Population-Based Liability Determination, Mass Torts, and the Incentives for Suit, Settlement, and Trial

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We explore how the incentives of a plaintiff, when considering filing suit and bargaining over settlement, differ between suits associated with stand-alone torts cases and suits involving mass torts. We contrast "individual-based liability determination" (IBLD), wherein a clear description of the mechanism by which a defendant's actions translate into a plaintiff's harm is available, with "population-based liability determination" (PBLD), wherein cases rely on the prevalence of harm in the population to persuade a judge or jury to draw an inference of causation or fault. PBLD creates a "rational optimism effect" on the plaintiff's part that is inherent in many mass tort settings. This effect creates incentives for higher settlement demands and results in greater *interim* expected payoffs for plaintiffs and, thus, an increased propensity to file suit. Consequently, defendants in PBLD cases face increased *ex ante* expected costs compared with the IBLD regime, thereby increasing incentives to take care. (*JEL* K13, K41, D82)

1. Introduction

In this article we explore how the incentives of a plaintiff, when considering filing suit and bargaining over settlement, can differ between those suits associated with stand-alone torts cases and those suits involving mass torts (e.g.,

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harms from broadly marketed pharmaceuticals). We show that there is a form of "rational optimism" on the plaintiff's part that is inherent in many mass tort settings; all else equal, this effect creates incentives for higher settlement demands and results in greater *interim* expected payoffs for plaintiffs.[1] Moreover, the increased (rational) aggressiveness that this effect induces in the plaintiff results in incentives to bring a suit that would otherwise fail to be brought and stronger incentives for the defendant to take care.

We view typical liability determination as reflecting a mix of "individual-based liability determination" (IBLD) and "population-based liability determination" (PBLD). IBLD reflects a situation wherein a clear description of the mechanism by which a defendant's actions translate into a plaintiff's harm is available. For example, in the 1921 case *In re Polemis*, direct cause was established via the chain that the fire that destroyed the steamship *Polemis* was due to a spark that ignited benzene vapors that had accumulated in the ship's hold; the spark was due to a heavy wooden plank that stevedores (employed by the charterers of the ship) had negligently knocked into the hold while they were shifting leaking cases of benzene (*In re An Arbitration Between Polemis and Another and Furness, Withy & Co. Ltd.*, 3 K.B. 560 [1921]).

In contrast, PBLD reflects population-based assessments that suggest that a defendant should (or should not) be held liable for a harm. Such cases rely on the prevalence of harm in the population to persuade a judge or jury to draw an inference of causation (or fault). In these cases, no exact mechanism of direct cause is explicitly stated, often because the relevant science cannot reliably list the exact sequence of events and decisions that link an initial action to an eventual harm. For an example of a successful plaintiff's case that relied entirely on a population-based assessment, see *Manko v. United States* (636 F. Supp. 1419 [WD MO, 1986]; affirmed 8th Cir., 1987). Louis Manko had received a swine flu vaccine and had contracted Guillain-Barre Syndrome (GBS), a neurological disorder. The US government, which had directed the provision of the vaccine to the population and had agreed to absorb liability for harms arising from the vaccine, claimed that liability extended only to those whose harms arose during a 10-week window following administration of the vaccine. Manko's case rested on showing that even though his contraction of GBS had occurred 13 weeks after being vaccinated, it was statistically consistent with an epidemiological model used to show general causation for the population of 10-week victims (we provide more detail below). Alternatively, for a case wherein a defendant successfully used population-based (again, epidemiological) evidence to dispute general causation in a breast-implant action, see *Norris v. Baxter Healthcare Corp.*, 397 F.3d 878 (10th Cir., 2005).

The use of population-based evidence is frequently at the heart of many mass torts; evidence of this is seen in the recurring "battle of the statistical experts," which occurs in such cases. Epidemiological evidence regarding

1. The expression "*interim*" indicates that the parties know their types (e.g., the plaintiff knows she has been harmed), but some uncertainty remains (the outcomes of settlement negotiations and/or trial).

causation has figured prominently in products liability actions involving, for example, the anti-nausea drug Bendectin, radiation exposure, exposure to dioxin (Agent Orange), and smoking.[2] It seems likely that such evidence will figure prominently in ongoing litigation involving the diet drug cocktail Phen-Fen and the pain reliever Vioxx. In Section 2 we discuss some examples in more detail (considering both causation and fault) and contrast them with more classic IBLD cases. These two bases for liability determination[3] influence findings of causation, and sometimes (under negligence) of fault, and can differentially affect a plaintiff's assessment of the likely outcome of undertaking a suit.

1.1 The Research Strategy Used in This Article

Our objective is to analyze the effect of using PBLD on the economic incentives for potential plaintiffs and potential defendants (e.g., incentives to file, settlement demands, and incentives for care) in the case of mass-marketed products or situations of mass harm. Our comparison point is the same bundle of economic incentives under IBLD. This is a complex subject, and the purpose of any analysis is to try to characterize the primary forces at work.

In order to accomplish this we will do four things to sharpen the analysis. First, although we will identify the differential incentive for a potential defendant to take care, tracing that back to the equilibrium care level must wait for another article. Second, we will focus on an individual plaintiff's suit; although some mass torts are addressed via (successfully certified) class action suits, others proceed on a more disaggregated basis.[4] Third, we purposely abstract from some important complicating issues likely to be associated with mass tort actions, including latency, heterogeneous predispositions for harm among plaintiffs, scale economies in litigation, and defendant strategies for managing information.[5]

2. See Green et al. (2000: 335, footnote 5) for case citations; again, note that not all these cases have resulted in decisions for the plaintiffs. This is one of a collection of articles in the Reference Manual on Scientific Evidence (2000), which is published by the Federal Judicial Center to help judges understand and vet scientific evidence that is submitted in court.

3. Our analysis uses a "proportional liability" model in contrast with a "threshold liability" model that generates a binary decision of liable/not-liable (for a discussion of this distinction, see Shavell 1987). The use of a proportional liability model is fairly standard in settlement analyses, especially when abstracting from the way evidence is mapped into a verdict. For an analysis using evidence to achieve a proportional assessment, which then leads to a threshold decision, see Daughety and Reinganum (2000a). As Calfee and Craswell (1984) observe, uncertainty in legal standards can convert a threshold model into a proportional model, as we do in Section 6 below.

4. Plaintiffs proceed individually or in smaller classes for a variety of reasons: their situations may be sufficiently diverse as to preclude class certification or some may opt out. We return to this issue and how this analysis may contribute to an extension that incorporates class action considerations, in Section 7. For a model of class formation, see Che (1996, 2002).

5. Mass tort victims may not "know" immediately that they have been hurt or who has hurt them. Plaintiffs may differ in terms of underlying attributes that may independently cause, or contribute to, their harm. Costs for pursuing (or defending) a mass-tort claim are likely to be quite different from those involved in the more traditional (one-suit) model. Defendant firms may employ confidentiality to further suppress information flows and thereby suppress potential plaintiff claims.

Fourth, we simplify the analytical modeling of PBLD by relating it to the fraction of people harmed, which we assume is the defendant's private information. A nice example might be the epidemiological analysis used to prove causation that is involved in mass torts arising from a new drug that is marketed. Drugs are tested before the Food and Drug Administration (FDA) approves them for general distribution; after approval, the general distribution of the drug constitutes a large-scale test, frequently with millions of subjects. Lawsuits over harms arising in this post-approval environment may have access to all the earlier testing results, but plaintiffs contemplating filing a suit generally do not have access to what is happening post-approval, and much of that will only come out in a combination of (typically) lengthy discovery and, if settlement fails, trial.

