the injurer's probability of carelessness is lower than $\bar{\lambda}_j$.

Lemma 1.1 considers the victim's best response as a function of his litigation cost and the injurer's strategy.

LEMMA 1.1

- (a) *If $k \geq d_L^j$, the victim lacks a credible threat to go to trial.*
- (b) *If $k < d_L^j$, the victim plays a mixed strategy, $\theta_j^S \in [0,1]$, if $\lambda_j = \bar{\lambda}_j$. The victim makes a high settlement demand with certainty if $\lambda_j > \bar{\lambda}_j$, and a low settlement demand with certainty if $\lambda_j < \bar{\lambda}_j$.*

Proof. See Appendix.

Lemma 1.1(a) implies that when the victim's litigation cost is sufficiently high, only AON supports the victim's threat to go to trial. In particular, when $d_L^A > k \geq d_L^S$, the victim has a credible threat to go to trial under AON, but not under PD. The rationale for

this result is as follows. The victim's threat to go to trial depends on his maximum expected payoff from going to trial (d_L^j). Since the victim's maximum expected recovery at trial is higher under AON than under PD (since, by Assumption 1, $q_L = d_L^A > d_L^S$), AON has an advantage over PD in inducing compliance.

Lemma 1.2 below considers the injurer's probability of carelessness under which the victim is indifferent between making a low settlement demand and a high settlement demand under the different decision rules.

LEMMA 1.2

Assume $k < d_L^S$ so that the victim has a credible threat to go to trial under both AON and PD. Then the probability of carelessness under which the victim is indifferent between making a low settlement demand and a high settlement demand is higher under PD than under AON; that is, $\bar{\lambda}_S > \bar{\lambda}_A$.

Proof. Recall that $\bar{\lambda}_j = \frac{p_H k}{p_L(d_L^j - d_H^j) + p_H k}$. Since, by Assumption 1, $d_L^A - d_H^A > d_L^S - d_H^S$, it follows that $\bar{\lambda}_S > \bar{\lambda}_A$.

The rationale for Lemma 1.2 is as follows. The victim's settlement decision depends on the *difference* between his expected payoff from making a low settlement demand and a high settlement demand. Since a high settlement demand is higher under AON (since $q_L = d_L^A > d_L^S$), and a low settlement demand is lower under AON (since $q_H = d_H^A < d_H^S$), the difference between a high demand and a low demand is greater under AON than under PD. As a result, the victim's incentive to make a high settlement demand is greater under AON than PD. Therefore, to make the victim indifferent between making a low demand and a high demand, the equilibrium probability of carelessness must be higher under PD than under AON. Thus, the victim's greater

incentive to go to trial under AON induces a higher level of compliance under AON as compared to PD.¹²

4.2 The Injurer's Choice of Care

We now consider the injurer's choice of care. We assume that $k < d_L^S$ so that the victim has a credible threat to go to trial under both AON and PD. When the injurer chooses to take care, his expected payoff does not depend on whether the case is settled or resolved at trial (since the injurer will always decline a high settlement demand). The injurer's expected payoff when he take care is thus

$$-e - p_H d_H^j. \quad (11)$$

The first term is the injurer's cost of taking care. The second term is the ex-ante expected court award given that the injurer chooses to take care.

When the injurer does not take care, his expected payoff depends on the victim's settlement decision. The injurer's expected payoff when he does not take care is thus

$$-p_L [(1 - \theta_j) d_H^j - \theta_j d_L^j]. \quad (12)$$

The expression in (12) is equal to the probability of an accident given that the injurer does not take care multiplied by the sum of (the probability that the victim makes a low

¹² The result that the equilibrium probability of carelessness is lower under AON than under PD holds even if the victim cannot commit to go to trial. In such a case, the careless injurer must randomize between accepting and rejecting a high settlement demand so as to make the victim indifferent between taking the case to trial and dropping the case after a high settlement demand has been rejected. In any equilibrium, however, the victim *always* goes to trial. (To see this, note that if the victim drops the case with positive probability after a high settlement demand has been rejected, the careless injurer would *always* reject a high settlement demand; but this, in turn, would cause the victim to always take the case to trial.) The probability with which the careless injurer must reject a high settlement demand depends on the injurer's equilibrium probability of carelessness: the lower the equilibrium probability of carelessness, the higher must be the probability with which the injurer rejects a high settlement demand. The lowest (highest) equilibrium probability of carelessness is obtained when the careless injurer always rejects (accepts) a high settlement demand. However, the probability of carelessness is always lower under AON than under PD for any probability with which the careless injurer rejects a high settlement demand.

settlement demand) × (the amount of a low settlement demand) + (the probability that the victim makes a high settlement demand) × (the amount of a high settlement demand).

The injurer's incentive to take care depends on the difference between his expected payoff when he takes care (see (10)) and his expected payoff when he does not take care (see (11)). The maximum difference is obtained when $\theta_j = 1$, and it equals to $\Delta_j \equiv p_L d_L^j - p_H d_H^j$. When the injurer's cost of taking care is sufficiently high, so that $e > \Delta_j$, the injurer never takes care. For such a cost, the injurer's expected payoff is higher if he does not take care than if he does even if the victim always makes a high settlement demand.

The minimum difference between the injurer's expected payoff when he takes care (see (10)) and his expected payoff when he does not take care (see (11)) is obtained when $\theta_j = 0$ and it equals to $\Delta_j^* \equiv d_H^j (p_L - p_H)$. When the cost of taking care is sufficiently low, so that $e < \Delta_j^*$, the injurer always takes care. For such a cost, the injurer's expected payoff is higher if he takes care than if he does not even if the victim always makes a low settlement demand.

We next solve for the cut-off probability of a high settlement demand for which the injurer is indifferent between taking care and not taking care for intermediate costs of care such that $\Delta_j^* \leq e \leq \Delta_j$. The injurer is indifferent between taking and not taking care if:

$$-p_L[(1-\theta_j)d_H^j - \theta_j d_L^j] = -e - p_H d_H^j. \quad (13)$$

The right-hand side is the injurer's expected payoff when he does not take care. The left hand side is the injurer's expected payoff when he takes care.

Solving for θ_j that satisfies the equality in (13) we get

$$\bar{\theta}_j = \frac{e - d_H^j(p_L - p_H)}{p_L(d_L^j - d_H^j)}. \quad (14)$$

The injurer is indifferent between taking care and not taking care if the victim's probability of making a high settlement demand is $\bar{\theta}_j$. The injurer strictly prefers to take care if the victim's probability of making a high settlement demand is higher than $\bar{\theta}_j$, and strictly prefers not to take care if the victim's probability of making a high settlement demand is lower than $\bar{\theta}_j$.

Lemma 2.1 considers the injurer's best response as a function of his cost of taking care and the victim's strategy.

LEMMA 2.1

Assume $k < d_L^j$ so that the victim has a credible threat to go to trial under both AON and PD. Then:

- (a) *If $e > \Delta_j$, the injurer is careless with certainty.*
- (b) *If $e = \Delta_j$, the injurer plays a mixed strategy, $\lambda_j \in [0,1]$, if the victim makes a high settlement demand with certainty. Otherwise, the injurer is careless with certainty.*
- (c) *If $\Delta_j > e > \Delta_j^*$, the injurer plays a mixed strategy, $\lambda_j \in [0,1]$, if $\theta_j = \bar{\theta}_j$, is careless with certainty if $\theta_j < \bar{\theta}_j$, and takes care with certainty if $\theta_j > \bar{\theta}_j$.*
- (d) *If $e = \Delta_j^*$, the injurer plays a mixed strategy, $\lambda_j \in [0,1]$, if the injurer makes a low settlement demand with certainty. The injurer takes care with certainty if the victim makes a high settlement demand with positive probability.*
- (e) *If $e < \Delta_j^*$, the injurer takes care with certainty.*

Proof. See the Appendix.

