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Claudia Landeo
University of Alberta

Maxim Nikitin
International College of Economics and Finance NRU HSE

Sergei Izmalkov
New Economic School

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Claudia M. Landeo
Department of Economics, University of Alberta
Edmonton, AB T6G 2H4. Canada

Yale Law School
New Haven, CT 06520. USA
claudia.landeo@yale.edu

Maxim Nikitin
International College of Economics and Finance NRU HSE
Moscow. Russia
mnikitin@hse.ru

Sergei Izmalkov
New Economic School
Moscow. Russia
sizmalkov@nes.ru

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Abstract

This paper presents a strategic model of incentives for care and litigation under asymmetric information and self-serving bias, and studies the effects of damage caps. We contribute to the behavioral economics literature by generalizing the perfect Bayesian equilibrium concept to environments with biased litigants. Our main findings are as follows. First, our results suggest that self-serving bias might be welfare-reducing. The negative impact of this cognitive bias on social welfare is explained by the reduction in the level of care, and the increase in the likelihood of disputes. We also find that self-serving bias helps litigants commit to tough negotiation positions. However, it is economically self-defeating for the informed plaintiff. Second, our findings indicate that caps on non-economic damages might reduce the level of care. Importantly, we find that the positive effect of damage caps on lowering the likelihood of disputes, commonly attributed to caps, does not necessarily hold in environments with biased litigants: Caps might induce higher likelihood of disputes. Our findings are aligned with empirical and experimental evidence.

KEYWORDS: Settlement; Litigation; Incentives for Care; Caps on Non-Economic Damages; Self-Serving Bias; Asymmetric Information; Apparent Opponents; Perfect Bayesian Equilibrium; Motivated Reasoning; Divergent Beliefs; Universal Divinity Refinement; Motivated Anchoring; Non-Cooperative Games; Disputes; Pretrial Bargaining

JEL Categories: K13, K41, C72, D82, Z18, J58, J52

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1 Introduction

In civil litigation, although most cases settle before trial, many do not settle early, and some do not settle at all. Delayed settlement or impasse causes high costs for the parties and for society.[1] Babcock et al. (1995a, 1997a, 1997b) and Loewenstein et al. (1993) propose an explanation for disputes that rests on a judgment error called "self-serving bias." Self-serving bias refers to the litigant's biased beliefs that the court decision will favor his case due to the interpretation of the facts of the dispute in his own favor.[2] In information environments characterized by ambiguity, even when the parties are exposed to the exact same information, they might arrive at expectations of an adjudicated settlement that are biased in a self-serving manner. As a result, higher likelihood of disputes might be observed.[3] Note that the litigation outcomes might influence the decisions of potential injurers regarding their expenditures on accident prevention (Png, 1987; Landeo et al., 2006, 2007a, 2007b). Hence, social welfare and the effects of tort reform might be also affected by self-serving bias.[4] Despite the active experimental literature on self-serving bias, there has been very little theoretical work on this topic. Our paper contributes to the law and economics literature by constructing a strategic model of incentives for care and litigation under asymmetric information and self-serving bias, and by studying the effects of damage caps in environments with biased litigants.

Babcock et al. (1995a, 1996) and Loewenstein et al. (1993) experimentally study the effects of self-serving bias on the likelihood of disputes. Their experimental environment

[1]The direct costs of tort litigation in the U.S. reached $247 billion in 2006 (Towers Perrin Tillinghast, 2007). Tort costs in the U.S. (as a percentage of the gross domestic product) are double the cost in Germany and more than three times the cost in France or the United Kingdom (Towers Perrin Tillinghast, 2005).

[2]Babcock, Loewenstein, and colleagues' work builds on seminal research in social psychology regarding self-serving bias (Messick and Santis, 1979; Ross and Sicoly, 1982; Kunda, 1990, 1987; Danitioso et al., 1990; Darley and Gross, 1983; Dunning et al., 1989; Thompson and Loewenstein, 1992). Self-serving bias is attributed to motivated reasoning, which can be understood as peoples' propensity to reason (by attending only to some of the available information) in a way that supports their subjectively favored propositions. Kunda (1990) argues that "People rely on cognitive processes and representations to arrive at their desired conclusions, but motivation plays a role in determining which of these will be used on a given occasion" (p. 481). "[S]elf-serving biases are best explained as resulting from cognitive processes guided by motivation because they do not occur in the absence of motivational pressures" (Kunda, 1987; p. 636).

[3]Given that self-serving bias reduces the size of the surplus generated by an out-of-court settlement, this cognitive bias might actually be *self-defeating* in economic terms (i.e., it might decrease litigants' payoffs). See Section 3 for details. We will use the terms *likelihood of disputes* and *likelihood of trial.* interchangeably.

[4]The common perception that excessive awards at trial promote unnecessary litigation (Danzon, 1986) and the escalation of liability insurance premiums (Sloane, 1993; Economic Report of the President, 2004) has motivated tort reforms such as damage caps (limits on the size of the awards granted at trial).

consists of a pretrial bargaining game between a plaintiff and a defendant.[5] Their findings suggest that subjects exhibit self-serving bias, and that this cognitive bias increases the likelihood of disputes.[6] Importantly, these studies also indicate that self-serving bias is robust to debiasing interventions (Babcock et al., 1995a, 1997a).[7] Field data suggest that self-serving bias does not vanish with experience. In fact, seasoned labor negotiators, lawyers, and judges exhibit self-serving bias and other cognitive errors. Babcock et al. (1996) study Pennsylvania school teachers' salary negotiations. In this type of negotiations, it is common for the school district and the union representatives to use agreements in comparable communities as a reference. Their findings indicate that both parties choose their comparable school districts in a self-serving manner. Eisenberg (1994) analyzes data from a survey conducted with experienced bankruptcy lawyers and bankruptcy judges regarding their perceptions of the bankruptcy system and their performance. Comparisons of judges' and lawyers' responses also suggest self-serving bias.[8]

The theoretical law and economics literature on settlement and litigation has been focused on two other sources of disputes, divergent (but unbiased) beliefs about the trial outcome due to uncertainty regarding the judicial adjudication, and asymmetric information about the strength of the plaintiff's case. Priest and Klein (1984) study a framework that allows for *unbiased* errors in the litigants' estimates of the trial outcome. Their findings suggest that disputes occur when, *randomly*, the plaintiff's estimate of the award at trial exceeds the defendant's by enough to offset the incentive for settlement generated by risk aversion and trial costs (see also Landes, 1971; Posner, 1973; Gould, 1973; Shavell, 1982).[9] Reinganum and Wilde (1986) construct a signaling model between an informed plaintiff and an uninformed defendant, and show that, even in cases in which both parties share common beliefs about the

[5]These studies involve robust experimental designs. Specifically, the authors use laboratory environments, structured bargaining, rich context (i.e., they provide complex information about a legal case to the subjects), and human subjects paid according to their performance.

[6]See Landeo's (2009) experimental work on split-awards tort reform (where the state takes a share of the punitive damages awarded to the plaintiff) for additional evidence of self-serving bias in litigation environments.

[7]Debiasing interventions refer to techniques intended to reduce the magnitude of the bias. See Babcock et al. (1997b) for a description of one of the few effective debiasing procedures, which can be applied only after a dispute occurs.

[8]For instance, sixty percent of lawyers report that they always comply with the bankruptcy fee guidelines, but judges report that only eighteen percent of attorneys always comply.

[9]See Prescott et al. (2010) for a pretrial bargaining model with complete information and divergent priors, which accommodates self-serving bias under certain conditions. See also Watanabe (2010) for a recent game-theoretic model of filing and litigation under divergent but *unbiased* priors and complete information. Finally, see Yildiz (2003) for a more general bargaining model without common (but unbiased) priors.

likelihood of a judgment in favor of the plaintiff, asymmetric information about the damages suffered by the plaintiff suffices to generate disputes (see also Png, 1983, 1987; Bebchuck, 1984; Nalebuff, 1987; Schweizer, 1989; Spier, 1992).[10]

We build on Reinganum and Wilde's (1986) work on settlement and litigation, and extend their framework in several interesting and important ways. Our main contributions are as follows. First, our setting encompasses two sources of disputes, asymmetric information (but common priors) about the economic losses, and self-serving beliefs (divergent and biased beliefs) about the size of the non-economic damages awarded at trial.[11] Second, our framework incorporates a previous stage to the litigation game. In this stage, the potential injurer chooses his level of care (expenditures on accident prevention).[12] Hence, this environment is appropriate to study the effects of self-serving bias not only on litigation outcomes but also on incentives for care and social welfare. Third, we study the effects of caps on non-economic damages under biased litigants by extending our basic framework.[13] Fourth, we contribute to the behavioral economics literature by generalizing the perfect Bayesian equilibrium concept to environments with biased litigants.

Our benchmark model involves a two-stage game between two Bayesian risk-neutral parties, a potential plaintiff and a potential defendant.[14] In the first stage, the potential injurer decides his level of care, which determines the probability of accidents. This decision depends on the cost of preventing accidents and on the expected litigation loss in case of an accident. We assume that every injured potential plaintiff has an economic incentive to file a lawsuit. Then, if an accident occurs, the second stage, called the litigation stage, starts.

The litigation stage consists of a take-it-or-leave it game, where a plaintiff and a defendant negotiate prior to costly trial. Using the court to resolve the dispute is costly, and may be subject to error. We assume that the plaintiff (the first mover) has private information about the amount of her economic losses.[15] Given the uncertainty and unpredictability regarding

[10] See also Landeo et al. (2007) for a model of liability and litigation under asymmetric information. See Waldfogel (1998) for an empirical test of models of divergent (but unbiased) beliefs and asymmetric information.

[11] Compensatory damages involve economic and non-economic damages. Non-economic damages are primarily intended to compensate plaintiffs for injuries and losses that are not easily quantified by a dollar amount (pain and suffering, for instance). These awards have been widely criticized for being unpredictable. See for instance *Prindilus v. New York City Health Hospitals Corporation*, 743 N.Y.S.2d 770 (N.Y. App. Div. 2002).

[12] We will use the terms *potential injurer* and *defendant* interchangeably.

[13] Caps on non-economic damages have been widely implemented by U.S. states. By 2007, twenty-six U.S. states had enacted some type of caps on non-economic damages (Avraham and Bustos, 2010).

[14] We will use the terms *potential plaintiff* and *plaintiff* interchangeably.

[15] As Reinganum and Wilde (1986) argue, although information is exchanged during bargaining, at the

the determination of non-economic damages, and following empirical regularities regarding the elicitation of cognitive biases (Babcock et al. 1997),[16] we assume that the players exhibit self-serving beliefs about the size of the non-economic damages awarded at trial.[17] Following empirical regularities (Ross and Sicoly, 1982; Loewenstein, et al., 1993), we also assume that the litigants are unaware of their own bias and the bias of their opponent (i.e., the biased litigant believes that her opponent shares her beliefs). As a result, each litigant plays a game against *an apparent opponent*, i.e., against an opponent that appears as *actual* to the biased litigant. We denote this strategic setting as the *strategic environment with apparent opponents*, and apply a generalization of the perfect Bayesian equilibrium concept to this environment. We focus our analysis on the universally-divine fully-separating perfect Bayesian equilibrium in which the potential injurer spends resources on accident prevention, each plaintiff's type make a different settlement offer, and the defendant randomizes between accepting and rejecting the offer. Accidents and disputes do occur in equilibrium.

The main findings from our benchmark model are as follows. First, our results suggest that the defendant's bias decreases his expenditures on accident prevention, and hence, increases the likelihood of accidents. Second, both litigants' biases increase the likelihood of disputes. Third, our results indicate that, although self-serving bias help litigants commit on tough negotiation positions, it is economically self-defeating for the informed plaintiff. The plaintiff's self-serving bias dilutes the first-mover advantage observed in environments in which only asymmetric information is considered. Fourth, our findings suggest that that the plaintiff's bias is always welfare reducing. The defendant's bias is welfare reducing only in cases of under-deterrence (i.e., when the defendant's level of care is lower than the socially optimal level).

We then illustrate the benefits of incorporating self-serving bias into the theoretical analysis of tort reform by extending our basic framework to study the effects of caps on non-economic damages. Experimental evidence on caps (Pogarsky and Babcock, 2001) suggests that this tort reform might influence litigation outcomes not only by directly reducing the expected award at trial but also by indirectly affecting litigants' beliefs about the award at trial.[18] These findings also indicate that the effects of caps on litigants' beliefs depend on the relationship between the size of the cap and the value of the underlying claim. Follow-

end of this process there might still be some residual uncertainty on the part of the defendant about the level of true economic losses.

[16]Babcock et al. (1997) argue that environments characterized by ambiguous information might elicit self-serving bias on litigants' beliefs.