Since a potential plaintiff must contemplate whether or not to file suit, anticipating the likely outcome of a bargaining process and the possibility of trial, she forecasts the likelihood of the defendant being found liable by using the past information about the pre-approval drug tests and any information gleaned from more recent events. Although drug research is likely to evolve over time, this latter aspect is difficult to capture in a form that is tractable. Therefore, we focus on the pre-approval information and the post-approval experience of being harmed as the simplest version of what information the plaintiff can accumulate when considering her litigation strategy. Combining these is a job for Bayes' Rule; we provide a stark example below and use the general principle in our analysis from Section 3 on.

In order to focus on how the basis of liability determination influences the incentives to bring suit, make settlement demands, and proceed to trial,[6] we follow a *ceteris paribus* style of analysis that takes the standard IBLD model and simply changes the liability basis to PBLD (holding everything else constant) so as to isolate the basic incentives of interest. We will return in Section 7 to contemplate the effects on our results of some of the complicating factors mentioned above.

1.2 An Illustration of the Rational-Optimism Effect of PBLD

In this section, we describe how a rational plaintiff (or a plaintiff that is advised by a rational attorney) responds to the fact that liability determination will involve population-based evidence. To see the basic source of this effect, assume that a product is purchased by 1000 buyers and that either 10 or 50 buyers will be harmed, with equal likelihood; that is, either 1% or 5% of the population "exposed" to the product will be harmed, each with probability 1/2. We assume that every individual in the overall population of the 1000 buyers is equally likely to be among those harmed; no individual has a predisposition for

6. We will use the word "trial" to represent the costly terminal phase of the legal process wherein all information becomes common knowledge and payoffs are determined. We recognize that this phase could occur before an actual trial (e.g., if thorough discovery is costly and results in common knowledge, then the parties will likely settle rather than continue on to trial).

being harmed. Thus, if 10 people are harmed, any individual buyer has a 1% chance of being harmed; call this probability A, so $A = \Pr\{\text{an individual is harmed} \mid \text{harm rate} = 1\%\} = 0.01$. Similarly, if 50 people are harmed, any individual buyer has a 5% chance of being harmed; call this probability B, so $B = \Pr\{\text{an individual is harmed} \mid \text{harm rate} = 5\%\} = 0.05$. These probabilities represent *ex ante* information.

Assume that the victim knows the foregoing information and is considering the value of a suit against the defendant. In the IBLD case, this information is not of particular interest to the plaintiff since (for example) demonstrating cause will depend upon showing a chain of events from the defendant's action to the plaintiff's harm. However, if the likelihood that the defendant will be found liable is increasing in the fraction of the buyers who are harmed, then this information is relevant. When the victim considers her situation, she has already been harmed, so she now views this issue from an *interim* position and asks which group is more likely to have occurred (since this affects the expected payoff from filing the suit).[7] Thus, she wishes to compute the probability that the harm rate is x (where x is either 1% or 5%) given that she has been harmed. As a rational plaintiff she would use Bayes' rule to update the likelihood of the rate of harm (note, since A and B are each multiplied by the prior probability of 1/2, we cancel these halves out in what follows):

$$\Pr\{\text{harm rate} = 1\% \mid \text{the victim was harmed}\} = A/(A+B) = 1/6 < 1/2.$$

$$\Pr\{\text{harm rate} = 5\% \mid \text{the victim was harmed}\} = B/(A+B) = 5/6 > 1/2.$$

That is, while the prior assessments of the harm rate are 1/2 for each group, the *interim* assessments are quite different. This is because there are two groups that the victim could be in: the smaller group of victims or the larger group of victims. Since the victim has been harmed, it is rational for her to place a higher likelihood on the outcome that she is part of the larger group of victims rather than the outcome that she is part of the smaller group of victims. Thus, if the value of suing will be influenced by (say) the fraction of the population harmed, this dependence enters her forecast of that fraction via Bayes' rule. The plaintiff will use the above estimate of 5/6 (and the complementary probability that $\Pr\{\text{harm rate} = 1\% \mid \text{the victim was harmed}\} = 1/6$) when computing her expected payoff from filing a suit, bargaining over settlement, and possibly going to trial.

Note that the foregoing computation is *not* the result of a model that posits optimism about the likelihood of winning a suit on the part of the victim. Rather, in the context of (say) a mass-marketed product, it is the recognition that harm is likely to have occurred in other cases (I've been harmed; I'll bet others have been, too.) and that mass harm can play a role in supporting a

7. Deneckere and Peck (1995) and Dana (2001) use this idea, in a different context, to model a consumer's assessment of the size of market demand, conditional on being active in the market.

finding of liability on the part of a defendant that leads to a rational optimism on the part of the plaintiff.[8] The effect here is that there is settlement bargaining "in the shadow of other related harms," which induces a shift of the plaintiff's assessment toward higher values of the likelihood of the defendant being found liable.[9] Furthermore, as all victims individually update in this manner, the potential defendant ends up facing more suits, each involving a more aggressive plaintiff.

1.3 Plan of the Article

We show that incorporating this effect in the analysis implies an increased settlement demand, a higher *interim* expected recovery for the plaintiff, an increased propensity to file suit, and higher *ex ante* expected costs for the defendant in comparison with a traditional (asymmetric information) analysis of suit, settlement, and trial. In Section 2 we provide examples of cases wherein the two bases of liability determination appear. In Section 3 we provide formal models of what we mean by IBLD and PBLD. In Section 4 we provide a "pure" IBLD model of suit, settlement, and trial as a simple extension of the standard screening model; we then re-formulate the analysis for a "pure" PBLD model. Section 5 contains the comparisons of the incentives created by the two types of liability determination. Section 6 addresses some issues of robustness by considering a signaling version of the IBLD and PBLD models and uses the results of the two types of games (screening and signaling) to characterize the consistent results the models generate. We also show that our results in Sections 3, 4, and 5 readily generalize to more complex relationships between the harm rate and the defendant's likelihood of being found liable. Section 7 provides a summary and a discussion of some further (and broader) implications of our analysis as well as a potential extension of our model of PBLD. Proofs of all propositions, and the details of the generalizations discussed in Section 6, are in the Appendix.

2. Examples of IBLD and PBLD

2.1 IBLD and PBLD in the Context of Causation

Examples of IBLD, wherein direct cause is established via an explicit sequence of causes and effects, form some of the "classics" of torts classes and law and economics courses; *In re Polemis*, as discussed earlier, is one such case. As a second example, in *Palsgraf v. Long Island Railroad*, even though direct

8. In independent work, Benoit and Dubra (2007) use a model of this sort (wherein an agent updates her beliefs about a relevant random variable based on the receipt of a noisy signal) to argue that alleged instances of overconfidence arising out of surveys and experiments can be rationalized as Bayesian updating.

9. Of course, someone who used the product and was not harmed would update her assessment and thereby compute an *interim* estimate of the likelihood of the larger group of possible victims having been harmed that was less than the prior of 1/2. However, this does not matter, as unharmed users will not be able to sue since we assume that harm is observable and verifiable.

cause was not sufficient to win the day, Mrs. Palsgraf was clearly hurt due to a chain of events leading from actions on the part of the railroad's employees to a set of scales on the railroad platform (where she was standing) falling onto her. That event was due to the explosion of a package that fell under the wheels of the train, which (in turn) was caused by the efforts of employees to get a passenger (who was carrying the package of fireworks that slipped loose onto the tracks under the wheels) onto the train as it was departing the station.[10]

Many manufacturing-defects suits are primarily IBLD cases. For example, a customer who buys a bottle of a beverage and finds a half-decomposed mouse in it needs only to show that it was more likely than not that the mouse got in the bottle before the product left the bottling plant (see *Shoshone Coca-Cola Bottling Co. v. Dolinski*, 82 Nev. 439 [1966]); there is no need to consider how frequently this occurs. Finally, even though the number of casualties in an airplane crash may be in the hundreds, the National Transportation Safety Board attempts to use engineering analysis and science to describe the causal chain and provide reasons for the crash in terms of one or more specific failures (e.g., pilot error or airframe failure). Such an event may lead to lawsuits, but these are not PBLD lawsuits simply because many people are affected.