Parts (a)-(c) imply that only AON induces the injurer to take care when the cost of taking care is sufficiently high, since the difference between the injurer's expected payoffs when he takes care and when he does not take care is higher under AON. In particular, when

the injurer's cost of taking care is high ($\Delta_A \geq e > \Delta_S$), the injurer will never take care under PD, but under AON his strategy depends on the victim's strategy.

Part (e) implies that when the injurer's cost of taking care is low ($\Delta_S^* > e \geq \Delta_A^*$), the injurer always takes care under PD, but under AON his strategy depends on the victim's strategy. The reason for this result is as follows. If an accident occurs, the injurer is expected to pay at least the amount of the low settlement demand (given that the victim has a credible threat to go to trial). Since a low settlement demand is higher under PD than under AON (because $d_H^S > d_H^A$), the injurer's incentive to take care and to thereby reduce the probability of accident is greater under PD than it is under AON. When the cost of taking care is lower than Δ_S^* but higher than Δ_A^* , the injurer's benefit from the reduced probability of accident exceeds his cost of taking care under PD, but not under AON.

Lemma 2.2 considers the probability that the victim makes a high settlement demand for which the injurer is indifferent between taking care and not taking care under the different decision rule.

LEMMA 2.2

Assume that $k < d_L^j$ and that $\Delta_S > e > \Delta_S^$. Then there exists a cut-off value $\bar{e} = \frac{(p_L - p_H)(\delta_A d_H^S - \delta_S d_H^A)}{(\delta_A - \delta_S)}$, where $\Delta_S^* < \bar{e} < \Delta_S$ and $\delta_j \equiv d_L^j - d_H^j$, such that the probability of a high settlement demand for which the injurer is indifferent between taking care and not taking care is lower under AON if $e > \bar{e}$, higher under AON if $e < \bar{e}$, and is identical under AON and under PD if $e = \bar{e}$.*

Proof. See Appendix.

The intuition behind Lemma 2.2 is as follows. The injurer's decision whether to take care depends on the *difference* between his expected payoff when he takes care and when

he does not take care. The injurer's expected damage payments are higher under PD than under AON when the probability with which the victim makes a high settlement demand is low. By contrast, the injurer's expected damage payments are higher under AON than under PD when the probability with which the victim makes a high settlement demand is high. When the injurer's cost of taking care is sufficiently high ($e > \bar{e}$), it takes a higher probability of a high settlement demand to make the injurer indifferent between taking care and not taking care. Consequently, the probability of a high-settlement demand that is required to keep the injurer indifferent between taking care and not taking care is lower under AON. In contrast, when the cost of taking care is sufficiently low ($e < \bar{e}$), it takes a lower probability of a high settlement demand to make the injurer indifferent between taking care and not taking care. Consequently, the probability of a high settlement demand that is required to keep the injurer indifferent between taking care and not taking care is lower under PD.

4.3 Equilibrium Outcomes

Lemma 3 presents the Pareto-efficient subgame-perfect Nash equilibria of the game.

LEMMA 3

(a) If $k \geq d_L^j$ then $(\lambda_j, \theta_j) = (1, w)$.

(b) If $k < d_L^j$ then

$$(\lambda_j, \theta_j) = \begin{cases} (1,1) & \text{if } e > \Delta_j \\ (\bar{\lambda}_j, 1) & \text{if } e = \Delta_j \\ (\bar{\lambda}_j, \bar{\theta}_j) & \text{if } \Delta_j^* < e < \Delta_j \\ (0,0) & \text{if } 0 < e \leq \Delta_j^*. \end{cases}$$

Proof. The proof follows directly from Lemmas 1 and 2.¹³

¹³ Note that the injurer's strategy is discontinuous in the cost of taking care (at $e = \Delta_j^*$ and $e = \Delta_j$).

Lemma 3 implies that there exist three types of subgame perfect Nash equilibria:

Pure-Strategy equilibria: $(\lambda_j, \theta_j) = (1, w)$, $(\lambda_j, \theta_j) = (1, 1)$, or $(\lambda_j, \theta_j) = (0, 0)$. There are two types of pure strategy equilibria. In the first type, the injurer never takes care and the victim either lacks a credible threat to go to trial or always makes a high settlement demand. In the second type, the injurer always takes care and the victim always makes a low settlement demand.

Hybrid equilibria: $(\lambda_j, \theta_j) = (\bar{\lambda}_j, 1)$. In the hybrid equilibria, the injurer mixes between taking care and not taking care, whereas the victim always makes a high settlement demand.¹⁴

Mixed-strategy equilibria: $(\lambda_j, \theta_j) = (\bar{\lambda}_j, \bar{\theta}_j)$. In the mixed-strategy equilibria, the injurer mixes between taking care and not taking care, whereas the victim mixes between making a low settlement demand and making a high settlement demand.

5. Social Welfare

In this section we consider social welfare under AON and PD. The expected social cost under AON and PD is equal to:

$$\lambda_j p_L + (1 - \lambda_j)(p_H + e) + (1 - \lambda_j)p_H \theta_j k, \text{ for } j \in \{A, S\}. \quad (15)$$

The first and second terms are the expected cost of the primary activity: The first term is the expected cost of accidents plus the expected cost of taking care when the injurer does not take care; the second term is the expected cost of accidents when the injurer takes care. The third term is the expected cost of litigation. Note that the case proceeds to trial if and only if the victim presents a *high* settlement demand to the *careful* injurer.

¹⁴ Note that when $e = \Delta_j$, any probability of carelessness $\lambda_j \in [\bar{\lambda}_j, 1]$ may be an equilibrium strategy, but $\lambda_j = \bar{\lambda}_j$ is the Pareto-efficient equilibrium strategy. Similarly, when $e = \Delta_j^*$, any probability of carelessness $\lambda_j \in [0, \bar{\lambda}_j]$ may be an equilibrium strategy, but $\lambda_j = 0$ is the Pareto-efficient equilibrium strategy.

Proposition 1 below compares the injurer's and the victim's equilibrium strategies under AON and under PD for different values of the litigation cost and the cost of taking care (the proof of Proposition 1 is in the Appendix). For ease of exposition, we define various ranges of litigation costs and costs of taking care as follows. We say the litigation cost is 'low' if $k < d_L^S$, 'high' if $d_L^S \leq k < d_L^A$, and 'very high' if $k \geq d_L^A$. We say the cost of taking care is 'very low' if $e \leq \Delta_A^*$, 'low' if $\Delta_A^* < e \leq \Delta_S^*$, 'intermediate' if $\Delta_S^* < e \leq \Delta_S$, 'high' if $\Delta_S < e \leq \Delta_A$, and 'very high' if $e > \Delta_A$. We summarize this terminology in Table 2.

TABLE 2

LITIGATION COST					
Range:	$k < d_L^S$		$d_L^S \leq k < d_L^A$		$k \geq d_L^A$
Description:	Low		High		Very High
COST OF TAKING CARE					
Range:	$e \leq \Delta_A^*$	$\Delta_A^* < e \leq \Delta_S^*$	$\Delta_S^* < e \leq \Delta_S$	$\Delta_S < e \leq \Delta_A$	$e > \Delta_A$
Description:	Very low	Low	Intermediate	High	Very high

PROPOSITION 1.1

The injurer is careless with certainty under PD, but plays a mixed strategy $\lambda_A = \bar{\lambda}_A$ or is careful with certainty under AON when (i) the litigation cost is high and the cost of taking care is not very high; or (ii) the litigation cost is low and the cost of taking care is high. ||

Proposition 1.1 presents the cases in which the injurer never takes care under PD, but always takes care or mixes between taking care and not taking care under AON. Accordingly, the expected cost of the primary activity is lower under AON than under PD. The advantage of AON over PD in inducing care comprises two cases. First, when the victim's litigation cost is high, only AON supports the victim's threat to go to trial (part (i)). This is because the victim's maximum expected recovery at trial is higher

under AON than under PD. Note that under PD the case never reaches trial either because the injurer always accepts the victim's high settlement demand or because the victim does not have a credible threat to go to trial. Under AON, by contrast, the case *may* go to trial if the injurer does not always take care. The second case in which the injurer never takes care under PD, but may take care under AON, is when the injurer's cost of taking care is high (part (ii)). The advantage of AON over PD in inducing carefulness stems from the fact that the maximum difference between the injurer's expected damage payments when he takes care and when he does not take care is greater under AON than under PD. Note that under AON the expected litigation cost is positive, because both the injurer and the victim play mixed strategies. Under PD, by contrast, the case never goes to trial because the injurer always accepts the victim's high settlement demand.