[17]The process of constructing these biased beliefs is not explicitly modeled in our setting.

[18]Landeo's (2009) experimental findings regarding the effects of the split-award tort reform also suggest that this tort reform might affect litigants' beliefs.

ing these empirical regularities, we extend our benchmark framework by incorporating caps of non-economic damages, and modeling the bias on litigants' beliefs about the size of the award at trial as a function of the cap.

We find that caps on non-economic damages decrease the defendant's level of care (and hence, increases the likelihood of accidents) if litigants are not biased. This result also holds in case of biased litigants if the defendant perceives the cap as relatively low (with respect to his biased estimation of the non-economic award at trial). Importantly, we find that the positive effect of damage caps on lowering the likelihood of disputes, commonly attributed to caps,[19] might not necessarily be observed in environments with biased litigants: Caps might induce higher likelihood of disputes if the defendant perceives the cap as relatively low (with respect to his biased estimation of the non-economic award at trial), and the plaintiff perceives the cap as relatively high (with respect to her biased estimation of the non-economic award at trial). As a result, caps on non-economic damages might be welfare reducing. Hence, this tort reform should be adopted with caution.

These results are aligned with empirical evidence regarding the effects of caps on level of care in medical malpractice environments (Zabinski and Black, 2011; Currie and MacLeod, 2008), and with experimental results regarding the effects of caps on disputes in pretrial bargaining settings (Pogarsky and Babcock, 2001; Babcock and Pogarsky, 1999). Our work underscores the importance of incorporating asymmetric information and cognitive biases in the theoretical analysis of tort reform. It also suggests that our theoretical framework provides a useful tool for assessing the effects of public policy.[20]

Our paper is part of a small theoretical law and economics literature on disputes and self-serving bias. Farmer and Pecorino (2002) extend Bebchuk's (1984) screening model of settlement and litigation by allowing for self-serving bias.[21] They find conditions under which self-serving bias increases the likelihood of disputes. Deffains and Langlais (2009) present a different extension of Bebchuk's (1984) framework that allows for self-serving bias and

[19] See Quayle (1992) and Atiyah (1980).

[20] In his seminal work on theoretical law and economics, Shavell (1982) states that "[T]he aim [of a model] is [...] to provide a generally useful tool for thought" (p. 56).

[21] The source of information asymmetry in this model is the defendant's probability of being found liable at trial (only known by the defendant). Although the defendant is informed about his probability of being found liable at trial, the authors assume that both players exhibit self-serving bias regarding this parameter. Note that empirical findings on self-serving bias (Babcock and Loewenstein, 1997) suggest that self-serving bias is elicited in environments characterized by ambiguity, which is not the case of the defendant regarding his probability of being found liable at trial. Note also that in the environment studied by Farmer and Pecorino (2002), the biased litigants choose equilibrium strategies that according to their opponents should be played with zero probability in equilibrium.

risk aversion.[22] Their findings suggest that self-serving bias has an ambiguous effect on the probability of trial and equilibrium settlement amount. To the best of our knowledge, ours is the first formal analysis of incentives for care, litigation outcomes, and caps on non-economic damages in strategic environments characterized by asymmetric information and self-serving bias.

Although our paper is motivated on pretrial bargaining and legal disputes, we believe that our findings, insights, and technical contributions might apply to other contexts as well. Bargaining and impasse are prevalent in environments such as labor contract negotiations (Farber, 1978; Kennan and Wilson, 1989, 1993; Babcock and Olson, 1992; Babcock et al., 1996), and partnership dissolution processes (Brooks et al., 2010).[23] The complexity and ambiguity of these environments might elicit self-serving bias.

The rest of the paper is organized as follows. Section 2 presents the benchmark framework, describes the strategic environment with apparent opponents, outlines the generalization of the perfect Bayesian equilibrium concept, and summarizes the equilibrium solution. Section 3 analyzes the effects of litigants' self-serving beliefs on equilibrium strategies and litigants' payoffs, and discusses the effects of self-serving bias on social welfare. Section 4 extends the theoretical analysis by allowing for caps on non-economic damages, and discusses the direct and indirect effects of caps on potential injurer's incentives for care and likelihood of disputes. Section 5 concludes the paper and discusses avenues for future research.

2 Benchmark Model

We model the interaction between two Bayesian, risk-neutral players, a potential injurer and a potential plaintiff, as a sequential game of asymmetric information (but common priors) about the plaintiff's economic losses, and self-serving beliefs (divergent and biased beliefs) about the size of the non-economic damages awarded at trial.

The game proceeds as follows. The potential injurer first decides his optimal level of care (the probability of accidents λ).[24] To achieve a probability of accidents λ, the potential

[22]In this model, the source of information asymmetry is the plaintiff's probability of succeeding at trial (only known by the plaintiff). Although the plaintiff is informed about his probability of succeeding at trial, both litigants exhibit self-serving bias on this parameter. Contrary to empirical findings, the authors assume that the litigants' self-serving biases are common knowledge. In addition, they assume that plaintiffs have preferences characterized by probabilistic risk-aversion. The defendants are risk-neutral players.

[23]Marital dissolution environments (Wilkinson-Ryan and Small, 2008) represent an additional interesting application.

[24]The optimal level of care for the potential injurer might not be aligned with the optimal level of care from a social point of view. See Section 3.3 (social welfare analysis).

injurer has to spend on care (accident prevention). The cost of care is denoted by $K(\lambda)$. We assume that all potential injurers have the same cost of care, which is common knowledge. We also assume that $K(\lambda)$ is a smooth and continuously differentiable function defined on the interval $(0, 1]$, with $K'(\lambda) < 0$, $K'' > 0$, $K(1) = 0$ and $\lim_{\lambda \to +0} K(\lambda) = +\infty$. The optimal level of care, i.e., the optimal λ, is the one that minimizes the defendant's total expected loss $L_D = K(\lambda) + \lambda l_D$, where l_D is the expected litigation loss. We take the expected litigation loss as parametric in order to describe L_D, but ultimately l_D will be derived as the continuation value of the litigation stage, and hence it will reflect the outcomes at the litigation stage.[25] We assume that accident occurrence is common knowledge.

If an accident occurs, Nature decides the plaintiff's economic losses x (plaintiff's type) from a continuum of types, distributed on $[\underline{x}, +\infty)$.[26] We define $f(x)$ as the strictly increasing probability density function of the distribution of plaintiffs by type. We assume that $f(x)$ is known by the plaintiff and the defendant, and that the realization of x is revealed only to the plaintiff. We assume that the plaintiff also suffers stochastic non-economic losses y (independent of x), with probability density function $g(y)$, support $[\underline{y}, +\infty)$, and expected value μ, which are unknown to the players. We assume that only the realization of y is revealed to the plaintiff. However, the plaintiff does not have a credible way to convey this information to the defendant (or to the court). The potential plaintiff then decides whether to file a lawsuit. We assume that that the plaintiff's expected payoff from suing is positive. Therefore, every injured plaintiff has an incentive to file a lawsuit.

Next, the litigation stage starts. It is modeled as a take-it-or-leave-it game between a defendant and a plaintiff. The plaintiff has the first move and makes a settlement proposal S to the defendant, where $S \in (-\infty, +\infty)$. After observing the proposal, the defendant, who only knows the distribution of economic losses x, decides whether to accept or reject the proposal. The defendant's decision is based on his updated beliefs about the plaintiff's type. If the defendant accepts the proposal (i.e., settles out-of-court), the game ends and the defendant pays to the plaintiff the amount proposed. If the defendant rejects the proposal, costly trial occurs. The plaintiff and the defendant incur exogenous legal costs (c_P and c_D, respectively). The total legal costs are denoted by $C = c_P + c_D$. Both, the individual and total legal costs are common knowledge. The court then decides whether to award

[25]The assumptions about $K(\lambda)$ ensure that, for any positive value of l_D, $L(\lambda)$ has a unique interior minimum $\lambda^* \in (0, 1)$, and that λ^* is decreasing in l_D. See the Lemma and its proof in the Appendix.

[26]The introduction of biased beliefs about the size of the award requires the assumption that the distribution of actual types is unbounded from above. If the actual types were distributed over the interval $[\underline{x}, \bar{x}]$, the plaintiff with the highest type and self-serving beliefs about the size of the award at trial would make an offer that exceeded the equilibrium offer for a plaintiff with type $\bar{x}$, which cannot be an equilibrium strategy from the defendant's perspective.

compensatory damages to the plaintiff and the amount of the award.[27] Our framework allows for court errors. There is an exogenous probability $(1-\pi)$ that the court will make a mistake and rule incorrectly against the plaintiff. It rules correctly with the complementary probability π, which is common knowledge.

If the court rules in favor of the plaintiff, it grants a compensatory award to the plaintiff. We assume that the compensatory award includes compensation for economic and non-economic losses.[28] We assume that the realization of the economic losses x are perfectly assessed by the court, and hence the economic damages are equal to x. However, the court does not know the distribution or the realization of the non-economic losses y. We denote the compensatory award by tx,[29] where $t > 1$ (i.e., the court always awards non-economic damages, in addition to the economic damages). Note that t can be interpreted as the *ratio of the compensatory award relative to the economic losses*. We denote the non-economic damages by $A = (t-1)x$, i.e., the non-economic damages A are equal to the compensatory award at trial tx minus the economic damages x. The intuition behind the assumption that the non-economic damages are proportional to the economic damages is that courts estimate non-economic losses (and grant non-economic damages) by using the only variable they know: The realization of economic losses x.

Following empirical regularities (Babcock et al., 1997), we assume that an information environment characterized by ambiguity regarding the court's decision about the non-economic damages (and hence, about the ratio of the compensatory award relative to the economic losses, t) will elicit litigants' self-serving beliefs about t. Specifically, we assume that the plaintiff believes that the ratio of the compensatory award relative to the economic losses

[27] The most common liability rules used by courts in tort cases are the negligence and strict liability rules. Under the negligence rule, the injurer will be held liable only if he exercised precaution below a level usually determined by the court (reasonable care or due care standard). Under strict liability, the court does not have to set any level of due care because the injurer has to bear the costs of the accident regardless of the extent of his precaution. Product liability and medical malpractice cases generally involve the application of strict liability and negligence rules, respectively. We assume that the court applies a strict liability rule. However, our results are robust to environments in which the negligence rule is applied.

[28] Economic and non-economic damages are the main components of compensatory damages. For instance, consider the definition of damages in auto accident cases in Texas. Economic damages are defined (very generally) as money damages intended to compensate an injured party for actual economic loss. Non-economic damages, on the other hand, may include physical pain and suffering, mental or emotional pain or anguish, disfigurement, physical impairment, loss of companionship and society, inconvenience, loss of enjoyment of life, injury to reputation, loss of consortium (loss of spousal companionship and services) (Texas Statutes Civil Practice and Remedies Code, Chapter 41: Damages, Sections 41.001(4) and 41.001(12)).

[29] We assume that the compensatory award (economic and non-economic damages) is proportional to the economic losses x. However, our results are robust to other specifications of the relationship between the compensatory damages and x.

is equal to $t + h_P$ (an additive bias), and the defendant believes that this ratio is equal to $t - h_D$, where $h_P > 0$ and $h_D > 0$.[30] Hence, the biased type x plaintiff believes that the compensatory award at trial and the non-economic damages will be $(t + h_P)x$ and $(t + h_P - 1)x$, respectively. The biased defendant believes that a type x plaintiff will get a compensatory award at trial equal to $(t - h_D)x$, and non-economic damages equal to $(t - h_D - 1)x$. Importantly, following experimental evidence from social psychology (Ross and Sicoly, 1982) and behavioral economics (Loewenstein, et al., 1993), we also assume that the litigants are neither aware of their own bias nor aware of the bias of the other party. In other words, each litigant presumes that her individual belief about the ratio of the compensatory award relative to the economic losses is correct and shared by her opponent. Specifically, the plaintiff presumes that $t + h_P$ is the shared belief, and the defendant presumes that $t - h_D$ is the shared belief. As a result, each biased litigant plays a game against *an apparent opponent*. We denote this strategic environment as the "strategic environment with apparent opponents."

2.1 Generalization of the Perfect Bayesian Equilibrium Concept

We generalize the perfect Bayesian equilibrium (PBE) concept to the strategic environments with apparent opponents. In this equilibrium, each litigant believes that her opponent plays an equilibrium strategy that reflects the litigant's biased beliefs about the compensatory award at trial. Then, the litigant's equilibrium strategy corresponds to her best response to the equilibrium strategy of her apparent opponent.

The Definition presents the characterization of the PBE concept in strategic environments with apparent opponents. Let S and b denote the strategies and posterior beliefs, respectively. The subscripts P and D indicate that the player is the plaintiff or the defendant, respectively; and, the superscript a indicates an apparent player.