Although they differ in a variety of ways, what the foregoing cases have in common is that there was no reason to rely on the frequency of mishaps in the population to address causation. In each case the path from the harm back to the precise location of error can be reasonably described via a backward-looking description of the events involved, in isolation from what might have happened in untold other (similar) instances of unloading ships, assisting passengers, and bottling drinks.

In contrast, our model of PBLD assumes that the defendant is more likely to be found liable in a given case if the exposed population is found to have experienced a higher frequency of harm. Information about the experience of exposed populations is often introduced to argue for general causation (i.e., exposure is capable of causing the kind of harm the plaintiff experienced). According to the Reference Manual on Scientific Evidence (see the article by Green et al., 2000: 335), "Judges and juries increasingly are presented with epidemiologic evidence as the basis of an expert's opinion on causation. In the courtroom, epidemiologic research findings are offered to establish or dispute whether exposure to an agent caused a harmful effect or disease." Since a plaintiff will also have to establish specific causation (i.e., exposure caused her specific harm, possibly attested to by a medical expert who examined the plaintiff), the strength of evidence about general causation will be influential but need not be decisive. It does appear, however, that strong general causation evidence (e.g., a high rate of relative risk for a product compared with, say, natural causes of a disease) can substitute for weaker specific causation evidence.[11]

10. *Palsgraf v. Long Island Railroad Co*., 248 N.Y. 339 (1928). For a discussion of some of the details and the legal ramifications of this case, see Posner (1990) and Goldberg et al. (2004).

11. See Green et. al. (2000: 383–4) though, as noted therein, this substitution possibility is not uniformly accepted.

As suggested earlier, an example of a virtually pure PBLD case involves the swine flu vaccination program; the following discussion is based on the district court's opinion in *Manko v. United States* (636 F. Supp. 1419 [WD MO, 1986]; affirmed 8th Cir., 1987). In 1976, the US government instituted an immunization program against the swine flu. To induce pharmaceutical companies to manufacture the vaccine, the federal government assumed all liability for injuries stemming from its use. The program began on October 1, 1976, and was halted on December 18, 1976, when data collected by the Center for Disease Control (CDC) (which was monitoring the program) suggested that the vaccine might be causing GBS, a neurological disorder resulting in paralysis from which most, but not all, patients recover.

Both parties agreed that Louis Manko had received the vaccine and had contracted GBS; moreover, the defendant (the US government) had agreed that the plaintiff did not need to prove negligence in order to establish liability. The only issue in dispute was whether the swine flu vaccine caused the plaintiff's GBS, which had been diagnosed 13 weeks after he received the vaccine.[12] Thus, the trial over liability was reduced to a battle of statistical and epidemiological experts over whether the vaccine (at least) doubled the risk of contracting GBS 13 weeks after vaccination. All the experts relied on data collected by the CDC during the conduct of the vaccination program, although some of it was incomplete and disputes arose regarding how to deal with the flawed data. Moreover, since the CDC had discontinued its rigorous data collection when the program was halted, the litigants' experts used different procedures to project the extent of unreported cases (in both the vaccinated and unvaccinated populations) into the relevant time period, and predictably came to different conclusions.[13] Even after correcting for the risk that the plaintiff had independently contracted GBS from an intervening episode of the flu, the district court concluded (*Manko*, at 1438) that " . . . plaintiff's GBS contracted in January 1977 was caused by the October 1976 swine flu vaccination." The critical difference between this type of case and the IBLD cases discussed earlier is that the backwards-looking description is fairly ineffective in clarifying exactly how harm has occurred: medical and biological sciences are simply unable to provide a precise mechanism of how things happened. Instead, courts must rely on a comparative analysis of populations that were and were not exposed to an agent of interest. The purpose of such analysis is to assert whether the exposure meaningfully increased the likelihood of harm and therefore was more likely than not to have been the cause of the harm.

12. Based on a study conducted by the CDC, the US government had already conceded liability for cases of GBS arising within 10 weeks of vaccination. "Therefore, claimants had to demonstrate only that they had received a vaccination and that their subsequent episode of GBS occurred within ten weeks of receiving the influenza vaccine" (Ginzburg 1986: 429).

13. In an interesting twist, the district court imposed discovery sanctions on the government for its refusal to make available to the plaintiff's experts documents that might have clarified some of the incomplete observations. The nature of the court-imposed sanction was to interpret vague or incomplete data in the most favorable light for the plaintiff.

2.2 IBLD and PBLD in the Context of Fault, Design Defect, and Failure-to-Warn

For an example of IBLD in the context of fault, consider the famous paragraph of *U.S. v Carroll Towing Co.* (159 F.2d 169 [2nd Cir., 1947], at 173) which gives rise to the "Hand Rule," wherein Judge Hand makes clear that the presence of an attendant (the "bargee") could be expected to reduce the probability of the accident. This is an assertion of IBLD since it is the individual (or in this case, the firm's agent) whose extended absence can be viewed as increasing the expected loss, leading to a Hand Rule–based assertion of fault. This case also makes clear that when we refer to IBLD versus PBLD cases, we are not using the presence or absence of a probability assessment as the dividing line.

However, a finding of fault can reflect PBLD considerations in a variety of ways. According to Goldberg et al. (2004: 857), one conception of design defect is based on a risk-utility test: " . . . a product is defectively designed if the risks of its design outweigh its utility." Thus, observational evidence regarding the safety benefit of a design change would presumably be pertinent to the liability calculus: the higher the fraction of individuals that have been harmed by the current design, the more likely it will be found that an alternative design (one that is safer, but perhaps more costly) should have been chosen instead. In some cases, a firm's product may be found to be unreasonably dangerous (even though there is no alternative design available to the firm). For instance, Merck's pain reliever Vioxx was supposed to be at least as effective as Naproxen, but with fewer adverse gastrointestinal side effects. In ongoing litigation, it is alleged that Vioxx substantially increases the risk of heart attack which (under a risk-utility test) may render it unreasonably dangerous, in which case Vioxx should not have been sold (or should not have continued to be sold, after Merck is alleged to have discovered its true risks). Finally, in the case of failure to warn (Goldberg et al., 2004: 926): " . . . the product is defective not because of how it has been designed or made, but because it should have been delivered with more information for consumers about the dangers associated with it, and how to use it safely." Again, this suggests that aggregate experience should be relevant: the higher the fraction of users that has been harmed by the product (which fraction could have been reduced by a warning), the more likely it will be found that a warning should have been provided.

For an example involving a design defect, in *Jarvis v Ford Motor Co.* (283 F.3d 33 [2nd Cir., 2002]) an appeals court ruled that a jury had properly found that a design flaw in the cruise control mechanism of Ford Motor Company's 1991 Aerostar had led to Kathleen Jarvis's accident. The court stated (at 38): "To prove negligence, Jarvis was not required to establish what specific defect caused the Aerostar to malfunction." Furthermore, the court argued that the presence of numerous similar accounts supported the finding of negligence (at 54):

> Jarvis's testimony, the testimony of other Aerostar owners who had similar experiences, and evidence of hundreds of other reported cases of sudden acceleration in Aerostars, combined with an expert's scientific explanation of how cruise control may have malfunctioned and of an

inexpensive remedy, were all found admissible by the district court. Together, this evidence provided the jury with a sufficient evidentiary basis to reasonably conclude that the cruise control mechanism had been defectively designed.