PROPOSITION 1.2

The injurer is careful with certainty under PD, but plays a mixed strategy $\lambda_A = \bar{\lambda}_A$ under AON, when the litigation cost is low and the cost of taking care is low. ||

Proposition 1.2 presents the case in which the injurer always takes care under PD, but randomizes between taking care and not taking care under AON. Accordingly, the expected cost of the primary activity is lower under PD than under AON. The advantage of PD over AON in inducing carefulness stems from the fact that the injurer's minimum expected damage payments (obtained when the victim always makes a low settlement demand) are higher under PD than AON. Thus, when the cost of taking care is low and the victim has a credible threat to go to trial, the injurer under PD always takes care even if the victim always makes a low settlement demand. In contrast, the injurer under AON would still find it optimal to randomize between taking care and not taking care, because the injurer's minimum expected damage payments under AON are lower than under PD. Note that the case never reaches trial under PD since under PD the victim always makes a low settlement demand. Under AON, by contrast, the expected litigation cost is positive because both the injurer and the victim play mixed strategies.

PROPOSITION 1.3 (*Mixed-strategy equilibria*)

(a) *When the litigation cost is low and the cost of taking care is intermediate, the injurer and the victim play mixed strategies under both AON and PD.*

(b) The injurer's equilibrium probability of carelessness is lower under AON as compared to PD.

(c) The victim's equilibrium probability of making a high settlement demand is lower under AON if $e > \bar{e}$, higher under AON if $e < \bar{e}$, and is identical under AON and under PD if $e = \bar{e}$, where $\bar{e} = \frac{(p_L - p_H)(\delta_A d_H^S - \delta_S d_H^A)}{(\delta_A - \delta_S)}$. ||

Proposition 1.3 presents the case in which the injurer and the victim randomize their actions under both AON and PD. As was shown in Lemma 1.2, the equilibrium probability of carelessness is always lower under AON as compared to PD, because the victim has a stronger incentive to make a high settlement demand under AON. Consequently, the expected cost of the primary activity is lower under AON than under PD. In contrast, as was shown in Lemma 2.2, the equilibrium probability of a high settlement demand may be either higher or lower under AON than under PD, depending on the injurer's cost of taking care. Consequently, when the victim's probability of making a high settlement demand is higher under AON, the expected litigation cost is higher under AON than under PD. This is because the injurer is more likely to be careful under AON than under PD and because the probability of litigation increases in the equilibrium probability of carefulness.¹⁵ In contrast, when the victim's probability of making a high settlement demand is lower under AON than under PD, the expected litigation cost *may* be lower under AON even though the injurer is more likely to decline a high settlement demand under AON.

Tables 3 summarizes the results of Propositions 1.1-1.3 (the shaded squares represent the mixed-strategy equilibria):

¹⁵ Recall that the expected litigation cost is given by $(1 - \lambda_j)p_H\theta_j$.

TABLE 3

DECISION RULE THAT MINIMIZES THE EXPECTED SOCIAL COST OF THE PRIMARY ACTIVITY (LEFT) AND THE EXPECTED LITIGATION COST (RIGHT)

Litigation cost → Cost of care ↓	Low	High	Very high
Very low	=	=	=
Low	=	AON	AON
Intermediate	=	AON	AON
High	=	AON	PD
Very high	=	AON	=

Litigation cost → Cost of care ↓	Low	High	Very high
Very low	=	=	=
Low	=	PD	PD
Intermediate	=	PD	PD if $e \leq \bar{e}$
High	=	PD	PD
Very high	=	=	=

‘=’: The expected cost under AON and PD is equal.

Proposition 2 compares the effect of an increase in the litigation cost and the cost of taking care on the expected cost of the primary activity and the expected litigation cost under AON and under PD in the mixed-strategy equilibria.

PROPOSITION 2 (*comparative statics*)

Consider equilibria in which the injurer and the victim play mixed strategies under both AON and PD.

(a) *As the litigation cost increases:*

- (i) *the expected cost of the primary activity increases more rapidly under PD than under AON, and*
- (ii) *the expected litigation cost increases more rapidly under AON than under PD.*

(b) *As the cost of taking care increases:*

- (i) *the expected cost of the primary activity increases more rapidly under AON as compared to PD, and*
- (ii) *the expected litigation cost increases more rapidly under PD as compared to AON.*

Proof. See the Appendix.

Consider first part (a). As the litigation cost increases, the victim's relative incentive to make a high settlement demand under AON versus PD increases. As a result, the equilibrium probability of carelessness increases more rapidly under PD relative to AON. This in turn implies that the advantage of AON over PD in inducing compliance increases in the victim's litigation cost.

The effect of an increase in the litigation cost on the expected litigation cost under AON versus PD is twofold. On the one hand, as the litigation cost increases, the equilibrium probability of carelessness increases more rapidly under PD relative to AON (as shown in part (i)). Consequently, the probability that the injurer accepts a high settlement demand increases more rapidly under PD as compared to AON. This effect causes the expected litigation cost to increase more rapidly under AON than under PD. On the other hand, because the equilibrium probability of carelessness is always lower under AON than under PD, an increase in the litigation cost results in a higher expected litigation cost under PD as compared to AON. This effect causes the expected litigation cost to increase more rapidly under PD than under AON. As shown in the Appendix, the former effect dominates the latter. Accordingly, the expected litigation cost increases more rapidly under AON as compared to PD as the victim's litigation cost increases.

Consider next part (b). The expected social *benefit* from taking care (excluding the expected litigation cost) is equal to $p_L - (p_H + e)$. It is easy to see that as the cost of taking care increases, the social benefit from carefulness decreases. It follows that the advantage of AON over PD in inducing carefulness decreases as the cost of taking care increases. In contrast, as the cost of taking care increases, AON results in an increasingly lower expected litigation cost. This is because, as the cost of taking care increases, the plaintiff's equilibrium probability of making a high settlement demand increases more rapidly under PD as compared to AON. Accordingly, the expected litigation cost increases more rapidly under PD as compared to AON.

The results of Proposition 2 are summarized in Table 4:

TABLE 4 -- COMPARATIVE STATICS

	Expected Cost of Primary Activity	Expected Litigation Cost
Litigation cost ↑	Increases more rapidly under PD	Increases more rapidly under AON
Cost of Care ↑	Increases more rapidly under AON	Increases more rapidly under PD

6. The Case of Non-Settlement

To highlight the importance of settlement for our results, we briefly consider the case in which the parties may *not* settle the case before trial. In the absence of settlement, the victim must choose whether or not to file suit if an accident occurred. If the victim files suit, the case goes to trial; otherwise, the case is dropped. Note that the advantage of AON over PD in inducing compliance remains the same if the victim's litigation cost is sufficiently high, since the victim will have a credible threat to file suit under AON, but not under PD. In such a case, the injurer takes care (at least probabilistically) under AON, but never takes care under PD. Similarly, if the injurer's cost of taking care is sufficiently high, the difference between the injurer's expected damage payments when he takes care and when he does not take care is lower than the cost of taking care under AON, but not under PD, even if the victim always files suit. As a result, the injurer takes care (probabilistically) under AON, but never takes care under PD. We will accordingly focus on the mixed-strategy equilibria.