DEFINITION: *The set* $(S_P, S_D, S_P^a, S_D^a, b_P, b_D, b_P^a, b_D^a)$ *is a PBE of the game with apparent opponents if*

(1A) S_P *is the best response of the plaintiff, given* S_D^a *and* b_P*;*
(1B) S_D *is the best response of the defendant, given* S_P^a *and* b_D*;*
(1C) S_P^a *is the best response of the apparent plaintiff, given* S_D *and* b_P^a*;*
(1D) S_D^a *is the best response of the apparent defendant, given* S_P *and* b_D^a*;*

[30] For the case of a multiplicative bias (a different strategy to modeling the bias), these ratios would be th_P and th_D respectively, where $h_P > 1$ and $h_D < 1$. Our qualitative results are robust to this alternative modeling strategy. Our qualitative results are also robust to litigants' (additive) biases on π or on c_D. Proofs of robustness of the qualitative results to alternative specifications of the bias are available upon request.

(2A) b_P is consistent with S_P and S_D^a;
(2B) b_D is consistent with S_D and S_P^a;
(2C) b_P^a is consistent with S_P^a and S_D; and,
(2D) b_D^a is consistent with S_D^a and S_P.

Consistency implies that the beliefs are updated using the Bayes' rule, whenever possible.

This equilibrium concept specifies the litigants' strategies and beliefs, the apparent opponents' strategies and beliefs, and the belief updating rule for both litigants and their apparent opponents. Hence, this equilibrium concept encompasses two perfect PBE, one for the pair plaintiff-apparent defendant, and the other for the pair defendant-apparent plaintiff. We denote this equilibrium as the "PBE of the game with apparent opponents."

2.2 Equilibrium Solution

This section discusses the solution of the game. While intuition is included in the text, the proofs are relegated to the Appendix.

We focus our analysis on the universally-divine (Banks and Sobel, 1987), fully-separating (every type of plaintiff makes a different settlement offer) PBE of the strategic environment with apparent opponents. This equilibrium is empirically relevant. Although the potential injurer always finds it optimal to spend on accident prevention, we still expect accidents to happen with a positive probability in equilibrium. Disputes do occur in equilibrium. They are originated by asymmetric information *and* self-serving bias.

Proposition 1 specifies the equilibrium strategies, and the equilibrium and off-equilibrium beliefs that support these strategies. Define $\underline{S}_P = \pi(t+h_P)\underline{x}+c_D$ and $\underline{S}_D = \pi(t-h_D)\underline{x}+c_D$ as the lowest values of the settlement demand, from the point of view of the biased plaintiff and biased defendant, respectively.

PROPOSITION 1: *The following strategy profile, together with the players' beliefs, describe the unique universally-divine fully-separating PBE of the game with apparent opponents.*[31]

[31] Note that the optimal strategies and equilibrium beliefs of the fully-separating equilibrium (described below) hold under any off-equilibrium beliefs. In this sense, there is an equivalence class of fully-separating equilibria with the same equilibrium strategies and equilibrium beliefs but different off-equilibrium beliefs (see Reinganum and Wilde, 1986). Note also that this game has partially-pooling equilibria. However, these partially-pooling equilibria do not survive the Universal-Divinity refinement (Banks and Sobel, 1987). Finally note that there are no pure-pooling equilibria in this game. The Appendix presents the proof of existence and uniqueness (in terms of the equilibrium outcome) of the fully-separating PBE described in Proposition 1. These arguments also hold in the environments describes in Propositions 5 and 7.

(A1) The apparent defendant chooses the level of care (probability of accidents) $\lambda^{a*} = \arg\min\{K(\lambda) + \lambda \int_{\underline{x}}^{+\infty} [\pi(t + h_P)x + c_D] f(x)dx\}$.

(B1) The apparent defendant chooses the probability of rejection of a settlement demand S $p^a(S) = 1 - e^{-(S - \underline{S}_P)/C}$ *for* $S \geq \underline{S}_P$*, and* $p^a(S) = 0$ *for* $S < \underline{S}_P$.

(C1) The plaintiff of type x chooses the settlement demand $S = \pi(t + h_P)x + c_D$.

(D1) The equilibrium beliefs of the apparent defendant upon observing the settlement demand S are $b^a(S) = (S - c_D)/[\pi(t + h_P)]$ *for* $S \geq \underline{S}_P$*, and the off-equilibrium beliefs are* $b^a(S) = \underline{x}$ *for* $S < \underline{S}_P$.

(A2) The defendant chooses the level of care (probability of accidents) $\lambda^* = \arg\min\{K(\lambda) + \lambda \int_{\underline{x}}^{+\infty} [\pi(t - h_D)x + c_D] f(x)dx\}$.

(B2) The defendant chooses the probability of rejection of a settlement demand S $p(S) = 1 - e^{-(S - \underline{S}_D)/C}$ *for* $S \geq \underline{S}_D$*, and* $p(S) = 0$ *for* $S < \underline{S}_D$.

(C2) The apparent plaintiff of type x chooses the settlement demand $S = \pi(t - h_D)x + c_D$.

(D2) The equilibrium beliefs of the defendant upon observing the settlement demand S are $b(S) = (S - c_D)/[\pi(t - h_D)]$ *for* $S \geq \underline{S}_D$*, and off-equilibrium beliefs are* $b(S) = \underline{x}$ *for* $S < \underline{S}_D$.

It is straightforward to show that the litigation stage strategies for the plaintiff and defendant are incentive-compatible and aligned with the players' equilibrium and off-equilibrium beliefs.[32] First, analyze the plaintiff's settlement offer. In equilibrium, the plaintiff of type x makes a settlement demand $S = \pi(t + h_P)x + c_D$, which corresponds to the expected loss at trial for the defendant from the biased plaintiff's point of view. Second, consider the reply from the defendant. In equilibrium, the defendant randomizes between accepting and rejecting the offer as a way to induce the plaintiff to reveal her true type. Given that higher settlement demands are accepted less frequently (and the court perfectly observes the plaintiff's type at trial), the plaintiff's expected payoff from disguising herself as a higher type is lower than her expected payoff from truthfully revealing her type. Note that the plaintiff's settlement demand serves as a signal for the defendant. Given the litigants' biased beliefs, however, this signal is noisy. Third, assess the defendant's choice of care. The defendant's optimal level of care λ (probability of accidents) minimizes her total expected loss $L(\lambda) = K(\lambda) + \lambda l_D$, where $l_D = \int_{\underline{x}}^{+\infty} [\pi(t - h_D)x + c_D] f(x)dx$ are litigation losses expected by the biased defendant. Her incentives for care are, of course, affected by her expected litigation losses. When a potential injurer expects smaller losses due to an accident, she spends less on accident prevention. This, in turn, increases the likelihood of accidents.

[32] See Appendix for details.

Two additional features of this equilibrium deserve to be mentioned. First, every plaintiff's equilibrium settlement proposal observed by the defendant belongs to the set of equilibrium strategies for the apparent plaintiff (the plaintiff who shares the defendant's beliefs). In other words, the biased defendant is never *surprised* when observing the optimal strategy from the biased plaintiff. In fact, the biased defendant attributes offer $S = \pi(t + h_P)x + c_D$ to a plaintiff of type $x_D = \frac{S - c_D}{\pi(t - h_D)} > x$, and rejects it with a higher probability. The second interesting feature refers to the off-equilibrium beliefs. Following Reinganum and Wilde (1986), we adopt the following intuitive off-equilibrium beliefs: if $S < \underline{S}_D$, then $b(S) = \underline{x}$, and if $S < \underline{S}_P$, then $b^a(S) = \underline{x}$, for the defendant and apparent defendant, respectively. That is, if an off-equilibrium demand is made, the defendant (or apparent defendant) believes that it comes from the lowest plaintiff's type $\underline{x}$.[33]

Consider now the game outcomes. We define the probability of trial as the expected probability of rejection (aggregating across plaintiffs' types). It is easy to show that the probability of trial and the litigants' expected payoffs conditional on accident occurrence are as follows. The probability of trial is

$$\int_{\underline{x}}^{+\infty} p(\pi(t + h_P)x + c_D)f(x)dx.$$

The expected payoff for the plaintiff of type x, V_P, is

$$V_P = (1 - p(x))[\pi(t + h_P)x + c_D] + p(x)(\pi t x - c_P).$$

The expected payoff for the defendant who meets a type x plaintiff is

$$-(1 - p(x))[\pi(t + h_P)x + c_D] - p(x)(\pi t x + c_D).$$

Then, the defendant's expected payoff (aggregating across plaintiffs' types) is

$$V_D = \int_{\underline{x}}^{+\infty} \{-(1 - p(x))[\pi(t + h_P)x + c_D] - p(x)(\pi t x + c_D)\} f(x)dx.$$

[33]Note, however, that our equilibrium strategies are actually supported by any off-equilibrium beliefs. In fact, when the defendant observes a settlement demand $S < \underline{S}_D$, he will accept the offer with certainty regardless his beliefs about the plaintiff's type. In this sense, a class of fully-separating equilibria, characterized by the equilibrium strategies (and equilibrium beliefs) described in Proposition 1 and any set of off-equilibrium beliefs, exists (see Reinganum and Wilde, 1986). Hence, our equilibrium outcomes (and our analysis of the effects of litigants' biases) are robust to any set of off-equilibrium beliefs.

3 Effects of Self-Serving Bias

This section describes the effects of the litigants' biases on the equilibrium strategies, litigants' expected payoffs, and social welfare.

3.1 Effects on Equilibrium Strategies

Proposition 2 summarizes the effects of the litigants' biases on the settlement demand, probability of rejection, the probability of trial, and incentives for care. Note that the *unconditional* values refer to the whole game (the litigation stage and the defendant's level of care stages).

PROPOSITION 2: The effects of self-serving bias on the equilibrium strategies are as follows.

(1) For any given plaintiff's type x, the settlement demand is increasing in the plaintiff's bias. The expected settlement demand is also increasing in the plaintiff's bias.

(2) For any plaintiff's type x, the probability of rejection is increasing in both litigants' biases. The probability of trial is also increasing in both litigants' biases.

(3) An increase in the defendant's bias reduces the defendant's expenditures on care and increases the probability of accidents.

The intuition is as follows. Consider first the effects of self-serving bias on the settlement demand. An increase in the plaintiff's bias affects his beliefs of the defendant's loss at trial: The biased plaintiff anticipates a higher defendant's expected loss at trial. As a consequence, the plaintiff increases his settlement demand. Second, consider the effects of self-serving bias on the probability of rejection. The plaintiff's bias affects the probability of rejection through its effect on the settlement demand: A higher plaintiff's bias increases his settlement demand, and hence, increases the probability of rejection. The defendant's bias affects the probability of rejection through its effect on the defendant's beliefs about the plaintiff's economic losses x_D: A higher defendant's bias decreases x_D, and hence, reduces his expected loss at trial. As a result, it increases the probability of rejection. Third, consider the effect of self-serving bias on the potential injurer's level of care and probability of accidents. A larger defendant's bias reduces her expected litigation loss. Hence, she is less concerned about the occurrence of accidents and economizes on care.[34]

[34]Note that uncertainty and ambiguity regarding the court's non-economic damages award is assumed to be a permanent feature of civil litigation. Hence, potential injurers are also exposed to these environments, and hence, to self-serving biases.

Interestingly, our findings regarding the effects of the plaintiff's bias on the settlement offer and the effects of the defendant's bias on the likelihood of rejection suggest that self-serving bias serves the litigants to commit to tough negotiation positions. Note that impasse increases legal expenditures (and hence, reduces the size of the pie). Then, self-serving bias might be *self-defeating* in terms of the litigants' economic payoffs. (See next section for details.)

Our results are aligned with the experimental findings on self-serving bias in pretrial bargaining environments (see Babcock et al., 1995a, 1997; Loewenstein, et al., 1993; and, Landeo, 2009). In these experiments, subjects are randomly assigned the role of plaintiff or defendant and given detailed materials outlining a personal injury lawsuit. Before pretrial bargaining, each subject predicts the trial outcome after being assured their prediction would not be shared with their adversary. Although the plaintiff and the defendant subjects receive identical case materials, plaintiffs' estimates exceed defendants' estimates by a significant margin. Hence, these studies demonstrate that subjects consistently arrive at self-serving predictions of trial outcomes, and that these self-serving predictions induce higher likelihood of disputes. Although these environments involve ambiguity, both litigants are symmetrically exposed to this ambiguity. Our results regarding the likelihood of disputes are, of course, exacerbated by the presence of asymmetric information.