The recent settlements entered into between various dioceses of the Catholic Church with those claiming they were (as children) molested by priests appears to be a good example of PBLD, especially as regarding the possibility of finding fault on the part of Church officials should the cases go to trial. Some states have extended civil liability by adjusting the statute of limitations so as to allow more filings than would otherwise be possible.[14] One effect of this has been to increase substantially the number of cases filed, as victims were able to learn that they were not isolated cases of abuse (since early settlements were concluded with confidentiality agreements) and were more willing to come forward. The onslaught of cases (and the substantially increased level of average compensation paid)[15] has also led many to conclude that Church authorities contributed significantly to the harm via a policy of hiding the crimes from the police and re-assigning accused priests to activities involving youth. Here there is an argument both of individual culpability (on the part of specific priests) as well as of vicarious liability on the part of officials who not only did not correct the problem but whose actions enhanced its impact on unsuspecting parishioners. It is likely that only Church authorities have an accurate estimate of organizational culpability. Here, frequency-of-harm information appears to be contributing to the success of lawsuits (and, in this case, obtaining much larger settlements), as the priests themselves are essentially judgment proof.

3. A Formal Comparison of IBLD and PBLD

In this section, we describe the formal model of liability determination using individual-based versus population-based evidence. In both cases, we envision a population of individuals of measure N who are potential victims. Let $\delta \in [\underline{\delta}, \infty)$ represent the amount of harm and the damages awarded at trial; δ is assumed to be verifiable by the court. Moreover, we assume that there is some minimum value of damages $\underline{\delta} > 0$, so there are no "nuisance" suits. At some points of the analysis we will allow δ to vary across plaintiffs, but it is always

14. For example, in 1992, California added a year to the statute of limitations for (civil) suits claiming sexual abuse of children; this added a number of cases in the Los Angeles, as well as other, dioceses. Recently, Connecticut and Maryland have substantially extended the civil statute of limitations, including making the new limitations retroactive.

15. Recent settlements in Los Angeles have averaged over one million dollars, as compared with those in earlier cases in Boston, which were in the tens of thousands of dollars; for a description of the cases involving the Boston Archdiocese, see Investigative Staff of the *Boston Globe* (2002). These are primarily individual suits, though some have been consolidated for settlement purposes.

viewed as being common knowledge to the plaintiff (P) and the defendant (D) at the time of any settlement negotiations. P's litigation costs consist of the trial cost, denoted as c_P, and a filing fee, denoted as $K \in [0, \infty)$ (which we suppress until it is needed).[16] Again, at some points of the analysis we will allow K to vary across plaintiffs. If the case goes to trial, D will also incur a trial cost, denoted as c_D. We assume that c_P and c_D are positive and common across all cases; let $C \equiv c_P + c_D$. Finally, let α denote the fraction of the population that is harmed, where α is distributed according to a differentiable distribution $F(\bullet)$ with density $f(\bullet)$. We further assume that $f(\bullet)$ is positive and continuous everywhere on [0, 1], and we denote the mean by μ_F.

Each victim individually contemplates filing and pursuing a suit. In the case of PBLD, the likelihood that D will be found liable depends on the fraction of the exposed population that has been harmed, that is, on α. In what follows we assume that this fraction represents the probability that D is found liable. This is a simplification, since one might expect that even moderate values of α might readily map to a very high likelihood of being found liable. In the Appendix we show that (essentially) identical results to those shown in this section and in Sections 4 and 5 would hold in an analysis wherein liability was modeled as any differentiable, strictly increasing function of α.[17] Since it is common knowledge between P and D that D's likelihood of being found liable (if the fraction of the population harmed is α) is given by α, their common prior distribution over D's likelihood of being found liable is $F(\alpha)$ under PBLD.

In the case of IBLD, individual-based evidence is used to determine liability; let $\lambda \in [0, 1]$ be the likelihood of a defendant D being found liable at trial. To maintain as much comparability as possible between IBLD and PBLD, we assume that it is common knowledge for P and D that the possible values of λ also follow the distribution $F(\bullet)$. Since (by hypothesis) α is not relevant to liability determination under IBLD, α and λ are assumed to be independent random variables.

Given these common priors for P and D, we now consider how the parties develop *interim* distributions regarding D's liability based on their respective experiences. First, for the case of IBLD, we assume that Nature draws a likelihood of liability λ according to the distribution F and reveals it to D, but not to P, who learns only that she has been harmed. For example, in the *Shoshone* case discussed in Section 2, λ might reflect the bottling plant's sanitation and rodent/infestation control policies. Under IBLD, D's *interim* distribution is a spike at the true value of λ, whereas P's *interim* distribution is the same as the prior $F(\bullet)$, since P's experience of being harmed provides no further information about λ.

16. We view K as including not only the simple act of filing some articles, but also the disutility of pursuing a case. In cases such as the lawsuits over child abuse by priests, K is likely to include a large disutility element for some potential plaintiffs. Thus, K need not be a trivial cost.

17. We provide more detail on this issue in Section 6. However, introducing such a generalization at this point would complicate the exposition without adding any insight.

For the case of PBLD, we again assume that Nature draws a likelihood of liability α according to the distribution F and reveals it to D. For example, in the case of pharmaceuticals, there are likely to be animal studies and some (relatively small) human studies as required by the FDA, which generate the prior F. However, marketing the drug to the general public constitutes a large-scale study, in which α is realized. At this point, Nature reveals to the firm the actual value of α (e.g., the firm receives complaints or reports of adverse side effects back from the field), so D's *interim* distribution is a spike at the true value of α. At the same time, an individual user only learns whether she has been harmed, not the fraction of all users who have been harmed.

However, a plaintiff who does not observe α directly can use the fact that she herself was harmed to update her beliefs about the distribution of α (as was illustrated in Section 1). To see this, suppose that there is a population of mass N of users of a product and that a fraction α of the population is harmed. Since each user is equally likely to be among those harmed, the conditional probability of a particular user being harmed (given that αN are harmed) is $\alpha N/N = \alpha$. The probability (density) that αN users are harmed is given by $f(\alpha)$. Thus, the unconditional probability (density) of both a particular user being harmed and αN users being harmed is given by $\alpha f(\alpha)$. Finally, the unconditional probability that a particular user will be harmed is given by $\int_0^1 tf(t)\mathrm{d}t$; this is simply the mean of the prior distribution, μ_F.

Combining these expressions using Bayes' rule, a particular user who is harmed has an *interim* density over α given by $g(\alpha) \equiv \alpha f(\alpha)/\int_0^1 tf(t)\mathrm{d}t = \alpha f(\alpha)/\mu_F$. Let $G(\alpha)$ be the corresponding distribution, and let μ_G denote the expected value of α using the distribution G. Notice that, whereas P and D share a common prior F, at the *interim* stage their distributions are different; P's *interim* distribution is G, whereas D's is a mass point at the true value of α. Moreover, D knows (i.e., D can compute) the distribution that P will use to calculate her *interim* expected payoff. As stated below in Proposition 1, the distribution G first-order stochastic dominates (FOSDs) the distribution F, meaning that $G(\alpha) \leq F(\alpha)$ for all α, with strict inequality for at least some subinterval of α values.