In the mixed-strategy equilibria, AON is no longer certain to induce a higher rate of carefulness than PD when the parties may *not* settle the case before trial. In particular, in any mixed strategy equilibrium, the equilibrium probability of carelessness is higher under PD when the victim's litigation cost is sufficiently high, but higher under AON when the litigation cost is sufficiently low. To see this, observe that to make the victim indifferent between filing suit and not filing suit, the injurer's probability of carelessness must be such that

$$\hat{\lambda}_j d_L^j + (1 - \hat{\lambda}_j) d_H^j - k = 0, \quad (16)$$

where $\hat{\lambda}_j$ is the victim's updated probability that the injurer was careless given that an accident occurred. The first term on the left-hand side is the victim's expected payoff from going to trial given that the injurer did not take care. The second term is the victim's expected payoff from going to trial given that the injurer took care. The last term is the victim's litigation cost. Plugging in $\frac{\lambda_j p_L}{\lambda_j p_L + (1-\lambda_j) p_H}$ for $\hat{\lambda}_j$ (see (7)) and solving for λ_j that satisfies (16) we get

$$\bar{\lambda}_j = \frac{p_H(k - d_H^j)}{\Delta^j - k \cdot (p_L - p_H)}. \quad (17)$$

PROPOSITION 3 (*no settlement*)

Assume that the parties may not settle the case before trial and that $d_L^S > k > d_H^S$. Then there exists a cut-off value $\bar{k} \equiv \frac{d_H^S \Delta^A - d_H^A \Delta^S}{(\Delta^A - \Delta^S) + (d_H^S - d_H^A) \cdot (p_L - p_H)}$, where $d_L^S > \bar{k} > d_H^S$, such that the equilibrium probability of carelessness is lower under AON if $k > \bar{k}$, higher under AON if $\bar{k} < k$, and is identical under AON and under PD if $k = \bar{k}$. In particular, when Type I and Type II errors are equal ($q_L = 1 - q_H$), then $\bar{k} = 0.5$.

The intuition behind Proposition 3 is as follows. In the absence of settlement, the equilibrium probability of carelessness is such that the victim is indifferent between filing suit and not filing suit. In particular, the greater (lower) the victim's expected court award, the stronger (weaker) will be his incentive to bring suit. The equilibrium probability of carelessness thus depends on the victim's expected court award given his (updated) belief about the injurer's choice of care. When the injurer is more likely to have been careless, bringing suit under AON will yield a higher payoff for the victim than bringing suit under PD. In contrast, when the injurer is more likely to have been careful, PD will yield the victim a higher payoff from bringing suit. Whether AON or PD induces a higher rate of carefulness depends on the magnitude of the victim's litigation cost. For sufficiently high litigation cost ($k > \bar{k}$), the equilibrium probability of carelessness is higher under PD. This is because in such case the injurer's equilibrium

probability of carelessness is relatively high, and thus the victim's expected court award is higher under AON than under PD. For low litigation cost, by contrast, the equilibrium probability of carelessness is higher under AON. This is because in such case the injurer's equilibrium probability of carelessness is relatively low, and thus the victim's expected court award is higher under PD than under AON.

In contrast to the injurer's equilibrium probability of carelessness, the victim's equilibrium probability of making a high settlement demand is always higher under PD than under AON. To see this, note that the victim's equilibrium probability of making a high settlement demand must be such that the injurer is indifferent between taking care and not taking care. Recall that the difference between the ex-ante expected court award when the injurer takes care and when he does not take care is higher under AON than it is under PD. The injurer's incentive to take care is accordingly greater under AON than under PD. It therefore takes a greater threat of litigation to induce the injurer to take care under PD than it would under AON.¹⁶ The expected litigation cost, however, *may* be higher under AON, because the equilibrium probability of carelessness may be lower under AON than under PD. Last, when the equilibrium probability of carelessness is higher under AON than under PD, the expected litigation cost is lower under AON.

7. Conclusion

This paper compared the all-or-nothing standard (AON) and the proportionate damages standard (PD) by considering their incentive effects on the plaintiff's decision to settle the case ex-post and on the defendant's decision to comply with the legal standard ex-ante. We showed that AON generally induces a higher rate of compliance than PD, although it may result in a higher level of litigation. The advantage of AON over PD in inducing compliance is threefold: (i) the plaintiff has a credible threat to go to trial under

¹⁶ To see this formally, note that the injurer is indifferent between taking care and not taking care if $\rho_j(p_L d_L^j - p_H d_H^j) - e = 0$, where ρ_j is the victim's probability of filing suit. Solving for $\bar{\rho}_j$, the value of ρ_j under which the injurer is indifferent between taking care and not taking care, gives $\bar{\rho}_j = \frac{e}{\Delta^j}$, where $\Delta^j = p_L d_L^j - p_H d_H^j$. Since, by Assumption 1, $\Delta^A > \Delta^S$, it follows that $\bar{\rho}_S > \bar{\rho}_A$.

AON even when the cost of litigation is high; (ii) the defendant has an incentive to comply with the legal standard under AON even when the cost of compliance is high; and (iii) when the cost of litigation and the cost of compliance are not high, the plaintiff has a greater incentive to go to trial under AON than under PD, thereby providing the defendant a greater incentive to comply with the legal standard under AON. If society is mainly concerned with minimizing the expected cost of the primary activity, then AON is (usually) superior to PD. This result thus provides an efficiency rationale for the prevalence of AON in civil litigation.

The paper's results also explain the divergence between settlement outcomes ('split the difference') and trial outcomes ('winner-takes-all'), and thereby address the concern that the allocation of damages in settlement negotiations is not replicable in trial. In particular, the more polarized trial outcomes under AON than under PD entail more polarized settlement options under AON than under PD. As a result, the plaintiff's incentive to go to trial (i.e., to present a high settlement demand) is greater under AON than under PD. This, in turn, maximizes the defendant's incentive to comply with the legal standard. In contrast, if the parties cannot settle the case before trial, then the plaintiff's incentive to file suit may be either greater or lower under AON as compared to PD. Specifically, if the defendant is likely to be liable, then the plaintiff has a greater incentive to file suit under AON than under PD, but if the defendant is not likely to be liable, then the plaintiff has a greater incentive to file suit under PD than under AON. Accordingly, the defendant's incentive to comply with the legal standard may be either stronger or weaker under AON as compared to PD. Whether AON or PD induces more compliance depends on the amount of the plaintiff's litigation cost.

The paper also showed that the advantage of AON over PD in inducing compliance (in the mixed-strategy equilibria) varies with the plaintiff's litigation cost and the defendant's cost of compliance. An increase in the plaintiff's litigation cost increases the advantage of AON over PD in inducing compliance, whereas an increase in the cost of compliance decreases this advantage.

Future research may extend the analysis by relaxing the assumption that expenditures on compliance and litigation are fixed and exogenously determined. An alternative assumption is that the costs of compliance as well as the costs of litigation are determined endogenously by the parties. Different decision rules would likely differ in their effect on the parties' choice of the level of compliance and legal expenditure.

Appendix

ASSUMPTION 1

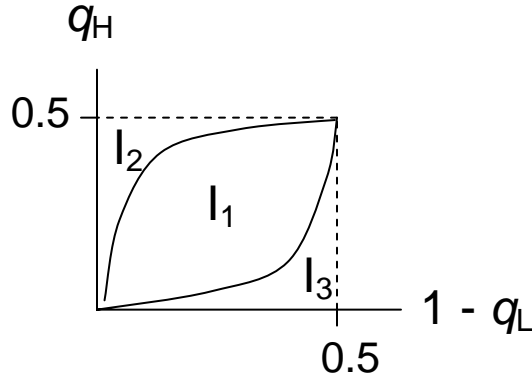
If the rates of Type I and Type II errors are sufficiently low, and the difference between the error rates is sufficiently small, then the ex-post expected court award is higher under AON than under PD if the injurer did not take care, and is lower under AON than under PD if the injurer took care: $d_L^A > d_L^S > d_H^S > d_H^A$.

We proceed by proving the following lemma.

LEMMA A1

Let I_1 , I_2 , and I_3 denote the regions in Figure 1 below, defined as functions of Type I ($1 - q_L$) and Type II (q_H) errors. Let $\hat{q}_L \equiv 1 - q_L$. Denote by $A(I_i)$ the area circumscribed in I_i , for $i=1,2,3$. Note that $\sum_i A(I_i) = 0.25$.