The Corollary outlines the effects of self-serving bias on the unconditional probability of trial and the expected legal costs.

COROLLARY: The effects of self-serving bias on the unconditional probability of trial and expected legal costs are as follows.

(1) The unconditional probability of trial is increasing in both litigants' biases.

(2) The conditional and unconditional expected legal costs are increasing in both litigants' biases.

These results are intuitive. The unconditional probability of trial is increasing in both litigants' biases due to the effect of the defendant's bias on the probability of accidents and the effects of both litigants' biases on the probability of trial. Regarding the effects on legal costs, note that legal costs, c_P and c_D, are incurred only in case of trial. Note also that the probability of rejection is increasing in both litigants' biases, and higher probability of rejection implies higher legal costs. Finally note that these results also hold for the whole game (unconditional expected legal costs). In fact, the defendant's bias reduces his expenditures on care and makes accidents more likely. As a result, the unconditional expected legal costs also increase.

3.2 Effects on Litigants' Payoffs

Proposition 3 describes the effects of the litigants' biases on their expected payoffs. Unconditional values refer to the whole game.

PROPOSITION 3: The effects of self-serving bias on the litigants' expected payoffs are as follows.

(1) An increase in the defendant's bias increases his expected payoff and reduces the plaintiff's expected payoff.

(2) An increase in the plaintiff's bias reduces her expected payoff and her unconditional expected payoff. It increases the defendant's expected payoff and his unconditional expected payoff if and only if $h_P \int_{\underline{x}}^{+\infty} \zeta x^2 f(x)dx > \frac{C}{\pi} \int_{\underline{x}}^{+\infty} \zeta x f(x)dx$*, where* $\zeta \equiv e^{-[\pi(t+h_P)x - \pi(t-h_D)\underline{x}]/C}$.

Analyze the effects of the defendant's bias on his expected payoff. The plaintiff of type x demands $\pi(t + h_P)x + c_D$, which is greater than the defendant's expected loss at trial $\pi tx + c_D$. Then, the defendant would be better off by rejecting the demand. The probability of rejection goes up when the defendant's bias is higher. Hence, the defendant's bias will increase his expected payoff. Note that the impact of the defendant's bias on the defendant's unconditional expected payoff is ambiguous: A higher defendant's bias generates lower litigation losses for the defendant but it also reduces her expenses on care (and hence, it increases the likelihood of an accident). Consider now the effects of the defendant's bias on the plaintiff's expected payoff. The plaintiff will be better off if the settlement demand is accepted because her expected gain at trial $\pi tx - c_P$ is smaller than the settlement demand $\pi(t + h_P)x + c_D$. Therefore, an increase on the probability of rejection (due to a higher defendant's bias) will reduce the plaintiff's expected payoff.

Next, assess the effects of the plaintiff's bias on her expected payoff. The plaintiff's bias affects her payoff through its effect on the settlement offer and the probability of trial. An increase in the plaintiff's bias increases the settlement demand. As a result, it increases the plaintiff's expected payoff for a given probability of rejection. However, this higher demand is rejected with a higher probability. We show in the Appendix that the second effect always dominates the first one. Hence, an increase in the plaintiff's bias unambiguously hurts her. Consider now the effects of the plaintiff's bias on the defendant's expected payoff. Similar two effects are observed in case of the defendant's expected payoff. The defendant might be worse off because the settlement demand is higher for a given probability of rejection. However, the higher demand increases the probability of rejection, which benefits the defendant. We show in the Appendix that the second effect dominates the first one under a specific condition. As a result, the plaintiff's bias might benefit the defendant. These results hold in the litigation game and in the whole game (defendant's unconditional expected payoff) because the plaintiff's bias has no impact on the level of care.

Interestingly, in the litigation game under asymmetric information studied by Reinganum and Wilde (1986), the informed plaintiff enjoys a first-mover advantage. In fact, the plaintiff extracts the whole surplus generated by the out-of court agreement. The defendant gets just what he expects to get at trial. The presence of self-serving bias, however, dilutes this advantage. The payoff losses suffered by the plaintiff due to his own bias suggest that this bias is actually "self-defeating" (in economic terms) in a take-it-or-leave-it strategic environment in which the plaintiff is the first mover. On the other hand, the positive effects of the defendant's bias on her expected payoff, on the other hand, indicate that her bias is "self-serving" (in economic terms) in this strategic environment.[35]

3.3 Effects on Social Welfare

Define the social cost of accidents (welfare loss) as the sum of expenses on accident prevention, the unconditional (economic and non-economic) harm to the plaintiff, and the unconditional legal costs in case of trial, and denote it by $L_W(\lambda)$.

$$L_W(\lambda) = K(\lambda^*) + \lambda^* l_W, \tag{1}$$

where $l_W = \mathrm{E} \int_x [x + y + (c_P + c_D)p(x)]f(x)dx$.

Proposition 4 summarizes the effects of the plaintiff's and defendant's biases on welfare loss.

PROPOSITION 4. *An increase in the plaintiff's bias reduces social welfare. An increase in the defendant's bias reduces social welfare if* $l_D < l_W$.

Consider the effects of the plaintiff's bias. The bias of the plaintiff has no impact on accident prevention or on the probability of accident, but it increases the probability of trial. As a result, the bias of the plaintiff is welfare reducing. Analyze now the effects of the defendant's bias. Remember that l_D represents the litigation loss as perceived by the biased

[35] Remember, however, that the litigants' biases help them commit to tough negotiation positions. Note also that there might be other non-economic benefits from self-serving bias. Research in social psychology suggests that these biases are beneficial to the well-being of individuals. For instance Taylor and Brown (1988) argue that self-serving bias might positively affect mental health, including the ability to engage in productive and creative work, and the ability to be happy or contended. This might explain the resilience of this cognitive bias to debiasing mechanisms. See Bar-Gill (2007) for an interesting theoretical analysis of the persistence of optimistic beliefs, under an evolutionary game-theoretic approach.

defendant, then it influences the defendant's level of care. If prior to the increase in the defendant's self-serving bias, $l_D < l_W$, an increase in the defendant's bias unambiguously decreases social welfare. Two factors are at play here. First, if prior to the increase in the defendant's bias, potential injurers exercise too little care (from a social point of view), then the increase in the defendant's bias reduces the level of care even further, affecting negatively social welfare. Second, the higher defendant's bias increases the probability of trial, which increases l_W. As a result, the bias of the defendant is welfare reducing if $l_D < l_W$.[36]

Our findings regarding the potential negative effect of litigants' biases on social welfare suggest that effective debiasing mechanisms might be welfare improving (Jolls and Sunstein, 2006; Thaler and Sunstein, 2008; Jolls, 2007; Jolls et al., 1998; Babcock et al., 1997b).[37]

4 A Model of Caps on Non-Economic Damages under Self-Serving Bias

Caps on non-economic damages are widely used by U.S. states (Avraham and Bustos, 2011). This tort reform has been motivated by the common perception that excessive damage awards promote unnecessary litigation (Danzon, 1986) and the escalation of liability insurance premiums (Sloane, 1993). There are many different cap schemes. Some states use a flat dollar cap, a multiplier of compensatory damages, or a combination of both. Some caps pertain to all civil cases, while others are tailored to specific categories of cases, such as medical malpractice or product liability (Babcock and Pogarsky, 1999).[38] As an illustration, consider the medical malpractice tort reform enacted by Texas in 2003. The Texas Alliance for Patient Access (TAPA) provides the following description of this reform.[39]

[36] If $l_D >$l$_W$, on the other hand, the effect of an increase in the defendant's bias on social welfare is ambiguous. Two factors affect social welfare in opposite directions. First, before the increase in the defendant's bias, the defendant exercised too much care. Then, a reduction in the level of care is welfare improving. Second, the increase in the probability of trial due to the higher defendant's bias is welfare reducing. However, the second factor might still dominate. In fact, the parameters that positively affect the likelihood that $l_D > l_W$ (larger π and smaller h_D) also increase the quantitative importance of the probability-of-trial effect.

[37] Jolls and Sunstein (2006) propose the use of the law as a debiasing mechanism or rationality nudge. Specifically, debias through law refers to an intervention oriented to direct agents towards more rational behavior through the use of substantive law (such as consumer safety law and product risk communication regulations) or procedural regulations (such as regulations regarding pre-trial bargaining procedures). See also Simon et al. (2008).

[38] Babcock and Pogarsky (1999) argue that "the variety of statutory damage limitations share a common feature–they circumscribe a previously unbounded array of potential trial outcomes" (p. 345).

[39] See http://www.tapa.info/html/TexasLegislativeReforms.html for details. We thank Bernie Black for providing detailed information about this tort reform.

"Chief among the 2003 reforms was the passage of a non-economic damage cap, widely regarded as the lynch pin of the reform package ... Texas law now establishes a \$750,000 stacked cap for non-economic damages in a health care lawsuit. The capped figure changes depending upon the variety of defendants in a suit. Physicians are capped at \$250,000 exposure for non-economic damages; hospitals have a \$250,000 cap and an additional \$250,000 non-economic damage cap applies if a second, unrelated hospital or health care institution is named in the suit. The cap is applied on a per claimant basis with no exceptions and no adjustment for inflation. Past and future medical bills, lost wages, custodial care and prejudgment interest remain uncapped."

Experimental evidence on damage caps (Pogarsky and Babcock, 2001; Babcock and Pogarsky, 1999) suggests that this tort reform might influence litigation outcomes not only by directly reducing the expected award at trial but also by indirectly affecting litigants' beliefs about the award at trial. These findings also indicate that the effects of caps on beliefs depend on the relationship between the size of the cap relative to the underlying claim.[40]

We apply our strategic environment with apparent opponents to the study of caps on non-economic damages. Our framework employs a straightforward cap, i.e., a cap that limits the plaintiff's non-economic damages to a specific dollar amount. We denote the maximum value of non-economic damages by $\bar{A}$. We first study the direct effects of caps (that operate through the reduction of the expected award at trial) using an environment that abstracts from self-serving bias. We then incorporate self-serving bias into the framework to analyze the total effects of caps, direct and indirect effects (that operate through the litigants' beliefs). Following empirical regularities, we model the bias on litigants' beliefs about the size of the award at trial as a function of the cap.

[40] Babcock and Pogarsky (1999) analyze the effect on settlement rates of a damage cap set lower than the value of the underlying claim, using a bargaining experiment. They find that damage caps constrain the parties' judgments and produce more settlement. Pogarsky and Babcock (2001) extend this work by studying the effects of size of the damage caps relative to the actual damage on litigation outcomes. They find that litigants' beliefs about the size of the award are affected by the cap, in case of a relatively high cap, and that this motivating anchoring generates higher likelihood of dispute and higher settlement amounts. These studies also show that low caps (relative to the true damages) might act as *debiasing through law* mechanisms. Landeo (2009) finds that the split-awards tort reform can also act as a *debiasing through law* mechanism. See Jolls and Sunstein (2006) for a general discussion of debiasing through law.

4.1 Direct Effects of Caps: An Environment without Self-Serving Bias

Suppose a cap $\bar{A}$ is imposed on the non-economic damages part of the compensatory award $A = (t-1)x$. Proposition 5 describes the equilibrium of the game under caps on non-economic damages. Define $\tilde{x} = \frac{\bar{A}}{(t-1)}$ as the plaintiff's type for which the non-economic damages part of the compensatory award is equal to $\bar{A}$. The court award is tx for $x < \tilde{x}$ and $\bar{A} + x$ for $x \geq \tilde{x}$. Define $\underline{S} = \pi t \underline{x} + c_D$ as the lowest value of the settlement demand.

PROPOSITION 5: *The following set A-D characterizes the unique universally-divine fully-separating PBE of the game with caps on non-economic damages.*

(A) The defendant chooses the level of care (probability of accident) $\lambda^* = \arg\min\{K(\lambda) + \lambda[\int_{\underline{x}}^{\tilde{x}}[\pi t x + c_D]f(x)dx + \int_{\tilde{x}}^{+\infty}[(\pi(\bar{A}+x) + c_D]f(x)dx]\}$.

(B) The defendant chooses the probability of rejection of a settlement demand S, $p(S) = 1 - e^{-(S-\underline{S})/C}$ *for* $S \geq \underline{S}$, *and* $p(S) = 0$ *for* $S < \underline{S}$.

(C) The plaintiff of type $x \in (\underline{x}, \tilde{x})$ *chooses the settlement demand* $S = \pi t x + c_D$, *and the plaintiff of type* $x \in (\tilde{x}, +\infty)$ *chooses the settlement demand* $S = \pi(\bar{A} + x) + c_D$.