Proposition 1. Distribution G first-order stochastic dominates F; thus, $\mu_G > \mu_F$.

This mathematical characterization, that G FOSD F, is the same as the earlier intuitive characterization: the *interim* distribution places higher weight on the higher values of the random variable (namely, the fraction of the exposed population harmed) than does the prior distribution. For example, using the uniform distribution, $f(\alpha) = 1$ for $\alpha \in [0, 1]$, so $F(\alpha) = \alpha$ and $\mu_F = 1/2$. Therefore, $g(\alpha) = \alpha \times 1/(½) = 2\alpha$, $G(\alpha) = \alpha^2$ and $\mu_G = 2/3$. Note that $G(0) = F(0) = 0$, $G(1) = F(1) = 1$, and $G(\alpha) < F(\alpha)$ for $0 < \alpha < 1$; this is illustrated in Figure 1 below, where Figure 1(a) illustrates the density functions $f(\alpha)$ and $g(\alpha)$, whereas Figure 1(b) illustrates the distributions $F(\alpha)$ and $G(\alpha)$.

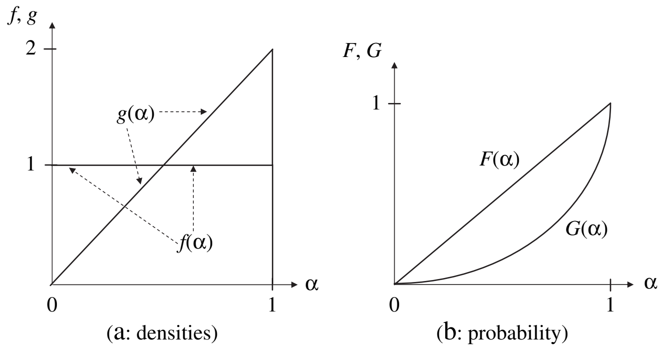

Figure 1. Comparison of Prior (*f*, *F*) and Posterior (*g*, *G*) Functions.

These preliminary results allow us to illustrate two effects of PBLD. We will first assume that damages are the same, and litigation and filing are costless, for all plaintiffs in order to isolate the effect of PBLD on *D*'s *ex ante* expected costs when all suits are filed and litigated. We will then assume that litigation costs are zero but filing costs are positive (and may vary, along with δ, across plaintiffs), in order to isolate the effect of PBLD on *P*'s incentive to file suit. In Section 4, we will consider the more plausible case of positive litigation costs in order to examine the effect of PBLD on settlement negotiations.

When δ is the common amount of harm and damages, and when litigation and filing costs are zero, all cases will be filed and tried. *D*'s *ex ante* expected costs under IBLD are given by $N\mathrm{E}(\alpha\lambda)\delta = N\mathrm{E}(\alpha)\mathrm{E}(\lambda)\delta = N(\mu_F)^2\delta$, since α and λ are independent. On the other hand, under PBLD the fraction of the population harmed is perfectly correlated with the likelihood of liability,[18] so *D*'s *ex ante* expected costs under PBLD are given by $N\mathrm{E}(\alpha^2)\delta$. Since $\mathrm{E}(\alpha^2) - (\mu_F)^2 = \mathrm{var}(\alpha) > 0$, *D*'s *ex ante* expected costs are higher under PBLD than under IBLD.

Now suppose that litigation costs are still zero (so that all cases filed go to trial), but a particular plaintiff *P*, suing for damages δ, must pay an amount $K > 0$ to file suit. *P*'s *interim* expected payoff from filing suit under IBLD is simply $\mu_F\delta - K$; the corresponding expression under PBLD is $\mu_G\delta - K$. Since $\mu_G > \mu_F$, *P*'s *interim* expected payoff from filing suit is higher under PBLD than under IBLD for any given values of δ and K. Thus, *P* will be willing to file suit for lower values of δ and/or higher values of K under PBLD than under IBLD. This translates into higher *interim* expected costs for *D* under PBLD.

4. IBLD versus PBLD in Suit, Settlement, and Trial

In this section, we make the more plausible assumption that both filing and litigation costs are positive and that the parties can engage in settlement

18. We thank an anonymous referee for pointing out this effect of PBLD.

negotiations. The IBLD version of the model in this section is based on Bebchuk's (1984) screening model of settlement bargaining,[19] modifying it to allow for filing decisions. Recall that Nature draws a likelihood of liability λ according to the distribution F, and reveals it to D, but not to P, who learns only that she has been harmed. Thus, D is the informed party, and P is the uninformed party in the screening game.

P has two decisions to make: (1) whether to file suit and (2) what settlement demand to make. For simplicity, we assume that P is committed to going to trial if her demand is rejected.[20] Recall that, at the time of settlement negotiations, P's damages δ and the trial costs c_P and c_D are common knowledge to P and D. However, D has private information about the likelihood that he will be found liable (that is, λ under IBLD and α under PBLD).

First, consider P's choice of settlement demand under IBLD; let S_F be the demand that P makes of D. D's expected cost (if his type is λ) if the case goes to trial is $\lambda\delta + c_D$, so if $S_F \leq \lambda\delta + c_D$ then D can do no better at trial and he therefore accepts the demand (we will assume that he accepts the demand if indifferent but this assignment is immaterial). In this case, S_F is transferred from D to P and P does not pay the cost c_P. If, however, $S_F > \lambda\delta + c_D$, then D rejects the demand and the case proceeds to trial, where P and D will each pay their respective trial costs.

Not knowing λ before trial, P chooses a demand to maximize her *interim* expected payoff, which includes both the *interim* expected payoff from trial and the *interim* expected settlement payment. Making a demand of S_F is equivalent to inducing a marginal type $\lambda = (S_F - c_D)/\delta$ who is just indifferent between trial and settlement. If D's actual type t is less than this value, then trial occurs and P receives $(t\delta - c_P)$. On the other hand, if D's actual type t equals or exceeds the marginal type, then D will accept the demand $S_F = \lambda\delta + c_D$; this occurs with probability $1 - F(\lambda)$. Let $Z(\lambda; F)$ be P's payoff if the marginal D type is λ and the distribution of the likelihood of liability is F. Thus,

$$Z(\lambda; F) \equiv \int_0^{\lambda} (t\delta - c_P) f(t) \mathrm{d}t + (\lambda\delta + c_D)(1 - F(\lambda)). \tag{1}$$

The decision problem for P is therefore to find a marginal type, λ^*, that maximizes $Z(\lambda; F)$; the corresponding optimal demand is $S_F^* = \lambda^*\delta + c_D$.

19. Surveys that discuss this model and some of the extensions include Hay and Spier (1998), Daughety (2000), Daughety and Reinganum (2005), and Spier (2007).

20. Nalebuff (1987) examines the case in which P would not want to proceed to trial against some D types. He shows that P will make an even higher demand in order to ensure that she will have a credible commitment to trial following rejection. Thus, at the *interim* stage, P is better off if she is committed to trial following rejection. This commitment can be achieved via a contract with P's attorney, which allocates the choice of the settlement demand and the decision to proceed to trial to P and the filing and litigation costs to the attorney. Assuming that P must pay the attorney a share of the award or settlement that covers the filing fee plus the expected costs of trial, then P will choose the settlement demand to maximize the *interim* expected value of the suit, and the suit will be filed whenever its *interim* expected value is nonnegative. See the Appendix for details.