FIGURE A1



Then:

- (a) $d_L^A > d_L^S$ for $\{\hat{q}_L, q_H\} \in I_1 \cup I_2$; $A(I_1 \cup I_2) = 0.204$.
- (b) $d_H^S > d_H^A$ for $\{\hat{q}_L, q_H\} \in I_1 \cup I_3$; $A(I_1 \cup I_3) = 0.204$.
- (c) $d_L^A > d_H^S > d_H^A > d_L^S$ for $\{\hat{q}_L, q_H\} \in I_1$; $A(I_1) = 0.1508$.
- (a) $d_L^A > d_L^S$ for $\{\hat{q}_L, q_H\} \in I_1 \cup I_2$; $A(I_1 \cup I_2) = 0.204$.

Proof. $d_L^A > d_L^S$ implies that

$$q_L > \frac{q_L^2}{q_L + q_H} + \frac{(1 - q_L)^2}{2 - q_L - q_H}. \quad (\text{A1})$$

Rearranging and collecting terms we get

$$-q_L q_H^2 + (1 + 2q_L^2 - 4q_L)q_H - (q_L^3 - 2q_L^2 + q_L) > 0. \quad (\text{A2})$$

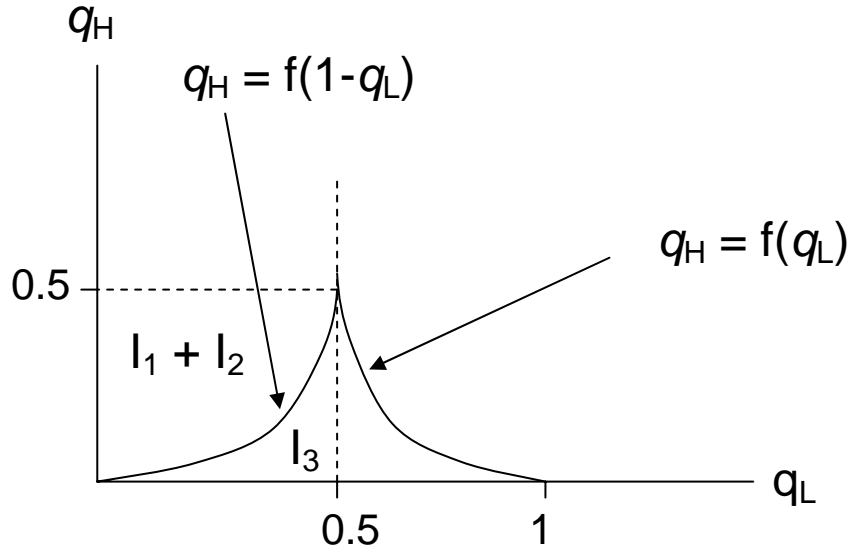
Solving for $q_L \in [0.5, 1]$ that satisfies (A2) as an equality yields:

$$q_H = \frac{1+2q_L^2-4q_L-\sqrt{16q_L^2-8q_L^3-8q_L+1}}{2q_L} \equiv f(q_L). \quad (\text{A3})$$

Thus $d_L^A > d_L^S$, for $\{q_L, q_H \mid q_H > f(q_L)\}$.

Now, recall that $q_L \in [0.5, 1]$. Let $\hat{q}_L \equiv 1 - q_L$. Then $q_H = f(q_L)$ and $q_H = f(\hat{q}_L)$ are symmetric about the $x = 0.5$ line (see Figure A2). It follows that $d_L^A > d_L^S$, for $\{\hat{q}_L, q_H\} \in I_1 \cup I_2$.

FIGURE A2



Computing the area circumscribed by $f(\hat{q}_L)$ and the x -axis (using computational software) yields:

$$A(I_3) = \int_{0.5}^1 f(\hat{q}_L) dq_L \cong 0.046. \quad (\text{A4})$$

Therefore,

$$\begin{aligned} A(I_1 \cup I_2) &= A(I_1 \cup I_2 \cup I_3) - A(I_3), \\ &= 0.25 - \int_{0.5}^1 f(\hat{q}_L) dq_L \cong 0.204. \end{aligned} \quad (\text{A5})$$

(b) $d_H^S > d_H^A$ for $\{\hat{q}_L, q_H\} \in I_1 \cup I_3$; $A(I_1 \cup I_3) = 0.204$. ■

$d_H^S > d_H^A$ for $\{\hat{q}_L, q_H\} \in I_1 \cup I_3$; $A(I_1 \cup I_3) = 0.204$.

Proof. $d_H^S > d_H^A$ implies

$$\frac{q_H q_L}{q_L + q_H} + \frac{(1 - q_H)(1 - q_L)}{2 - q_L - q_H} > q_H. \quad (\text{A6})$$

Rearranging and collecting terms we get

$$q_L^2(q_H - 1) + q_L(2q_H^2 - 2q_H + 1) + q_H - 3q_H^2 + q_H^3 > 0 \quad (\text{A7})$$

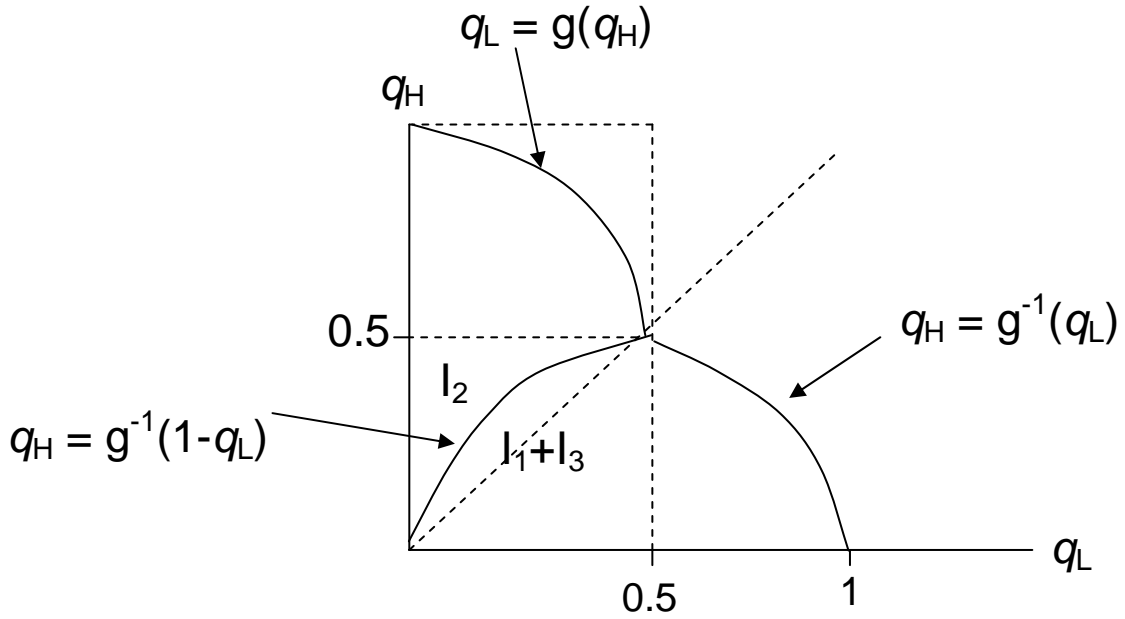
Solving for $q_H \in [0, 0.5]$ that satisfies (A7) as an equality yields:

$$q_L = \frac{2q_H^2 - 2q_H + 1 + \sqrt{8q_H^3 - 8q_H^2 + 1}}{2 - 2q_H} \equiv g(q_H) \quad (\text{A8})$$

Thus, $d_H^S > d_H^A$, for $\{q_L, q_H \mid q_L < g(q_H)\}$.