(D) The equilibrium beliefs of the defendant upon observing the settlement demand S *are* $b(S) = (S - c_D)/[\pi t]$ *for* $S \in (\underline{S}, \pi(\bar{A} + \tilde{x}) + c_D)$ *and* $b(S) = (S - c_D)/\pi - \bar{A}$ *for* $S \geq \pi(\bar{A} + \tilde{x}) + c_D)$, *and the off-equilibrium beliefs are* $b(S) = \underline{x}$ *for* $S < \underline{S}$.

Two features of the equilibrium are worth mentioning. First, this is a separating equilibrium. Each plaintiff's type makes a different settlement demand. Second, each plaintiff's type demands the amount that the defendant expects to lose in case of trial. Then, the plaintiff gets the surplus generated by an out-of-court settlement.

Proposition 6 summarizes the direct effects of caps on non-economic damages. Define low-type plaintiffs as those plaintiffs for which their type $x \leq \tilde{x}$, and high-type plaintiffs as those plaintiffs for which their type $x > \tilde{x}$, where $\tilde{x}$ represents the plaintiff's type for which the non-economic damages are equal to $\bar{A}$.

PROPOSITION 6: *The direct effects of caps on non-economic damages are as follows.*

(1) Caps reduce the settlement demands made by high-type plaintiffs, do not affect the settlement demands made by low-type plaintiffs, and hence, reduce the expected settlement demand.

(2) Caps reduce the probability of rejection of settlement offers made by high-type plaintiffs, do not affect the probability of rejection of settlement offers made by low-type plaintiffs, and hence, reduce the probability of trial.

(3) Caps reduce the defendant's expected litigation loss, and hence, increase the likelihood of accidents.

These findings suggest that caps on non-economic damages reduce the likelihood of disputes by lowering the average settlement demand. Although the reduction in the likelihood of disputes has a positive direct effect on welfare (i.e., it reduces the expected legal costs), it might negatively affect welfare by inducing lower incentives for care (and hence, higher likelihood of accidents).[41]

4.2 Total Effects of Caps on Non-Economic Damages: An Environment with Self-Serving Bias

Pogarsky and Babcock's (2001) experimental findings indicate that caps affect the perception of the expected award at trial (i.e., the biased variable) in the same direction for both litigants. Note that the plaintiff's self-serving bias implies that he believes that the award is higher than it actually is. The defendant's self-serving bias, on the other hand, implies that she believes that the award is lower than it actually is. Hence, caps should affect the self-serving bias of litigants in opposite directions. Specifically, a non-binding cap (i.e., a high cap relative to the true damage) should increase the perception of the award for both parties. As a result, the bias for the plaintiff will increase and the bias for the defendant will decrease. A binding cap (i.e., a low cap relative to the true damage), on the other hand, should reduce the perception of the award for both litigants. As a result, the bias of the plaintiff will decrease and the bias of the defendant will increase.

Following these empirical regularities, we model the bias on litigants' beliefs about the size of the award at trial as a function of the cap. We denote a post-cap value by the superscript *cap*. Consider first the case of the plaintiff. We will specify the impact of a cap on non-economic damages on the plaintiff's perception of the ratio of the compensatory award relative to the economic damages for his type, and then specify the impact of a cap on the whole distribution of plaintiff's types. These steps will allow us to specify the beliefs and strategies of the apparent defendant, who is supposed to behave optimally against the distribution of plaintiff's types.

Upon the imposition of a cap, the plaintiff believes that he and the apparent defendant play the game outlined in the previous subsection. Assume that prior to the cap, the plaintiff's perception of the ratio of the compensatory award relative to the economic losses is

[41] Note that the reduction in the level of care negatively affects welfare only if the defendants are under-deterred.

biased $(t+h_P)$. Following empirical regularities, we also assume that upon the announcement of the cap, the bias increases if and only if the perceived non-economic damages, $(t+h_P-1)x$ are smaller than the cap, $\bar{A}$. Finally, we assume that the plaintiff post-cap bias, $h_P^{cap}(x)$ never becomes negative. Then,

$$h_P^{cap}(x) = \max\{h_P + \alpha_P[\bar{A} - (t + h_p - 1)x], 0\}, \tag{2}$$

where $\alpha_P > 0$ is the cap revision coefficient for the plaintiff.

Consider now the case of defendant. The defendant does not know the plaintiff's type, but he forms beliefs about the post-cap ratio of the compensatory award relative to the economic losses for the whole distribution of plaintiff's types. Let x_{med} be the median of the distribution of economic damages.[42] Then, the median of the defendant's perceived biased distribution of the non-economic damages A_{med} is

$$A_{med} = x_{med}(t - h_D - 1). \tag{3}$$

We assume that the defendant expects smaller non-economic awards, i.e., the self-serving bias of the defendant increases, if the cap is smaller than the median of the biased distribution of expected non-economic awards ($\bar{A} < A_{med}$). The self-serving bias falls (the defendant expects a higher award) if the cap is larger than the median of the perceived distribution ($\bar{A} > A_{med}$). In addition, we assume that the bias of the defendant never becomes negative. Then,

$$h_D^{cap} = \max\{h_D + \alpha_D[(t - h_D - 1)x_{med} - \bar{A}], 0\}, \tag{4}$$

where $\alpha_D > 0$ is a revision coefficient for the defendant.

Equilibrium under Caps and Self-Serving Bias

Proposition 7 describes the unique universally-divine fully-separating equilibrium in the strategic environment with apparent opponents and caps on non-economic damages. This equilibrium characterizes beliefs and strategies for two pairs of players, plaintiff-apparent defendant and defendant-apparent plaintiff. Define $\tilde{x}_P^{cap} = \frac{\bar{A}}{(t+h_P^{cap}-1)}$ as the plaintiff's type for which the non-economic damages part of the compensatory award is equal to $\bar{A}$ from the post-cap point of view of the biased plaintiff; and, define $\tilde{x}_D^{cap} = \frac{\bar{A}}{(t-h_D^{cap}-1)}$ as the plaintiff's type for which the non-economic damages part of the compensatory award is equal to $\bar{A}$ from the post-cap point of view of the biased defendant.

[42]Note that x_{med} is defined as follows: $\int_{\underline{x}}^{x_{med}} xf(x)dx = \int_{x_{med}}^{+\infty} xf(x)dx$.

PROPOSITION 7: *The following strategy profile, together with the players beliefs, characterizes the unique universally-divine fully-separating PBE of the game with apparent opponents and caps on non-economic damages.*

(A1) The apparent defendant chooses the level of care (probability of accidents) $\lambda_a^* = \arg\min\{K(\lambda) + \lambda[\int_{\underline{x}}^{\tilde{x}_P^{cap}}[\pi(t+h_P^{cap})x + c_D]f(x)dx + \int_{\tilde{x}_P^{cap}}^{+\infty}[(\pi(\bar{A}+x)+c_D]f(x)dx]\}$.

(B1) Define $\underline{S}_P^{cap} = \pi(t+h_P^{cap})\underline{x} + c_D$. *The probability of rejection of a settlement demand* S *by the apparent defendant is* $p_a(S) = 1 - e^{-(S-\underline{S}_P^{cap})/C}$ *for* $S \geq \underline{S}_P^{cap}$*; and* $p_a(S) = 0$ *for* $S < \underline{S}_P^{cap}$.

(C1) The settlement demand of the plaintiff of type $x \in (\underline{x}, \tilde{x}_P^{cap})$ *is* $S = \pi(t+h_P^{cap})x + c_D$*; the settlement demand of the plaintiff of type* $x \in (\tilde{x}_P^{cap}, +\infty)$ *is* $S = \pi(\bar{A}+x) + c_D$.

(D1) The beliefs of the apparent defendant upon observing the settlement demand S *are* $b_a(S) = (S - c_D)/[\pi(t+h_P^{cap})]$ *for* $S \in (\underline{S}_P, \pi(\bar{A}+\tilde{x}_P^{cap}) + c_D)$*,* $b_a(S) = (S-c_D)/\pi - \bar{A}$ *for* $S \geq \pi(\bar{A}+\tilde{x}_P^{cap}) + c_D)$ *and* $b_a(S) = \underline{x}$ *for* $S < \underline{S}_P^{cap}$.

(A2) The defendant chooses the level of care (probability of accidents) $\lambda^* = \arg\min\{K(\lambda) + \lambda[\int_{\underline{x}}^{\tilde{x}_D^{cap}}[\pi(t-h_D^{cap})x + c_D]f(x)dx + \int_{\tilde{x}_D^{cap}}^{+\infty}[(\pi(\bar{A}+x)+c_D]f(x)dx]\}$.

(B2) Define $\underline{S}_D^{cap} = \pi(t-h_D^{cap})\underline{x} + c_D$. *The probability of rejection of a settlement demand* S *by defendant is* $p(S) = 1 - e^{-(S-\underline{S}_D^{cap})/C}$ *for* $S \geq \underline{S}_D^{cap}$*; and* $p(S) = 0$ *for* $S < \underline{S}_D^{cap}$.

(C2) The settlement demand of the apparent plaintiff of type $x \in (\underline{x}, \tilde{x}_D^{cap})$ *is* $S_a = \pi(t-h_D^{cap})x + c_D$*; the settlement demand of the apparent plaintiff of type* $x \in (\tilde{x}_D^{cap}, +\infty)$ *is* $S_a = \pi(\bar{A}+x) + c_D$.

(D2) The beliefs of the defendant upon observing the settlement demand S *are* $b(S) = (S - c_D)/[\pi(t-h_D^{cap})]$ *for* $S \in (\underline{S}_D^{cap}, \pi(\bar{A}+\tilde{x}_D^{cap}) + c_D)$*,* $b(S) = (S-c_D)/\pi - \bar{A}$ *for* $S \geq \pi(\bar{A}+\tilde{x}_D^{cap}) + c_D)$ *and* $b(S) = \underline{x}$ *for* $S < \underline{S}_D^{cap}$.

Total Effects of Caps

Define a relatively low cap from the point of view of the biased defendant as $\bar{A} < (t - h_D - 1)x_{med}$, i.e., a cap that is lower than the median of the distribution of non-economic awards perceived by the defendant. Define a relatively high cap from the point of view of the biased plaintiff as $\bar{A} > x(t + h_P - 1)$, i.e., a cap that is higher than the plaintiff's expected non-economic award at trial. Proposition 8 summarizes the (total) effects of caps on the potential injurer's level of care and the likelihood of disputes.

PROPOSITION 8. *If the defendant perceives the cap as relatively low, the cap on non-economic damages reduces the level of care and increases the likelihood of accidents. If,* *in addition, the plaintiff perceives the cap as relatively high, a cap on non-economic damages increases the settlement demand, increases the probability of rejection, and increase the unconditional probability of trial.*[43]

Consider the effects of caps on the level of care. If the litigants are biased, and the cap is perceived as relatively low by the defendant, then the defendant's bias will increase as a result of the cap. This reduces the defendant's expected litigation loss, and hence, its incentives for care. Analyze now the effects of caps on the probability of trial. Remember that in case of unbiased litigants, caps reduce the settlement demands and hence, reduce the probability of rejection and the probability of trial. In an environment with biased litigants, this result might not hold. Specifically, caps will increase the bias of the plaintiff if he perceives the cap as relative high. As a result, his settlement demand will increase. Caps will also increase the bias of the defendant if the defendant perceives caps as relatively low. Hence, two factors will induce a higher probability of rejection: The higher settlement demand (due to the higher plaintiff's bias), and the higher defendant's bias. As a result, the unconditional probability of trial will also increase.

Our findings are consistent with experimental results on the effects of caps on pre-trial bargaining outcomes. Pogarsky and Babcock (2001) find that caps that are high relative to the expected award at trial increase the likelihood of disputes. They argue that these findings might be the result of a cognitive mechanism called motivating anchoring, in which the high-level cap (relative to the damage level) becomes the focal point on the pretrial bargaining negotiations. Hence, caps might act as a *biasing through law* mechanism. Our results regarding the effects of caps on the potential injurer's level of care are also aligned with empirical findings. Zabinski and Black (2011) study the effects of the medical malpractice tort reform enacted in Texas in 2003. One of the main components of this reform involves caps on non-economic damages.[44] They find evidence suggesting an increase in adverse health events (proxy for overall hospital quality or level of care) associated with this tort reform. Currie and MacLeod (2008) theoretically and empirically study the effects of tort reform on the types of procedures performed, and the health outcomes of mothers and infants, in childbirth cases in the U.S.[45] They find that caps on non-economic damages increase complications of labor and delivery.[46]

[43] These two conditions imply $x < \frac{\bar{A}}{(t+h_P-1)} < \frac{\bar{A}}{(t-h_D-1)} < x_{med}$. Hence, the last result holds in case of plaintiffs' types lower than the median type.

[44] See Silver et al. (2008).