Assuming an interior solution to this optimization problem, the first-order condition for maximizing $Z(\lambda; F)$, evaluated at λ^*, can be written as follows:

$$f(\lambda^*)/(1 - F(\lambda^*)) = \delta/C. \tag{2}$$

The left-hand-side is the "hazard function" for the distribution F, which is $f(\lambda)/(1 - F(\lambda))$, evaluated at λ^*, while the right-hand-side is the level of P's damages divided by the sum of the court costs.

In order to ensure that there is a unique interior solution λ^*, we make two assumptions.

Assumption 1. $f(\lambda)/(1 - F(\lambda))$ is strictly increasing in λ.

Assumption 2. $f(0) < \delta/C$.

The effect of enforcing these two assumptions is illustrated in Figure 2 below. Assumption 1 is a standard assumption used in screening models and is a property of a variety of possible F distributions.[21] Note that $f(0)/(1 - F(0))$ is simply $f(0)$, while $f(\lambda)/(1 - F(\lambda))$ becomes arbitrarily large as λ goes to 1 (since $F(1) = 1$), so Assumption 2 is needed to guarantee an interior optimum. We formalize these observations in the following proposition.

Proposition 2. Under Assumptions 1 and 2, there exists a unique $\lambda^* \in (0, 1)$ that maximizes $Z(\lambda; F)$. This solution satisfies $f(\lambda^*)/(1 - F(\lambda^*)) = \delta/C$.

Thus, the equilibrium demand is $S_F^* = \lambda^*\delta + c_D$, and the interim payoff for P (now accounting for the filing cost) is $Z(\lambda^*; F) - K$; if this is nonnegative, then a suit will be filed, the demand S_F^* will be made, and a trial will occur with probability $F(\lambda^*)$. Finally, if D is of type t then his payoff is $t\delta + c_D$ if $t < \lambda^*$ and $\lambda^*\delta + c_D$ if $t \geq \lambda^*$.

Note that if Assumption 2 does not hold, then $f(0)$ is at or above δ/C, meaning that the optimal decision for P is to make a demand that pools all the types of D. Since the optimal value of λ is therefore $\lambda^* = 0$, the pooling offer is $S_F^* = c_D$ and all defendant types settle at this demand (this will also be the defendant's payoff). More precisely, as long as $c_D - K$ is nonnegative, a suit will be filed, S_F^* will be D's court costs, c_D, and there will no trials in equilibrium.

We now turn to the case in which the likelihood that D will be found liable depends on the fraction α of the exposed population that has been harmed.[22] A moment's reflection on the material involving IBLD makes it clear that under

21. See Bagnoli and Bergstrom (2005) for an extensive discussion of conditions that guarantee that a hazard function is strictly increasing in its argument, as well as a detailed review of when the property holds for a variety of well-known distributions.

22. As mentioned earlier, there can be multiple possible sources of cause for a harm. For example, there might be a natural rate of contracting a type of cancer. In the Appendix, we provide a model which accounts for this background effect and show its impact on $g(\alpha)$.

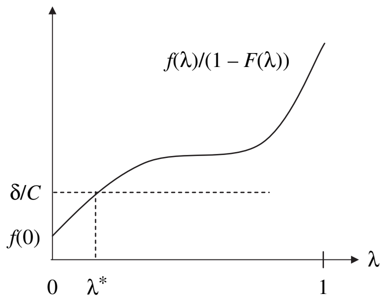

Figure 2. Using the IBLD Hazard Function to Find the Optimal Marginal Type.

PBLD the *interim* expected payoff to P, if the marginal type of D who is just indifferent between trial and settlement is α and the distribution of the likelihood of liability is G, is given by $\int_0^{\alpha}(t\delta - c_P)g(t)\mathrm{d}t + (\alpha\delta + c_D)(1 - G(\alpha))$. That is, the *interim* payoff to P in the PBLD model has the same form as that in the IBLD model, except for the judicious replacement of symbols as shown in equation (3) below:

$$Z(\alpha; G) \equiv \int_0^{\alpha}(t\delta - c_P)g(t)\mathrm{d}t + (\alpha\delta + c_D)(1 - G(\alpha)). \tag{3}$$

The first-order condition for this problem is parallel to the earlier one specified in equation (2); the following proposition formalizes this.

Proposition 3. There exists at least one value $\alpha^* \in (0, 1)$ that maximizes $Z(\alpha; G)$. This solution satisfies $g(\alpha^*)/(1 - G(\alpha^*)) = \delta/C$.

There are two qualitative differences between Proposition 1 and Proposition 3 that are worthy of comment. First, Proposition 3 does not assume that the hazard function $g(\alpha)/(1 - G(\alpha))$ is strictly increasing; this is not needed (nor can it generally be assured). In fact, the hazard function $g(\bullet)/(1 - G(\bullet))$ need not be strictly increasing even if $f(\bullet)/(1 - F(\bullet))$ is strictly increasing.[23] However, $g(\bullet)/(1 - G(\bullet))$ starts at zero (since $g(0) = 0\times f(0)/\mu_F = 0$ and $G(0) = 0$), and eventually is asymptotic to the vertical line at $\alpha = 1$ (since $g(1) > 0$ and $G(1) = 1$). This means it must cross (from below) the horizontal line at δ/C at least once. Further, $g(0) = 0 < \delta/C$, so we know that all optima are interior.

Second, Proposition 3 does not claim that there is a unique solution to the first-order condition for maximizing $Z(\alpha; G)$; the potential lack of monotonicity of $g(\bullet)/(1 - G(\bullet))$ means that there might be multiple optima, some local minima and some local maxima (this is illustrated in Figure 3 below).

23. If $F(\alpha)$ is the uniform distribution, it is straightforward to show that $g(\alpha)/(1 - G(\alpha))$ is monotonic and thus there is a unique optimum.

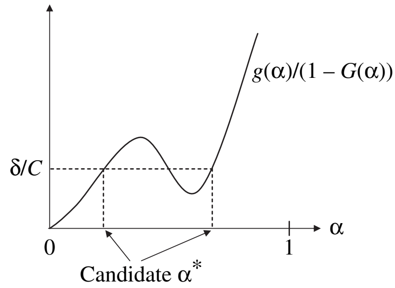

Figure 3. Using the PBLD Hazard Function to Find the Optimal Marginal Type.

Henceforth, we will use α^* to denote the value of α that provides the global maximum of $Z(\alpha; G)$; in the unlikely event that there are multiple such values, we will take α^* to be the minimum value of α that provides the global maximum of $Z(\alpha; G)$. Thus, the demand made of D is $S_G^* = \alpha^*\delta + c_D$ and the *interim* equilibrium payoff for P is $Z(\alpha^*; G)$; accounting for filing costs, a case will be brought as long as $Z(\alpha^*; G) - K$ is nonnegative.

5. Comparing the Results from the Two Alternative Models

The proofs of the propositions below, which detail the comparisons of the results of the two models, are in the Appendix. In what follows we provide an intuitive discussion of the results.

5.1 Comparing the IBLD and PBLD Optima

Fortunately, the potential lack of monotonicity of $g(\bullet)/(1 - G(\bullet))$ is not really a problem, as shown by the following two propositions and as illustrated in Figure 4 below.

Proposition 4. The hazard function associated with G always lies below that associated with F; that is, $g(\alpha)/(1 - G(\alpha)) < f(\alpha)/(1 - F(\alpha))$ for all $\alpha \in [0, 1)$.

This ordering of the hazard functions is illustrated in Figure 4. This has the immediate implication that P's optimal marginal type in the PBLD model, α^*, is always greater than her optimal marginal type in the IBLD model, λ^*. This further implies that the PBLD demand is always greater than that made in the IBLD model, as stated in the following proposition.