Let $g^{-1}(q_L)$ denote the *inverse* function of $g(q_H)$. Then $g(q_L)$ and $g^{-1}(q_L)$ are symmetric about the $x = y$ line. In addition, $g^{-1}(q_L)$ and $g^{-1}(\hat{q}_L)$, where $\hat{q}_L \equiv 1 - q_L$, are symmetric about the $x = 0.5$ line (see Figure A3). It follows that $d_H^S > d_H^A$ for $\{\hat{q}_L, q_H\} \in I_1 \cup I_3$.

FIGURE A3



Computing the area circumscribed by the function $g^{-1}(\hat{q}_L)$ and the x -axis (using computational software) yields:

$$A(I_1 \cup I_3) = \int_0^{0.5} g^{-1}(\hat{q}_L) d\hat{q}_L \cong 0.2041. \quad (\text{A9})$$

■

(c) $d_L^A > d_H^S > d_H^A > d_L^S$ for $\{\hat{q}_L, q_H\} \in I_1$; $A(I_1) = 0.1508$.

Proof. By Lemma A1(a), $d_L^A > d_L^S$ for $\{\hat{q}_L, q_H\} \in I_1 \cup I_2$. By Lemma A1(b), $d_H^S > d_H^A$ for $\{\hat{q}_L, q_H\} \in I_1 \cup I_3$. It follows that $d_L^A > d_L^S > d_H^A > d_H^S$ for $\{\hat{q}_L, q_H\} \in I_1$.

Since $A(I_1) = A(I_1 \cup I_3) - A(I_3)$, we have

$$A(I_1) = \int_{0.5}^1 g^{-1}(\hat{q}_L) d\hat{q}_L - \int_0^{0.5} g(q_H) dq_H = 0.204 - 0.0406 \cong 0.158. \quad (\text{A10})$$

■

LEMMA 1.1

(a) If $k \geq d_L^j$, the victim lacks a credible threat to go to trial.

Proof. The victim's maximum expected payoff from going to trial (obtained when the injurer never takes care) is $d_L^j - k$. We assume the victim drops the case if he is indifferent between taking the case to trial and dropping the case. Therefore, if $k \geq d_L^j$ the victim does not have a credible threat to go to trial.

(b) If $k < d_L^j$, the victim plays a mixed strategy, $\theta_j^S \in [0, 1]$, if $\lambda_j = \bar{\lambda}_j$. The victim makes a high settlement demand with certainty if $\lambda_j > \bar{\lambda}_j$, and a low settlement demand with certainty if $\lambda_j < \bar{\lambda}_j$.

Proof. Recall from (9) that the victim is indifferent between making a low demand and a high demand if $\lambda d_L^j + (1 - \lambda)(d_H^j - k) = d_H^j$. The equation holds for $\lambda = \bar{\lambda}_j$. For $\lambda > (<) \bar{\lambda}_j$, the left-hand side is greater (lower) than the right-hand side; accordingly, the injurer always makes a high (low) demand. ■

LEMMA 2.1

Assume $k < d_L^j$ so that the victim has a credible threat to go to trial under both AON and PD. Then:

(a) If $e > \Delta_j$, the injurer is careless with certainty.

Proof. The injurer's maximum expected damage payments if he does not take care are $p_L d_L^j$ (obtained when the victim always makes a high settlement demand). The injurer's expected damage payments plus the cost of care when he always takes care are $-e - p_H$. Thus, if $p_L d_L^j < -e - p_H d_H^j$ (that is, if $e > \Delta_j$), the left-hand side is greater than the right-hand side; accordingly, the injurer never takes care.

(b) If $e = \Delta_j$, the injurer plays a mixed strategy, $\lambda_j \in [0, 1]$, if the victim makes a high settlement demand with certainty. Otherwise, the injurer is careless with certainty.

Proof. Recall from (13) that the injurer is indifferent between taking care and not taking care iff $-(1 - \theta_j)p_L d_H^j - \theta_j p_L d_L^j = -e - p_H d_H^j$. When $e = \Delta_j$, this equation holds for $\theta_j = 1$. Thus, if the victim always makes a high settlement demand, the injurer is indifferent between taking care and not taking care. For $\theta_j < 1$, the right-hand side is greater than the left-hand side; the injurer therefore never takes

care. But then the victim must always make a high settlement demand, which will induce the injurer to always take care. This in turn rules out an equilibrium where $\theta_j < 1$.

(c) If $\Delta_j > e > \Delta_j^*$, the injurer plays a mixed strategy, $\lambda_j \in [0,1]$, if $\theta_j = \bar{\theta}_j$, is careless with certainty if $\theta_j < \bar{\theta}_j$, and takes care with certainty if $\theta_j > \bar{\theta}_j$.

Proof. When $\Delta_j > e > \Delta_j^*$, the equation $-(1-\theta_j)p_L d_H^j - \theta_j p_L d_L^j = -e - p_H d_H^j$ holds for $\theta_j = \bar{\theta}_j$. Thus, if the victim makes a high settlement demand with probability $\theta_j = \bar{\theta}_j$, the injurer is indifferent between taking care and not taking care. For $\theta_j < (>) \bar{\theta}_j$, the right-hand side is greater (lower) than the left-hand side; accordingly, the injurer never (always) takes care. But then the victim must always make a high (low) settlement demand. This in turn rules out an equilibrium where $\theta_j \neq \bar{\theta}_j$.

(d) If $e = \Delta_j^*$, the injurer plays a mixed strategy, $\lambda_j \in [0,1]$ if the injurer makes a low settlement demand with certainty. The injurer takes care with certainty if the victim makes a high settlement demand with a positive probability.

Proof. When $e = \Delta_j^*$, the equation $-(1-\theta_j)p_L d_H^j - \theta_j p_L d_L^j = -e - p_H d_H^j$ holds for $\theta_j = 0$. Thus, if the victim always makes a low settlement demand, the injurer is indifferent between taking care and not taking care. For $\theta_j > 0$ the left-hand side is greater than the right-hand side; accordingly, the injurer always takes care. But then the victim must always make a low settlement demand. This in turn rules out an equilibrium where $\theta_j > 0$.

(e) If $e < \Delta_j^*$, the injurer takes care with certainty.

Proof. The injurer's minimum expected damage payments when he does not take care are $p_L d_H^j$ (obtained when the victim always makes a low settlement demand). The injurer's expected damage payments plus the cost of care when he always takes care are $-e - p_H$. Thus, if $p_L d_H^j < -e - p_H d_H^j$ (that is, $e < \Delta_j$), the injurer always takes care. ■

LEMMA 2.2

Assume that $k < d_L^j$ and that $\Delta_S > e > \Delta_S^*$. Then there exists a cut-off value $\bar{e} = \frac{(p_L - p_H)(\delta_A d_H^S - \delta_S d_H^A)}{(\delta_A - \delta_S)}$,

where $\Delta_S^* < \bar{e} < \Delta_S$ and $\delta_j \equiv d_L^j - d_H^j$, such that the probability of a high settlement demand for which the injurer is indifferent between taking care and not taking care is lower under AON if $e > \bar{e}$, higher under AON if $e < \bar{e}$, and is identical under AON and under PD if $e = \bar{e}$.

Proof. Recall from (14) that $\bar{\theta}_j = \frac{e - d_H^j(p_L - p_H)}{p_L(d_L^j - d_H^j)}$.

It follows that

$$\begin{cases} 0 < \bar{\theta}_A < \bar{\theta}_S = 1 & \text{for } e = \Delta_S \\ 0 = \bar{\theta}_S < \bar{\theta}_A < 1 & \text{for } e = \Delta_S^* \end{cases} \quad (\text{A11})$$

Differentiating $\bar{\theta}_j$ with respect to e gives

$$\frac{d\bar{\theta}_j}{de} = \frac{1}{p_L \delta^j}, \text{ where } \delta^j = d_L^j - d_H^j. \quad (\text{A12})$$

Since, by Assumption 1, $\delta^A > \delta^S$, it follows that $\frac{d\bar{\theta}_A}{de} < \frac{d\bar{\theta}_S}{de}$ for $\Delta_S^* < e < \Delta_S$. Therefore, $\bar{\theta}_A(e)$ and $\bar{\theta}_S(e)$ are single crossing: there is a unique $e \in (\Delta_S^*, \Delta_S)$ such that $\bar{\theta}_A = \bar{\theta}_S$.