[45] Two tort reforms are studied, reform on the joint and several liability rule and caps on non-economic damages.

[46] See also Arlen (2000) for a discussion regarding the effects of damage caps on reducing defendant's

Our results regarding the welfare-reducing effects of damage caps under plausible scenarios suggest that this tort reform should be adopted with caution. Our work underscores the importance of studying incentives for care, litigation, and the effects of tort reform in settings that allow for asymmetry of information and litigant's self-serving beliefs.

5 Summary and Conclusions

Behavioral economics studies on self-serving bias in legal and labor environments provide robust evidence of the impact of this cognitive bias on impasse. However, this additional source of disputes has not been previously addressed in the theoretical law and economics literature on liability and litigation. Our work contributes to this literature by presenting a strategic model of incentives for care and litigation and by studying damage caps, in environments that allow for asymmetric information (and common priors) regarding the plaintiff's economic losses, and self-serving bias (divergent and biased beliefs) regarding the non-economic damages awarded at trial. Our theoretical framework involves empirically-relevant assumptions regarding the elicitation of self-serving bias, and the relationship between self-serving bias and caps on non-economic damages. Importantly, we contribute to the behavioral economics literature by generalizing the perfect Bayesian equilibrium concept to strategic environments with biased players.

This paper provides policy-relevant findings. First, our results suggest that social welfare might be negatively affected by self-serving bias under certain conditions. The negative impact of this cognitive bias on social welfare is explained by the reduction of the level of care and the increase of the likelihood of disputes. Interestingly, our results indicate that, although self-serving bias help litigants commit to tough negotiation positions, it is economically self-serving only for the defendant. Second, our findings indicate that damage caps might reduce the defendant's level of care. Interestingly, our results suggest that the positive effects of caps on reducing the likelihood of disputes, commonly associated with caps, do not necessarily hold in environments with biased litigants. In fact, we show that the presence of self-serving bias might reverse the positive effect of caps on impasse. Hence, policy-makers should adopt this tort reform with caution. Our findings are aligned with empirical and experimental evidence on pre-trial bargaining and caps on non-economic damages.

Our work is motivated on pretrial bargaining and legal disputes. However, the strategic environments discussed in this paper might be common to other settings. For instance, our findings regarding the effects of self-serving bias on disputes, and our technical contributions,

incentives to take optimal care.

might apply to collective bargaining negotiations, and to the assessment of the effects of collective bargaining laws on strikes (Currie and McConnell, 1991). Similarly, this research might benefit studies regarding partnership dissolution processes, and the efficiency effects of partnership dissolution mechanisms (Brooks et al., 2010). Extensions to our work might also involve the assessment of legal institutions that affect settlement and litigation, using environments that allow for self-serving litigants. For example, theoretical and experimental studies on lawyers' compensation schemes and agency problems (Miller, 1987; Dana and Spier, 1993), fee-shifting (Spier, 1994a), and the design of damage awards (Spier, 1994b) might be fruitful topics for research. Finally, future work might study asymmetries in the litigant's perception of her own bias and the bias of the other party, and the effects of these asymmetries on the likelihood of disputes.[47] These and other extensions remain fruitful areas for future research.

[47] This phenomenon is called "illusion of asymmetric inside." It is characterized by the conviction that one perceives events as they are but that the perception of other people might be biased (Pronin, 2004). Experimental economics methods might be used to assess the robustness of these social psychology findings.

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Appendix

This appendix presents the lemma, and the proofs to the lemma, propositions, and corollary.

LEMMA: *For any positive value of l_D, the function $L(\lambda)$ has a unique interior minimum, $\lambda^* \in (0,1)$. λ^* is decreasing in l_D.*

PROOF:

$$L'_D(\lambda) = K'(\lambda) + l_D.$$

By assumptions about the function $K(\lambda)$, the derivative of the total loss is monotonically increasing in λ, it is negative for sufficiently small values of λ, and it is positive for sufficiently large values of λ. Hence there exists a unique critical point, λ^*, such that $L'_D(\lambda^*) = 0$, and λ^* is the minimum point of $L_D(\lambda)$.

Totally differentiating the first-order condition $K'(\lambda^*) + l_D = 0$,

$$K''(\lambda^*)d\lambda^* + dl_D = 0.$$

Hence,

$$\frac{\partial \lambda^*}{\partial l_D} = -\frac{1}{K''(\lambda^*)} < 0.$$

An increase in l_D reduces the optimal probability of accident, λ^*, which implies an increase in the level of care, $K(\lambda^*)$. These results also hold for the apparent defendant. Q.E.D.

PROOF OF PROPOSITION 1:

The following steps show that the strategies described above form a perfect-Bayesian equilibrium and satisfy the universal divinity refinement. The equilibrium is unique in terms of equilibrium outcome. Without loss of generality we solve the game for the pair plaintiff – apparent defendant. For the pair defendant – apparent plaintiff we can solve the game in exactly the same way. We find the equilibrium by backward induction, i.e., we first show that the equilibrium of the litigation game is unique, characterize it, and then compute the unique equilibrium level of care of the apparent defendant.

We allow for mixed strategy equilibria of the litigation game. If any type x is mixing, arguments that follow apply to any pure strategy offer S in the support of the mixed strategy of type x.

Part (1)

Here we show that the litigation game equilibrium has to be monotone. Let $AS(X)$ be the set of offers made in equilibrium and accepted with positive probability (which can be smaller than one). Suppose types x_1 and x_2, $x_1 < x_2$, make offers S_1 and S_2, both $S_1, S_2 \in AS(X)$. We will show that $S_1 < S_2$ and $p_1 \equiv p^a(S_1) < p_2 \equiv p^a(S_2)$. Indeed, an incentive compatibility condition for x_2 means

$$(\pi(t+h_P)x_2 - c_P)p_1 + S_1(1-p_1) \le (\pi(t+h_P)x_2 - c_P)p_2 + S_2(1-p_2). \quad \text{(A1)}$$

Thus,

$$S_1(1-p_1) - S_2(1-p_2) \le (\pi(t+h_P)x_2 - c_P)(p_2 - p_1).$$

Similarly, using the incentive compatibility condition for type x_1,

$$S_1(1-p_1) - S_2(1-p_2) \ge (\pi(t+h_P)x_1 - c_P)(p_2 - p_1).$$

The last two inequalities imply that

$$(\pi(t+h_P)x_2 - c_P)(p_2 - p_1) \ge (\pi(t+h_P)x_1 - c_P)(p_2 - p_1).$$

Hence the last inequality requires that $p_2 \geq p_1$ (given that $x_1 < x_2$). Therefore, it must be the case that $S_2 > S_1$ (otherwise x_2 will prefer to demand S_1 rather than S_2). So, $p_2 > p_1$ (otherwise x_1 will demand S_2 rather than S_1).

Part (2)

Next, we show that all types of plaintiff make settlement demands that are accepted with positive probabilities in equilibrium.

Suppose that there exists x such that $S(x) \notin AS(X)$, that is, x makes an offer that is never accepted in equilibrium. This means that $AS(X) \leq \pi(t + h_P)x - c_P$ (each element of the set is smaller), as otherwise x would prefer to make an offer that is accepted with positive probability.

Let S^* be the maximum of the set $AS(X)$ and x^* solve $S^* = \pi(t+h_P)x^* - c_P$.[48] Clearly, the equilibrium payoff of player x^* is $\pi(t + h_P)x^* - c_P$, while for any $x < x^*$ the equilibrium payoff of x is at least $(\pi(t + h_P)x - c_P)p^* + S^*(1 - p^*)$, where $p^* = p^a(S^*)$.

Next, consider any offer $S_1 > S^*$. As S^* is the maximal of $AS(X)$, offer S_1 is rejected. We want to show that, using the universal divinity refinement, we can eliminate any $x < x^*$ from the support of the apparent defendant's beliefs given S_1. To do so, we actually use the *Never a Weak Best Response (NWBR) for signaling games* condition (Fudenberg and Tirole, 1991). According to this condition, if: (i) type x is just indifferent between his equilibrium payoff and offering S_1 expecting it being rejected with probability q_1; and (ii) there exist a type x' that strictly prefers offering S_1 with rejection probability q_1 to her equilibrium payoff, then the plaintiff should not believe that offer S_1 comes from x. Any type x that is eliminated under the NWBR condition will be eliminated under the universal divinity criterion.[49]

Consider any $x < x^*$, let q_1 and q_2 solve, respectively,

$$u^*(x) = (\pi(t + h_P)x - c_P)q_1 + (1 - q_1)S_1,$$

where $u^*(x)$ is the equilibrium payoff to type x, and

$$(\pi(t + h_P)x - c_P)p^* + (1 - p^*)S^* = (\pi(t + h_P)x - c_P)q_2 + (1 - q_2)S_1. \tag{A2}$$

Thus, q_1 is the probability of rejection of offer S_1 at which type x is indifferent between making S_1 and following her equilibrium action. Similarly, q_2 is the probability at which x is indifferent between S^* and S_1. As $S_1 > S^*$, $p^* < q_2$. Also, as $u^*(x) \geq (\pi(t + h_P)x - c_P)p^* + (1-p^*)S^*$ [the equilibrium payoff of x is at least as high as when offering S^*], we have $q_1 \leq q_2$. Consider now type x^*. As $p^* < q_2$, the right hand side of equation (A2) becomes larger if x is substituted for x^*. Thus, type x^* strictly prefers S_1 with probability of rejection q_2 to her equilibrium payoff from offer S^*. Since $q_1 \leq q_2$, S_1 with probability of rejection q_1 is also strictly preferred to S^* by x^*. Therefore, conditions (i) and (ii) of NWBR hold for types x and $x' = x^*$. Any type $x < x^*$ is eliminated from the support of beliefs $b^a(S_1)$ for all $S_1 > S^*$, and so $Eb^a(S_1) \geq x^*$.

Consider $S_1 = S^* + \varepsilon$ for a sufficiently small $\varepsilon > 0$, the expected loss to the apparent defendant from rejecting settlement S_1 is $\pi(t + h_P)b^a(S_1) + c_D \geq \pi(t + h_P)x^* + c_D =$

[48] If the maximum does not exist, let $S^* = \sup_S AS(X)$, and choose an increasing sequence $S_n \to S^*$, $S_n \in AS(X)$. For each S_n, we have $\pi(t + h_P)Eb^a(S_n) + c_D = S_n$ as the apparent defendant is indifferent between accepting and rejecting offer S_n. Therefore, $Eb^a(S_n)$ converges as well. Since supports of $b^a(S_n)$ are also ordered (as sets) by monotonicity, convergence of averages means that supports themselves converge (as sets) to $\frac{S^*-c_D}{\pi(t+h_P)}$. Then, $\sup\{\cup_n \text{Supp} b^a(S_n)\} = \frac{S^*-c_D}{\pi(t+h_P)} < x^* = \frac{S^*+c_P}{\pi(t+h_P)}$, so x^* is not the smallest type without a possibility of an accepted offer in equilibrium.

[49] See Fudenberg and Tirole (1991; pp. 451-454) for details.

$S^* + c_P + c_D > S^* + \varepsilon$. Thus, it is optimal for the apparent defendant to accept this settlement with probability 1. This means that all the types of the plaintiff $x \leq x^*$ strictly prefer making S_1 to their equilibrium offers — a contradiction.

Part (3)

We have established that all the types of the plaintiff make offers that are accepted with positive probability in equilibrium. It remains to be shown that no pooling of any kind is possible in equilibrium. If there are two types of the plaintiff $x_1 < x_2$ that make the same offer S, then any type $x \in (x_1, x_2)$ makes the same offer. Indeed, if $S(x) > S$, then monotonicity is violated for the pair (x, x_2). Similarly, if $S(x) < S$, then monotonicity is violated for the pair (x_1, x). Let x_1^S and x_2^S be the smallest and the largest types that make S.[50] Then, $\mathrm{Supp} b^a(S) = [x_1^S, x_2^S]$. Since the apparent defendant accepts S with positive probability,

$$S = \pi(t + h_P)Eb^a(S) + c_D < \pi(t + h_P)x_2^S + c_D. \tag{A3}$$

In equilibrium, the apparent defendant's beliefs given any offer $S' > S$ satisfy $x \geq x_2^S$. Indeed, this is due to monotonicity (Part (1)), if S' is made and so accepted with positive probability in equilibrium, or to NWBR (Part (2)), if S' is never made in equilibrium. In either case, the expected payoff to the apparent defendant from rejecting S' is at least $\pi(t+h_P)x_2^S + c_D$. On the other hand, if S' is close enough to S, then inequality (A3) holds for S' as well. Therefore, offer S' has to be accepted with probability 1, which means that all types $x < x_2^S$ want to deviate to S' — a contradiction.