Proposition 5. The settlement demand is higher, and more D-types go to trial, under PBLD than under IBLD; that is, $\alpha^* > \lambda^*$ and, consequently, $S_G^* = \alpha^*\delta + c_D > S_F^* = \lambda^*\delta + c_D$.

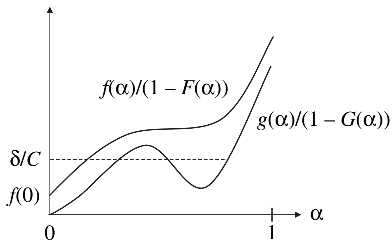

Figure 4. Comparison of Hazard Functions.

5.2 Comparing Payoffs and Filing Decisions

We can further exploit the result in Proposition 1 (that G first-order stochastic dominates F) to obtain the following ranking of P's *interim* equilibrium payoffs.

Proposition 6. $Z(\alpha^*;\ G) > Z(\lambda^*;\ F)$; that is, P's *interim* equilibrium expected payoff is higher in the PBLD model than in the IBLD model.

To characterize the filing decision, we indicate P's *interim* equilibrium payoff's dependence on the level of damages, δ, and incorporate the filing cost, K. For the IBLD model, a plaintiff with damages δ and filing cost K will file suit whenever $Z(\lambda^*;\ F,\ \delta) - K \geq 0$. On the other hand, for the PBLD model, such a plaintiff will file suit whenever $Z(\alpha^*;\ G,\ \delta) - K \geq 0$. For a given filing cost K, the set of plaintiff damages levels that will result in suit is $[\delta_F,\ \infty)$ for the IBLD model and $[\delta_G,\ \infty)$ for the PBLD model. Alternatively, for a given value of δ, the set of plaintiff filing cost levels that will result in suit in the IBLD model is $[0,\ K_F]$, where $K_F \equiv Z(\lambda^*;\ F,\ \delta)$; the analogous set in the PBLD model is $[0,\ K_G]$, where $K_G \equiv Z(\alpha^*;\ G,\ \delta)$. Summarizing, δ_G and δ_F are damages cut-offs for a given filing cost K, whereas K_G and K_F are filing cost cut-offs for a given damages level δ; the comparisons are provided in Proposition 7.

Proposition 7. The propensity to file suit will be higher if liability determination is population based than if it is individual based. Formally, for a given filing cost K, it follows that $\delta_F > \delta_G$ when $\delta_F > \underline{\delta}$ (and otherwise $\delta_G = \delta_F$); alternatively, for a given level of damages $\delta \geq \underline{\delta}$, it follows that $K_G > K_F$.

5.3 Defendant's Interim Expected Costs

Proposition 5 implies that, in the case of suits that would be filed under either regime, defendants in such suits will face costs under PBLD that are no less than, and for some types greater than, those under IBLD. Moreover, the implication of Proposition 7 is that for plaintiffs that would *fail to file* under IBLD, but *would* file under PBLD, these suits would further add to the expected costs for all types of defendant. We provide a summary of the foregoing payoff effects for the defendant in the following proposition.

Proposition 8. The defendant is worse off at the *interim* stage in the PBLD model than in the corresponding IBLD model. In particular, conditional on a suit being filed, the defendant of type t pays at least as much (and, for some values of t, strictly more) in the PBLD model than in the IBLD model. Moreover, more suits are filed in the PBLD model than in the IBLD model.

This proposition deals with D's costs at the *interim* stage; as noted previously, the fact that PBLD induces correlation between the number of victims and the likelihood of liability further increases D's *ex ante* expected liability costs (see the Appendix for a proof of this remark when $K = 0$ and δ is the same for all plaintiffs).

5.4 Likelihood of Trial and Social Efficiency Considerations and Comparisons

For a given suit, the equilibrium likelihood of trial in the IBLD regime is simply $F(\lambda^*)$. The equilibrium likelihood of trial is a more complex concept in the PBLD regime, because it depends on the point in time at which it is measured (i.e., *ex ante* or *interim*) and from whose point of view it is measured. Since we know from Proposition 5 that $\alpha^* > \lambda^*$, it is clear that the set of defendant types who reject the settlement demand in favor of trial is larger in the PBLD regime than in the IBLD regime.

It is interesting to note, however, that in the *interim* stage P does not necessarily expect that her more aggressive demand is more likely to be rejected. That is, she does not necessarily expect a higher *interim* equilibrium probability of trial under PBLD. From P's perspective, the *interim* equilibrium likelihood of trial in the IBLD model is $F(\lambda^*)$ whereas the *interim* equilibrium likelihood of trial in the PBLD model is $G(\alpha^*)$. The two first-order conditions tell us that:

$$g(\alpha^*)/(1 - G(\alpha^*)) = \delta/C = f(\lambda^*)/(1 - F(\lambda^*). \tag{4}$$

Thus, for any given case that is filed under either regime, P expects that the *interim* likelihood of a trial under the PBLD regime is less than the likelihood of a trial under the IBLD regime (i.e., $G(\alpha^*) < F(\lambda^*)$) if and only if $f(\lambda^*) < g(\alpha^*)$. Since, by definition, $g(\alpha^*) = \alpha^* f(\alpha^*)/\mu_F$, the condition for a *lower interim* likelihood of trial under PBLD than under IBLD is:

$$f(\lambda^*)/f(\alpha^*) < \alpha^*/\mu_F. \tag{5}$$

For example, if F is the uniform distribution, then $f(\lambda^*) = f(\alpha^*) = 1$, so condition (5) says that P's perceived *interim* likelihood of trial in this setting is lower under PBLD than under IBLD if $\alpha^* = (1 + C^2/\delta^2)^{1/2} - C/\delta > 1/2$; that is, if $\delta > 4C/3$ (which simply requires damages to be sufficiently greater than aggregate court costs). More generally (since the density f is continuous on [0, 1]), in the limit as δ becomes arbitrarily large, the left-hand-side of condition (5) must go to 1 since λ^* and α^* both go to 1, and the right-hand-side must go to $1/\mu_F > 1$. Therefore, there is some finite level of damages beyond which (for fixed C) condition (5) must hold.

From an *ex ante* perspective (i.e., prior to the realization of λ or α or any harm), it is similarly ambiguous as to whether IBLD or PBLD yields the higher *ex ante* expected number of trials and hence, which has the higher *ex ante* expected litigation costs. This is easily seen for the case in which filing costs $K = 0$, so that all cases are filed, and δ is the same for all plaintiffs (and thus λ^* and α^* are the same for all plaintiffs). Let L^I and L^P represent the *ex ante* expected litigation costs under IBLD and PBLD, respectively. Then $L^I \equiv \int_0^1 N\alpha F(\lambda^*)Cf(\alpha)\mathrm{d}\alpha = N\mu_F F(\lambda^*)C$, whereas $L^P \equiv \int_0^{\alpha^*} N\alpha Cf(\alpha)\mathrm{d}\alpha = N\mu_F G(\alpha^*)C$. *Ex ante* expected litigation costs are lower under PBLD than under IBLD if and only if $L^P < L^I$; that is, if and only if $G(\alpha^*) < F(\lambda^*)$ or, equivalently, if and only if inequality (5) holds. Incorporating positive filing costs will work against PBLD emerging as the lower-litigation-cost alternative, since more cases are filed under PBLD than under IBLD. Of course, in most cases society cannot actually choose between IBLD and PBLD regimes. Where PBLD is used, it is because little or no direct evidence is available (because, e.g., the mechanism through which the product causes harm is poorly understood) and precluding the use of population-based evidence would eviscerate any incentives for D to take care (or to invest in science that might help illuminate the mechanism of harm) and would provide no remedy to plaintiffs, possibly leading them to withdraw from the use of such products.