To find the value of e for which $\bar{\theta}_A = \bar{\theta}_S$, we solve for e that satisfies:

$$\bar{\theta}_A \equiv \frac{e - d_H^A(p_L - p_H)}{p_L(d_L^A - d_H^A)} = \frac{e - d_H^S(p_L - p_H)}{p_L(d_L^S - d_H^S)} \equiv \bar{\theta}_S. \quad (\text{A13})$$

Simplifying and rearranging terms we get $\bar{e} = \frac{(p_L - p_H)(\delta^A d_H^S - \delta^S d_H^A)}{(\delta^A - \delta^S)}$. ■

PROPOSITIONS 1.1 -1.3

Proposition 1.1-1.3 follow directly from Lemmas 1-3. Let $x = (\lambda_A, \theta_A)$ and $y = (\lambda_S, \theta_S)$ be the victim's and the injurer's equilibrium strategies under AON and under PD, respectively. The following strategy profiles constitute the Pareto-efficient subgame perfect Nash equilibria under the different decision rules, the litigation cost, and the cost of taking care:

- If $k \geq d_L^A$ then $x = y = (1, w)$.
- If $d_L^S \leq k < d_L^A$, then

$$\begin{cases} x = (1,1), & y = (1, w) & \text{if } e > \Delta_A \\ x = (\bar{\lambda}_A, 1), & y = (1, w) & \text{if } e = \Delta_A \\ x = (\bar{\lambda}_A, \bar{\theta}_A), & y = (1, w) & \text{if } e < \Delta_A \end{cases} \quad (\text{A14})$$

- If $k < d_L^S$, then

$$\begin{cases} x = y_s = (1,1) & \text{if } e > \Delta_A \\ x = (\bar{\lambda}_A, 1), & y = (1,1) & \text{if } e = \Delta_A \\ x = (\bar{\lambda}_A, \bar{\theta}_A), & y = (1,1) & \text{if } \Delta_A > e > \Delta_S \\ x = (\bar{\lambda}_A, \bar{\theta}_A), & y = (\bar{\lambda}_S, 1) & \text{if } e = \Delta_S \\ x = (\bar{\lambda}_A, \bar{\theta}_A), & y = (\bar{\lambda}_S, \bar{\theta}_S) & \text{if } \Delta_S > e > \Delta_S^* \\ x = (\bar{\lambda}_A, \bar{\theta}_A), & y = (0,0) & \text{if } e = \Delta_S^* \\ x = (\bar{\lambda}_A, \bar{\theta}_A), & y = (0,0) & \text{if } \Delta_S^* > e > \Delta_A^* \\ x = (0,0), & y = (0,0) & \text{if } e = \Delta_A^* \\ x = (0,0), & y = (0,0) & \text{if } e < \Delta_A^* \end{cases} \quad (\text{A15})$$

PROPOSITIONS 2(a)(i)

Consider equilibria in which the injurer and the victim play mixed strategies under both AON and PD. Then, as the litigation cost increases, the expected cost of the primary activity increases more rapidly under PD than under AON.

Proof. The expected cost of the primary activity in the mixed-strategy equilibria is given by $\varphi_j = \bar{\lambda}_j p_L + (1 - \bar{\lambda}_j)(p_H + e)$, for $j \in A, S$.

Differentiating φ_j with respect to k gives

$$\frac{d\varphi_j}{dk} = \frac{d\bar{\lambda}_j}{dk} (p_L - p_H - e). \quad (\text{A16})$$

Since $p_L - p_H - e > 0$ (see (1)), we will proceed by showing that $\frac{d\bar{\lambda}_S}{dk} > \frac{d\bar{\lambda}_A}{dk}$.

Recall from (10) that the mixed-strategy equilibrium probability of carelessness is given by $\bar{\lambda}_j = \frac{p_H k}{p_L(d_L^j - d_H^j) + p_H k}$, for $j \in A, S$.

Differentiating $\bar{\lambda}_j$ with respect to k gives

$$\frac{\partial \bar{\lambda}_j}{\partial k} = \frac{p_H p_L \delta^j}{(p_L \delta^j + p_H k)^2}, \text{ where } \delta^j = d_L^j - d_H^j. \quad (\text{A17})$$

We proceed by showing that $\frac{d\bar{\lambda}_S}{dk} > \frac{d\bar{\lambda}_A}{dk}$. Observe that $\frac{\delta^A}{(\delta^A)^2} < \frac{\delta^S}{(\delta^S)^2}$ (since $\frac{1}{\delta^A} < \frac{1}{\delta^S}$). Multiplying both sides by $\frac{1}{p_L}$ we get $\frac{\delta^A}{p_L(\delta^A)^2} < \frac{\delta^S}{p_L(\delta^S)^2}$. Since $2p_L p_H \delta^A k + (p_H k)^2 > 2p_L p_H \delta^S k + (p_H k)^2$ (since $\delta^A > \delta^S$), it follows that $\frac{d\bar{\lambda}_A}{dk} = \frac{\delta^A}{p_L(\delta^A)^2 + 2p_L p_H \delta^A k + (p_H k)^2} < \frac{\delta^S}{p_L(\delta^S)^2 + 2p_L p_H \delta^S k + (p_H k)^2} = \frac{d\bar{\lambda}_S}{dk}$ ■

PROPOSITIONS 2(a)(ii)

Consider equilibria in which the injurer and the victim play mixed strategies under both AON and PD. Then, as the litigation cost increases, the expected litigation cost increases more rapidly under AON as compared to PD.

Proof. The expected litigation cost in the mixed-strategy equilibria is given by $\kappa_j(k) = \bar{\theta}_j p_H (1 - \bar{\lambda}_j(k)) \cdot k$, for $j \in A, S$.

Differentiating κ_j with respect to k gives

$$\frac{d\kappa_j}{dk} = \theta_j p_H \left[1 - \bar{\lambda}_j - k \frac{d\bar{\lambda}_j}{dk} \right]. \quad (\text{A19})$$

Plugging in $\frac{p_H k}{p_L \delta^j + p_H k}$ for $\bar{\lambda}_j$ and $\frac{p_H p_L \delta^j}{(p_L \delta^j + p_H k)^2}$ for $\frac{d\bar{\lambda}_j}{dk}$ (see proof of Proposition 2(a)(i)), we get

$$\begin{aligned} \frac{d\kappa_j}{dk} &= \theta_j p_H \left(\frac{p_L \delta^j}{p_L \delta^j + p_H k} - \frac{p_H p_L \delta^j k}{(p_L \delta^j + p_H k)^2} \right) \\ &= \theta_j p_H \frac{(p_L \delta^j)^2}{(p_L \delta^j + p_H k)^2}. \end{aligned} \quad (\text{A20})$$

We proceed by showing that $\frac{d\kappa_A}{dk} - \frac{d\kappa_S}{dk} > 0$.

$$\begin{aligned} \frac{d\kappa_A}{dk} - \frac{d\kappa_S}{dk} &= \theta_j p_H \left(\frac{(p_L \delta^A)^2}{(p_L \delta^A + p_H k)^2} - \frac{(p_L \delta^S)^2}{(p_L \delta^S + p_H k)^2} \right) \\ &= \theta_j p_H \left(\frac{(p_L \delta^A)^2 (2p_L \delta^S p_H k + p_H^2 k^2) - (p_L \delta^S)^2 (2p_L \delta^A p_H k + p_H^2 k^2)}{(p_L \delta^A + p_H k)^2 (p_L \delta^S + p_H k)^2} \right) \\ &= \theta_j p_H \left(\frac{2p_H p_L^3 \delta^A \delta^S k (\delta^A - \delta^S) + p_H^2 k^2 [(\delta^A)^2 - (\delta^S)^2]}{(p_L \delta^A + p_H k)^2 (p_L \delta^S + p_H k)^2} \right) > 0, \end{aligned} \quad (\text{A21})$$

since, by Assumption 1, $\delta^A > \delta^S$. It follows that $\frac{d\kappa_A}{dk} > \frac{d\kappa_S}{dk}$. ■

PROPOSITIONS 2(b)(i)

Consider equilibria in which the injurer and the victim play mixed strategies under both AON and PD. Then, as the cost of taking care increases, the expected cost of the primary activity increases more rapidly under AON as compared to PD.