Part (4)

We have shown that all types of the plaintiff make separating settlement demands, and all these demands are accepted with positive probabilities. Furthermore, by monotonicity, the acceptance probability is strictly decreasing with the offer, and so for almost all x and their $S(x)$ the apparent defendant is indifferent between accepting and rejecting the settlement demand. Hence, for $x > \underline{x}_P$,

$$S(x) = \pi(t + h_P)x + c_D.$$

In equilibrium, the plaintiff of type x obtains payoff $u^*(x) = p^a(S(x))(\pi(t + h_P)x - c_P) + (1 - p^a(S(x)))S(x)$. Obviously, the equilibrium payoff function is continuous in x. Therefore, as $S(x)$ is continuous and $S(x) > \pi(t + h_P)x - c_P$, the probability of rejection $p^a(S)$ is also continuous at $S \in [\underline{S}_P, +\infty)$, where $\underline{S}_P = \pi(t+h_P)x+c_D$. Consider the incentive compatibility constraint (A1) of type x_2 pretending to be x_1. As $[S_1(1 - p_1) - S_2(1 - p_2) = S_2(p_2 - p_1) + (S_1 - S_2)(1 - p_1)$ and $S_2 - \pi(t + h_P)x_2 + c_P = c_D + c_P = C$, after combining the terms we obtain

$$(p_2 - p_1)C \leq (S_2 - S_1)(1 - p_1).$$

Analogously, by considering the incentive constraint of type x_1 pretending to be type x_2, we obtain

$$(S_2 - S_1)(1 - p_1) \leq (p_2 - p_1)C.$$

By combining these two inequalities and by taking limit of x_2 to x_1 we obtain that $p^a(S)$ is differentiable at all $x > \underline{x}_P$ and its derivative satisfies the following first-order differential equation

$$p^{a\prime}(S)C = 1 - p^a(S).$$

The solution to this equation is:

[50] If either type is making some other offer in equilibrium, then, by continuity, it is indifferent between making that offer and S. Without loss of generality, we may assume that both types offer S in equilibrium.

$$p^a(S) = 1 - \mu e^{-S/C},$$

where μ is a parameter to be determined using the initial condition.

Note that for the apparent defendant it is strictly optimal to accept any offer $S < \underline{S}_P$ no matter what his beliefs $b^a(S)$ are. Therefore, in equilibrium, $p(\underline{S}_P) = 0$. Otherwise, if $p(\underline{S}_P) > 0$, the lowest plaintiff type, $\underline{x}_P$, has an incentive to deviate and demand $\pi(t + h_P)\underline{x}_P + c_D - \epsilon$, for any sufficiently small $\epsilon > 0$, which will be accepted with certainty. Substituting the initial condition $p(\underline{S}_P) = 0$ into the equilibrium expression for $p^a(S)$ yields

$$\mu = -e^{\underline{S}_P/T}.$$

Therefore,

$$p^a(S) = 1 - e^{-(S-\underline{S}_P)/T}.$$

For off-equilibrium offers $S < \underline{S}_P$, we cannot further refine beliefs $b^a(S)$ using the universal divinity refinement, as all the plaintiff types are strictly worse making S under any beliefs than in equilibrium.

This completes the characterization of the separating universally divine PBE for the litigation game. It is unique in terms of equilibrium outcome.

Part (5)

Now, given the equilibrium of the litigation game, we compute optimal λ^a.

The expected loss of the apparent defendant in case of an accident is

$$\int_{\underline{x}_P}^{+\infty} (\pi(t + h_P)x + c_D) f(x) dx$$

By the Lemma, the loss-minimization problem of the apparent defendant has a unique solution, which is

$$\arg\min \left\{ K(\lambda) + \lambda \int_{\underline{x}_P}^{+\infty} (\pi(t + h_P)x + c_D) f(x) dx \right\}.$$

Q.E.D.

PROOF OF PROPOSITION 2:

Part (1)

$$\frac{\partial S(x)}{\partial h_P} = \pi x > 0.$$

Aggregating across types:

$$\frac{\partial ES}{\partial h_P} = \frac{\partial \int_{\underline{x}}^{+\infty} [\pi(t + h_P)x + c_D] f(x) dx}{\partial h_P} = \pi Ex > 0.$$

Q.E.D.

Part (2)

$$\frac{\partial p(S)}{\partial h_P} = \frac{\partial p}{\partial S} \frac{\partial S}{\partial h_P} = -e^{-(S-\underline{S}_D)/C} \left(-\frac{1}{C} \right) \pi x > 0;$$

$$\frac{\partial p(S)}{\partial h_D} = \frac{\partial p}{\partial \underline{S}_D} \frac{\partial \underline{S}_D}{\partial h_D} = -e^{-(S-\underline{S}_D)/C} \left(\frac{1}{C} \right) (-\pi \underline{x}) > 0.$$

$$\frac{\partial Ep(S(x))}{\partial h_P} = \frac{\partial \left[\int_{\underline{x}}^{+\infty} \left(1 - e^{-[(\pi(t+h_P)x+c_D)-(\pi(t-h_D)\underline{x}+c_D)]/C}\right) f(x)dx\right]}{\partial h_P} =$$

$$= \int_{\underline{x}}^{+\infty} \frac{\partial}{\partial h_P} \left[1 - e^{-[(\pi(t+h_P)x+c_D)-(\pi(t-h_D)\underline{x}+c_D)]/C}\right] f(x)dx$$

$$= \int_{\underline{x}}^{+\infty} \left[-e^{-[(\pi(t+h_P)x+c_D)-(\pi(t-h_D)\underline{x}+c_D)]/C} \left(-\frac{\pi x}{C}\right)\right] f(x)dx > 0.$$

$$\frac{\partial Ep(S(x))}{\partial h_D} = \frac{\partial \left[\int_{\underline{x}}^{+\infty} \left(1 - e^{-[(\pi(t+h_P)x+c_D)-(\pi(t-h_D)\underline{x}+c_D)]/C}\right) f(x)dx\right]}{\partial h_D} =$$

$$= \int_{\underline{x}}^{+\infty} \frac{\partial}{\partial h_D} \left[1 - e^{-[(\pi(t+h_P)x+c_D)-(\pi(t-h_D)\underline{x}+c_D)]/C}\right] f(x)dx$$

$$= \int_{\underline{x}}^{+\infty} \left[-e^{-[(\pi(t+h_P)x+c_D)-(\pi(t-h_D)\underline{x}+c_D)]/C} \left(-\frac{\pi \underline{x}}{C}\right)\right] f(x)dx > 0.$$

Q.E.D.

Part (3)

The biased defendant expects that his conditional (on accident) litigation loss will be

$$\int_{\underline{x}}^{+\infty} (\pi(t-h_D)x + c_D) f(x)dx,$$

which is inversely related to h_D. Hence, by the Lemma, an increase in the self-serving bias of the defendant will reduce the expenditures on care and increase the probability of accident. Q.E.D.

PROOF OF COROLLARY:

Part (1)

The unconditional probability of trial is the product of the probability of accident, which is increasing in the bias of the defendant (Proposition 2, part 3) and the conditional probability of trial, which is increasing in biases of both defendants (Proposition 2, part 2). Hence, the unconditional probability of trial is increasing in the biases of both defendants. Q.E.D.

Part (2)

Conditional on accident occurrence, the expected litigation costs equal

$$C \int_{\underline{x}}^{+\infty} p(S(x)) f(x)dx.$$

By Proposition 2, $p(S(x))$ depends positively on h_P and h_D for all x. Hence the integral expression is rising in both litigants' biases.

In the whole game, the (unconditional) expected litigation costs equal

$$\lambda C \int_{\underline{x}}^{+\infty} p(S(x)) f(x)dx.$$

An increase in the bias of the defendant reduces the level of care and increases the probability of accident (Proposition 2, part 3), λ. Hence the expected litigation costs increase. The bias of the plaintiff has no impact on the level of care. Therefore, the product of λ and the conditional litigation costs increase. Q.E.D.

PROOF OF PROPOSITION 3:

Part (1)

The expected payoff for the plaintiff of type x is

$$V_P = (1 - p(x))[\pi(t + h_P)x + c_D] + p(x)(\pi tx - c_P).$$

The expected payoff for the defendant when he meets the plaintiff of type x is

$$-(1 - p(x))[\pi(t + h_P)x + c_D] - p(x)(\pi tx + c_D).$$

Aggregating across plaintiff types, we get the expected payoff of the plaintiff:

$$V_D = -\int_{\underline{x}}^{+\infty} \{(1 - p(x))[\pi(t + h_P)x + c_D] - p(x)(\pi tx + c_D)\} f(x)dx$$

The only variable that depends on h_D is $p(x)$.

$$\frac{\partial p(x)}{\partial h_D} = -e^{-[S-(\pi(t-h_D)\underline{x}+c_D)]/C}\left[-\frac{\pi\underline{x}}{C}\right] > 0.$$

Therefore,

$$\frac{\partial V_P}{\partial h_D} = -(h_P x + C)\frac{\partial p(x)}{\partial h_D} < 0,$$

and

$$\frac{\partial V_D}{\partial h_D} = \int_{x=\underline{x}}^{+\infty} h_P x \frac{\partial p(x)}{\partial h_D} f(x)dx > 0.$$

Q.E.D.

Part (2)

First, consider the impact of the plaintiff's bias on the plaintiff's conditional expected payoff. Denote $\zeta \equiv 1 - p(S(x)) = e^{-[\pi(t+h_P)x - \pi(t-h_D)\underline{x}]/C}$.

$$\frac{\partial \zeta}{\partial h_P} = \zeta\left(-\frac{\pi x}{C}\right).$$

Hence, the conditional expected payoff of the plaintiff of type x is

$$V_P = (1 - \zeta)(\pi tx - c_P) + \zeta[\pi(t + h_P)x + c_D]$$

$$\frac{\partial V_P}{\partial h_P} = \frac{\partial \zeta}{\partial h_P}[C + \pi h_P x] + \zeta\pi x = \zeta\left[-\frac{\pi x}{C}(C + \pi h_P x) + \pi x\right] = \zeta\left[-\frac{\pi^2 x^2 h_P}{C}\right] < 0$$

Now consider the impact of the bias on the expected payoff of the defendant who faces the plaintiff of type x. Plaintiff's bias has no impact on the level of care and the probability of accident. Hence it affects the payoff of the defendant through the conditional (on accident) payoff only. The defendant's conditional expected payoff is

$$V_D = -\int_{\underline{x}}^{+\infty} \{(1-\zeta)(\pi t x + c_D) + \zeta[\pi(t + h_P)x + c_D]\} f(x)dx$$

Differentiating with respect to h_P yields

$$\frac{\partial V_D}{\partial h_P} = -\int_{\underline{x}}^{+\infty} \left[\pi h_P x \frac{\partial \zeta}{\partial h_P} + \pi x \zeta\right] f(x)dx =$$

$$= -\int_{\underline{x}}^{+\infty} \pi x \zeta \left[1 - \frac{\pi x h_P}{C}\right] f(x)dx$$

The derivative is greater/smaller than zero (the defendant is benefitted/hurt by an increase in h_P) if

$$h_P \int_{\underline{x}}^{+\infty} \zeta x^2 f(x)dx > \frac{C}{\pi} \int_{\underline{x}}^{+\infty} \zeta x f(x)dx$$

The bias of the plaintiff has no impact on the decision to take care and the probability of accidents. Therefore unconditional expected payoffs of both litigants move in the same direction as the expected payoffs. Q.E.D.

PROOF OF PROPOSITION 4:

Define social welfare loss as

$$L_W(\lambda) = K(\lambda^*) + \lambda^* l_W,$$

where l_W is

$$l_W = E\int_x [x+y+(c_P+c_D)p(x)]f(x)dx = \int_{\underline{y}}^{+\infty} \left[\int_x [x + y + (c_P + c_D)p(x)]f(x)dx\right] g(y)d(y) =$$

$$= \int_x [x + \int_{\underline{y}}^{+\infty} yg(y)d(y) + (c_P + c_D)p(x)]f(x)dx = \int_x [x + E(y) + (c_P + c_D)p(x)]f(x)dx =$$

$$\int_x [x + \mu + (c_P + c_D)p(x)]f(x)dx,$$

and $g(y)$ is the pdf function for y. Here, we used independence between x and y.

Let's prove the first part of the proposition. An increase on the plaintiff's bias affects social welfare through the probability of trial only. This probability increases for each level of damage x. Hence, social welfare loss increases when the plaintiff is more biased. Proceed now to prove the second part of the proposition. Note that λ^* denotes the choice of the defendant. Then, the effect of the defendant's bias on social welfare is

$$\frac{dL_W(\lambda)}{dh_D} = \frac{\partial L_W(\lambda)}{\partial \lambda^*}\frac{\partial \lambda^*}{\partial h_D} + \frac{\partial L_W(\lambda)}{\partial h_D}.$$

Compute the effects on each component. First, consider the direct effect via the probability of the trial.

$$\frac{\partial L_W(\lambda)}{\partial h_D} = \lambda^* \int_x \left[(c_P + c_D)\frac{\partial p(x)}{\partial h_D}\right] f(x)dx.$$

Given the defendant's bias h_D, if she receives an offer of $S = \pi(t - h_D)x + c_D$, she infers $x_D = \frac{S - c_D}{\pi(t-h_D)}$ and rejects it with probability

$$p(x_D) = 1 - e^{-\frac{\pi(t-h_D)(x_D - \underline{x})}{c_P + c_D}}.$$

Note that the plaintiff makes an offer $S = \pi(t + h_P)x + c_D$, thus $x_D = \frac{t+h_P}{t-h_D}x$. Hence, the probability of trial (expressed in terms of the actual x) is

$$p(x) = 1 - e^{-\frac{\pi(t-h_D)}{c_P+c_D}\left(\frac{t+h_P}{t-h_D}x - \underline{x}\right)}$$

We can express

$$(t - h_D)\left(\frac{t+h_P}{t-h_D}x - \underline{x}\right) = t\left(\frac{t+h_P}{t}x - \frac{t-h_D}{t}\underline{x}\right) = t\left(\frac{t+h_P}{t}x - \underline{x}\right) + h_D\underline{x}.$$

Therefore the probability of trial is

$$p(x) = 1 - e^{-\frac{\pi(t-h_D)}{c_P+c_D}\left(\frac{t+h_P}{t}x - \underline{x}\right)}\Psi,$$

where $\Psi(h_D) = e^{-\frac{\pi h_D \underline{x}}{c_P + c_D}}$.
We have

$$\frac{\partial p(x)}{\partial h_D} = e^{-\frac{\pi(t-h_D)}{c_P+c_D}\left(\frac{t+h_P}{t}x - \underline{x}\right)}\Psi(h_D)\frac{\pi\underline{x}}{c_P + c_D}.$$

In turn, the partial derivative expression becomes

$$\frac{\partial L_W(\lambda)}{\partial h_D} = \lambda^*\Psi(h_D)\pi\underline{x}\int_x \left(e^{-\frac{\pi(t-h_D)}{c_P+c_D}\left(\frac{t+h_P}{t}x - \underline{x}\right)}\right) f(x)dx = \lambda^*\pi\underline{x}\Psi(h_D)g(h_P).$$

The terms under the integral in $g(h_P)$ resemble the probability of acceptance of a settlement offer. Overall the integral is between 0 and 1 and goes to 0 if h_P goes to ∞. Note that the effect of the defendant's bias h_D operates only through Ψ: the higher the bias, the lower the overall effect. The computation of the indirect effect is simpler. Consider the defendant's loss,

$$L = K(\lambda) + \lambda l_D,$$

where

$$l_D = \int_x [\pi(t - h_D)x + c_D]f(x)dx.$$

The FOC implies

$$\frac{\partial K}{\partial \lambda} = -l_D.$$

By implicit function differentiation,

$$\frac{d\lambda^*}{dh_D} = -\frac{\partial l_D}{\partial h_D}/\frac{\partial^2 K}{\partial \lambda^2} = \pi E(x)/\frac{\partial^2 K}{\partial \lambda^2} > 0.$$

We can express the indirect effect as

$$\frac{\partial L_W(\lambda)}{\partial \lambda^*}\frac{\partial \lambda^*}{\partial h_D} = (l_W - l_D)\pi E(x)/K''(\lambda^*).$$

Hence, the total effect (direct and indirect effects) of the defendant's bias on social welfare loss is

$$\frac{dL_W(\lambda)}{dh_D} = (l_W - l_D)\pi E(x)/K''(\lambda^*) + \lambda^* \pi \underline{x} \Psi(h_D) g(h_P).$$

If $l_W > l_D$, both terms are positive. Hence, an increase in defendant's bias unambiguously reduces social welfare.[51] Q.E.D.

PROOF OF PROPOSITION 5:

Analyze the game by backward induction. Consider first the litigation game. It starts when the plaintiff files a lawsuit. For $x < \tilde{x}$, it is easy (following the steps of the proof of Proposition1) to show that this game has a separating equilibrium in which the plaintiff of type x makes a demand $S = \pi t x + c_D$.[52] Upon observing demand S, the defendant forms beliefs $b(S) = (S - c_D)/[\pi t]$ and rejects this proposal with probability $p(S) = 1 - e^{\{-\frac{(S-\underline{S})}{C}\}}$ if $S \geq \underline{S}$ and always accepts the proposal $S < \underline{S}$.

Now consider $x \geq \tilde{x}$. If the suit proceeds to trial, the defendant expects to lose $\pi(\bar{A}+x)+c_D$. It is straightforward to show that the structure of the solution will be very similar to the first case. The plaintiff of type x makes a settlement demand which is equal to the amount the defendant would lose in trial, i.e. $\pi(\bar{A}+x)+c_D$. The defendant correctly deduces the type of the plaintiff, and hence is indifferent between accepting and rejecting the demand. That is, $b(S) = (S - c_D)/\pi - A$ for $S \geq \pi(\bar{A}+\tilde{x})+c_D$). It is also easy to show that the probability of rejection, $p(S) = 1 - \phi e^{-\frac{S}{C}}$, where ϕ, is a coefficient to be determined using a boundary condition.

Next we show by contradiction that $p(S)$ must be a continuous function at $x = \tilde{x}$. Suppose not and assume that there exist two types, x_1 and $x_1 + \epsilon$ infinitely close to x_1 such that probability of rejection of $x_1 + \epsilon$ is greater than the probability of rejection of x_1 by some positive amount $\Lambda > 0$. Then the type $x_1 + \epsilon$ will benefit from deviating and pretending to be the type x_1. Using the same procedure, one ca show the impossibility of the case when the probability of rejection of x_1 is greater than the probability of rejection of $x_1 + \epsilon$ by a positive amount. Equating $1 - \phi e^{-\frac{S}{C}} = 1 - e^{-\frac{(S-\underline{S})}{C}}$ reveals that. Hence, $p(S) = 1 - e^{-\frac{(S-\underline{S})}{C}}$ is the rejection probability in equilibrium, for all $S \geq \underline{S}$. Thus we verified that conditions (B) - (D) are satisfied in the litigation game.

Proceed now to evaluate the defendant's optimal level of care. The equilibrium settlement offers, the probability of acceptance of each offer and the expected loss at trial allow us to compute the expected litigation loss of the defendant (conditional on accident), $[\int_{\underline{x}}^{\tilde{x}}[\pi t x + c_D]f(x)dx + \int_{\tilde{x}}^{+\infty}[(\pi(A+x)+c_D]f(x)dx]$. Therefore, condition (a) describes the optimal level of care. The solution exists because the function is continuous and the interval $[0, 1]$ is compact. Hence, this equilibrium exists. The proof of uniqueness follows the steps described in the proof of Proposition 1. Q.E.D.

[51]Note that this condition is sufficient but not necessary. An increase in π and a reduction in h_D reduce the (positive) difference between tx (the first term in the expression for l_W) and $\pi(t - h_D)x$ (the first term in the expression for l_D), and hence make $l_D > l_W$ more likely. However, the same parameters increase the direct (probability-of-trial) effect of the bias on the social welfare loss. Hence, even if $l_W < l_D$, the effect of the defendant's bias might still be welfare reducing.

[52]See proof of Proposition 1 for any of the two pairs, plaintiff-apparent defendant or defendant-apparent plaintiff).

PROOF OF PROPOSITION 6:

Part (1)

Consider first the effects on the settlement demand. The result holds trivially because for $x > \tilde{x}, \bar{A} + x < tx$, and therefore, the settlement demand of plaintiffs with $x > \tilde{x}$, $\pi(A + x) + c_D$ becomes smaller than $\pi tx + c_D$, their demand before the cap was imposed. Proposition 5 establishes that for $x \leq \tilde{x}$ the settlement demand is the same with, or without cap. Consider now the effects on the expected settlement demand. The result holds trivially if one aggregates across plaintiff's types

$$\int_{\underline{x}}^{+\infty} (\pi tx + c_D) f(x) dx > \int_{\underline{x}}^{\tilde{x}} (\pi tx + c_D) f(x) dx + \int_{\tilde{x}}^{+\infty} (\pi(\bar{A} + x) + c_D) f(x) dx.$$

Q.E.D.

Part (2)

$\pi(A + x) + c_D < \pi tx + c_D$ for $x > \tilde{x} = \frac{\bar{A}}{t-1}$ implies that

$$\int_{\tilde{x}}^{+\infty} (1 - \exp(-[\pi(A+x) + c_D - \underline{S}]/C)) f(x) dx < \int_{\tilde{x}}^{+\infty} (1 - \exp(-[\pi tx + c_D - \underline{S}]/C)) f(x) dx.$$

Therefore,

$$\int_{\underline{x}}^{\tilde{x}} (1 - \exp(-[\pi tx + c_D - \underline{S}]/C)) f(x) dx +$$

$$\int_{\tilde{x}}^{+\infty} (1 - \exp(-[\pi(A + x) + c_D - \underline{S}]/C)) f(x) dx <$$

$$< \int_{\underline{x}}^{+\infty} (1 - \exp(-[\pi tx + c_D - \underline{S}]/C)) f(x) dx,$$

which means that the probability of trial conditional on accident occurence is lower under caps (the left-hand side) than before caps (the right-hand side). Q.E.D.

Part (3)

Consider first the effects on the expected litigation loss.

$$\int_{\underline{x}}^{+\infty} (\pi tx + c_D) f(x) dx > \int_{\underline{x}}^{\tilde{x}} (\pi tx + c_D) f(x) dx + \int_{\tilde{x}}^{+\infty} (\pi(A + x) + c_D) f(x) dx.$$

The left-hand side is the expected litigation loss before the cap. The right-hand side is the expected litigation loss under the cap. This inequality holds because $A + x < tx$ for $x > \tilde{x}$. Thus, caps reduce the expected litigation loss, and hence, reduce the expenditures on accident prevention and raise the probability of accidents. The last result follows directly from the Lemma and the effects of caps on the expected litigation loss. Q.E.D.

PROOF OF PROPOSITION 7:

The unawareness of the litigants about their own bias and the bias of their opponent generates environments under caps and biased litigants (for the two pairs of litigants, plaintiff-apparent defendant and defendant-apparent plaintiff) that are similar to the environment with caps and unbiased litigants. Then, Proposition 7 essentially reproduces Proposition 5 taking into account the biased litigants' beliefs. Q.E.D.

PROOF OF PROPOSITION 8:

By equation (3), the condition $\bar{A} < (t - h_D - 1)x_{med}$ implies that the self-serving bias of the defendant rises, i.e., $h_D^{cap} > h_D$. Hence, the expected litigation loss of the defendant falls because

$$\int_{\bar{x}}^{+\infty} [\pi(t - h_D)x + c_D]f(x)dx =$$

$$= \int_{\bar{x}}^{\tilde{x}_D^{cap}} [\pi(t - h_D)x + c_D]f(x)dx + \int_{\tilde{x}_D^{cap}}^{+\infty} [\pi(t - h_D)x + c_D]f(x)dx >$$

$$> \int_{\bar{x}}^{\tilde{x}_D^{cap}} [\pi(t - h_D^{cap})x + c_D]f(x)dx + \int_{\tilde{x}_D^{cap}}^{+\infty} [\pi(\bar{A} + x) + c_D]f(x)dx.$$

The last inequality holds because $h_D^{cap} > h_D$, and because for $x > \tilde{x}_D^{cap} > \tilde{x}_D$, $\bar{A} + x > (t - h_D)x$. Hence, by the Lemma, a lower expected litigation loss implies a lower spending on care and a higher probability of accident.

In case of low type plaintiffs ($x < \tilde{x}_P$), by equation (2), the plaintiff's bias increases, i.e., $h_P^{cap} > h_P$. Therefore, his settlement demand $S = \pi(t + h_P^{cap})x + c_D$ also increases. Hence, the probability of rejection $1 - \exp(-[S - \underline{S}_D^{cap}]/C)$ increases for two reasons. First, S is larger under caps. Second, $\underline{S}_D^{cap} < \underline{S}_D$, i.e.,

$$\pi(t - h_D^{cap})\underline{x} + c_D = \underline{S}_D^{cap} < \underline{S}_D = \pi(t - h_D)\underline{x} + c_D.$$

As a result, the expected probability of trial also increases. Q.E.D.

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