Proof. The expected cost of the primary activity in the mixed-strategy equilibria is given by $\varphi_j(e) = \bar{\lambda}_j p_L + (1 - \bar{\lambda}_j)(p_H + e)$, for $j \in A, S$.

Differentiating φ_j with respect to e gives

$$\frac{d\varphi_j}{de} = 1 - \bar{\lambda}_j. \quad (\text{A22})$$

Since, by Lemma 3, $\bar{\lambda}_S > \bar{\lambda}_A$, it follows that $1 - \bar{\lambda}_A = \frac{d\varphi_A}{de} > \frac{d\varphi_S}{de} = 1 - \bar{\lambda}_S$. ■

PROPOSITIONS 2(b)(ii)

Consider equilibria in which the injurer and the victim play mixed strategies under both AON and PD. Then, as the litigation cost increases, the expected litigation cost increases more rapidly under PD as compared to AON.

Proof. The expected litigation cost in the mixed strategy equilibria is given by $\kappa_j = \bar{\theta}_j(e) \cdot p_H(1 - \lambda_j) \cdot k$, for $j \in A, S$.

Differentiating κ_j with respect to e gives

$$\frac{d\kappa_j}{de} = \frac{d\bar{\theta}_j}{de} \cdot p_H(1 - \lambda_j) \cdot k. \quad (\text{A23})$$

Recall from (14) that the equilibrium probability of a high settlement demand in the mixed-strategy equilibria is given by $\bar{\theta}_j = \frac{e - d_H^j(p_L - p_H)}{p_L(d_L^j - d_H^j)}$. We will thus proceed by showing that $\frac{d\bar{\theta}_S}{de} > \frac{d\bar{\theta}_A}{de}$.

Differentiating $\bar{\theta}_j$ with respect to e gives

$$\frac{d\bar{\theta}_j}{de} = \frac{1}{p_L \delta^j}, \text{ where } \delta^j = d_L^j - d_H^j. \quad (\text{A24})$$

Since, by Assumption 1, $\delta^A > \delta^S$, it follows that $\frac{1}{p_L \delta^S} = \frac{d\bar{\theta}_S}{de} > \frac{d\bar{\theta}_A}{de} = \frac{1}{p_L \delta^A}$. ■

PROPOSITION 3

Assume that the parties may not settle the case before trial and that $d_L^S > k > d_H^S$. Then there exists a cut-off value $\bar{k} \equiv \frac{d_H^S \Delta^A - d_H^A \Delta^S}{(\Delta^A - \Delta^S) + (d_H^S - d_H^A)(p_L - p_H)}$, where $d_L^S > \bar{k} > d_H^S$, such that the equilibrium probability of carelessness is lower under AON if $k > \bar{k}$, higher under AON if $\bar{k} < k$, and is identical under AON and under PD if $k = \bar{k}$. In particular, when Type I and Type II errors are equal ($q_L = 1 - q_H$), then $\bar{k} = 0.5$.

Proof. Recall from (17) that the equilibrium probability of carelessness is given by $\bar{\lambda}_j = \frac{p_H(k - d_H^j)}{\Delta^j - k \cdot (p_L - p_H)}$. It follows that

$$\begin{cases} 0 < \bar{\lambda}_A < \bar{\lambda}_S = 1 \text{ for } k = d_L^S \\ 0 = \bar{\lambda}_S < \bar{\lambda}_A < 1 \text{ for } k = d_H^S. \end{cases} \quad (\text{A25})$$

Recall from (16) that $\hat{\lambda}_j d_L^j + (1 - \hat{\lambda}_j) d_H^j - k = 0$, where $\hat{\lambda}$ is the victim's updated belief (in equilibrium) about the injurer's probability of carelessness. Let $\tilde{\lambda}_j$ denote the value of $\hat{\lambda}$ that satisfies this equation as an equality. Thus $\tilde{\lambda}_j = \frac{k - d_H^j}{d_L^j - d_H^j}$.

Differentiating $\tilde{\lambda}_j$ with respect to k gives

$$\frac{d\tilde{\lambda}_j}{dk} = \frac{1}{\delta^j}, \quad \text{where } \delta^j = d_L^j - d_H^j. \quad (\text{A26})$$

Since, by Assumption 1, $\delta^A > \delta^S$, it follows that $\frac{d\tilde{\lambda}_A}{dk} > \frac{d\tilde{\lambda}_S}{dk}$.

Now, $\bar{\lambda}_j = \frac{p_H \tilde{\lambda}_j}{p_L(1-\tilde{\lambda}_j) + p_H \tilde{\lambda}_j}$. Differentiating $\bar{\lambda}_j$ with respect to k (by the chain rule) gives

$$\frac{d\bar{\lambda}}{dk} = \frac{d\bar{\lambda}}{d\tilde{\lambda}} \cdot \frac{d\tilde{\lambda}}{dk} = \frac{p_L p_H}{[p_L(1-\tilde{\lambda}_j) + p_H \tilde{\lambda}_j]^2} \frac{1}{\delta^j} > 0. \quad (\text{A27})$$

Twice differentiating $\bar{\lambda}_j$ with respect to k we get

$$\frac{d^2 \bar{\lambda}_j}{dk^2} = \frac{p_L p_H (p_L - p_H)}{[p_L(1-\tilde{\lambda}_j) + p_H \tilde{\lambda}_j]^4} \frac{1}{\delta^j} > 0. \quad (\text{A28})$$

Recall that $\bar{\lambda}_A < \bar{\lambda}_S$ for $k = d_L^S$ and that $\bar{\lambda}_A > \bar{\lambda}_S$ for $k = d_H^S$. Since $\bar{\lambda}_A$ and $\bar{\lambda}_S$ are both increasing and convex in k they are single-crossing: there is a unique $k \in (d_H^S, d_L^S)$ such that $\bar{\lambda}_A = \bar{\lambda}_S$.

To find the value of k for which $\bar{\lambda}_A = \bar{\lambda}_S$, we solve for k that satisfies:

$$\frac{p_H(k - d_H^A)}{\Delta^A - k \cdot (p_L - p_H)} = \frac{p_H(k - d_H^S)}{\Delta^S - k \cdot (p_L - p_H)} \quad (\text{A29})$$

Simplifying and rearranging we get $\bar{k} \equiv \frac{d_H^S \Delta^A - d_H^A \Delta^S}{(\Delta^A - \Delta^S) + (d_H^S - d_H^A) \cdot (p_L - p_H)}$.

Consider the case where $q_H = 1 - q_L$. The ex-post expected court award under AON when $q_H = 1 - q_L$ is

$$\begin{cases} q_L \equiv d_L^A & \text{if } a = L \\ 1 - q_L \equiv d_H^A & \text{if } a = H. \end{cases} \quad (\text{A30})$$

The ex-post expected court award under PD when $q_H = 1 - q_L$ is

$$\begin{cases} q_L^2 + (1 - q_L)^2 \equiv d_L^S & \text{if } a = L \\ 2(1 - q_L)q_L \equiv d_H^S & \text{if } a = H. \end{cases} \quad (\text{A31})$$

Plugging in q_L , $1 - q_L$, $q_L^2 + (1 - q_L)^2$, and $2(1 - q_L)q_L$ for d_L^A , d_H^A , d_L^S , and d_H^S , respectively, in

$$\bar{k} \equiv \frac{d_H^S \Delta^A - d_H^A \Delta^S}{(\Delta^A - \Delta^S) + (d_H^S - d_H^A) \cdot (p_L - p_H)}, \quad \text{we get (after some algebra) } \bar{k} = \frac{1}{2}. \quad \blacksquare$$

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