6. Robustness Considerations

We now consider two modifications of the analysis above so as to show that our results are likely to hold for many conceivable bargaining scenarios and for a variety of ways of translating a population effect (such as heretofore represented by α) into the probability that D will be found liable. The first modification is to reverse the roles of who makes a take-it-or-leave-it offer to whom; below we analyze the signaling-game analog to the screening games in Section 4. No results are reversed, though some of the differences between IBLD and PBLD disappear; nevertheless, the *interim* expected payoff to P is still higher under PBLD than under IBLD. This means that the differences in incentives to file carry over to the signaling model, as does the direction of *ex ante* expected costs for D. Thus, to the degree that one imagines settlement bargaining to be better represented by, say, a random-proposer model (in an attempt to balance the opportunities to make a first move), the resulting effects will all go in the same direction as described in the propositions, though there may be some muting of these effects in the bargaining subgame.

The second modification below generalizes the model of PBLD we described in Section 3, relaxing the assumption that α represents both the fraction of users who are harmed and the probability of liability of the defendant. The second subsection below and the Appendix provide a modified screening analysis that shows that more sophisticated models of how α influences liability still have the same qualitative results indicated in our analysis of the PBLD regime and in the comparison with the results of the analysis of the IBLD regime.

6.1 Reversing the Timing in the Settlement Game: Signaling Instead of Screening

In the previous sections, we assume that the uninformed party (P) made a settlement demand of the informed party (D), resulting in a screening model. Alternatively, if the informed party D were to make a settlement offer to P, then the offer might reveal D's true type (λ or α), that is, there may be a separating equilibrium in a signaling game. We now describe such a separating equilibrium for the bargaining subgame and trace its implications for the overall game.[24]

We continue to assume that P has a credible threat to go to trial following failed negotiations (e.g., through a contingent-fee contract with an attorney; see the Appendix for details). There we show that, regardless of the liability regime, the D of type t offers $s^*(t) = t\delta$ for $t \in [0, 1]$ and P rejects the offer $s \in [0, \delta]$ with probability $r^*(s) = 1 - \exp\{-(\delta - s)/c_D\}$, resulting in an equilibrium probability of trial of $r^{**}(t) = r^*(s^*(t)) = 1 - \exp\{-(1-t)\delta/c_D\}$ against a D of type t. We also show that P's *interim* expected payoff is $V(F, K) = \mathrm{E}_F(t\delta - r^{**}(t)c_P) - K$ under IBLD and $V(G, K) = \mathrm{E}_G(t\delta - r^{**}(t)c_P) - K$ under PBLD. Since the function $t\delta - r^{**}(t)c_P$ is increasing in t, the fact that G FOSDs F implies that $V(G, K) > V(F, K)$; thus, more cases will be filed under PBLD than under IBLD.

6.2 The Likelihood of Liability as a Function of the Fraction of Users Harmed

In the PBLD model in Section 3, we assume that the probability that the defendant will be found liable is given by α, the fraction of users harmed. A more general model would allow liability, ℓ, to be a function L of α: $\ell \equiv L(\alpha)$. In the Appendix, we discuss generalizations that involve modeling this probability of liability as a differentiable and increasing function of α. To understand what type of models we have in mind, suppose that we use the square root of α as our representation of liability (instead of α). Then instead of, say, an observation that 25% of the users being harmed implies a 0.25 probability of D being found liable, now the observation that 25% of the users are harmed implies a 0.5 probability of D being found liable, since $0.5 = (0.25)^{1/2}$.

Figure 5 illustrates two examples of possible liability functions; in each panel the liability function used in Sections 4 and 5 above is shown as the dashed line, whereas the solid line shows a nonlinear example. For example, Figure 5(a) illustrates $L(\alpha)$ for a case such as the square root of α representation just discussed. On the other hand, Figure 5(b) illustrates $L(\alpha)$ as a "soft" threshold function. Such a function might arise from a building consensus about a level of relative risk that supports a finding of general causation.[25]

24. We present only a summary of the analysis here and in the Appendix; for details on how to solve such a model, see Reinganum and Wilde (1986).

25. See Green (2000); as discussed therein, a relative risk of 2 suggests that the source under scrutiny at least doubles the risk of harm. This is viewed by some as indicating a meeting of a preponderance-of-the-evidence standard. Thus, if β is the background risk and a relative risk of (approximately) 2 is required, then since α is the harm rate due to the product, $L(\alpha)$ should be sharply increasing in the neighborhood of $\alpha = \beta$. This produces the "soft" threshold model displayed; see Calfee and Craswell (1984) for a discussion of how Figure 5(b) could represent fault.

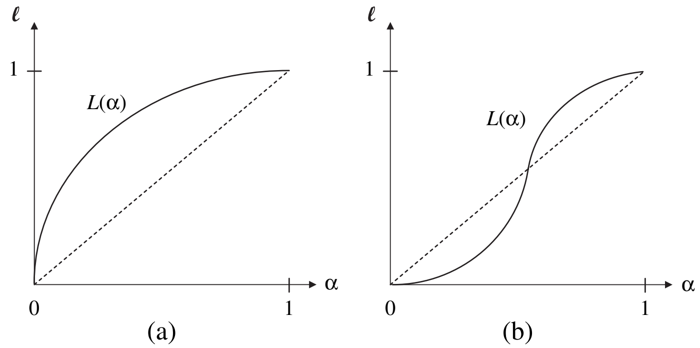

Figure 5. Two Examples of $L(\alpha)$.

The purpose of the material in the Appendix is to show that employing any differentiable, strictly increasing function $L(\alpha)$ makes no real change in the *interim* analysis since versions of the affected propositions still hold, albeit with quantitative adjustments made to the *interim* distribution of ℓ reflecting any specific function $L(\alpha)$.

7. Summary, Some Broader Implications, and Possible Extensions

7.1 Summary

Modern real-world cases are likely to involve a mix of individual-based and population-based aspects in overall liability determination; many mass tort cases are likely to involve PBLD elements. In this article, we have modeled liability as being wholly of one form or the other, so as to understand the incentives that each produces. Holding all else constant, in contrast with IBLD, PBLD creates increased incentives for the plaintiff to bring a case by increasing her *interim* expected payoff and results in an increased settlement demand made of the defendant.[26] Based on the prior distribution of actual harms, $F(\bullet)$, it might appear to an outsider that in certain types of cases plaintiffs are overly litigious, since they may file suit more often and make higher settlement demands than would be predicted based on $F(\bullet)$.[27] This might be interpreted as plaintiffs having an optimism bias. However, if population-based evidence will be used to establish liability, then it is completely rational for the plaintiff to use the (upward-revised) *interim* distribution $G(\bullet)$ in her decision making.

26. While some of the differences between the IBLD and PBLD results derived under a screening analysis disappeared when the problem was re-cast as a signaling model, no results were reversed and the essential predictions concerning how PBLD increases the stakes for all parties remained. Therefore, any random proposer model would inherit these same qualitative features.

27. An "outsider" might be someone who was never exposed to the source of harm. The appearance of litigiousness would be even stronger if the outsider was exposed but not harmed, since this person would have a downward-revised *interim* distribution over α; see footnote 9.

Our model assumes that victims are homogeneous in their propensity to be harmed; this facilitates the comparison between IBLD and PBLD. One could augment the model to consider victims who are heterogeneous in their propensity to be harmed; the *interim* distributions of victims with a higher propensity to be harmed (e.g., those with a pre-existing condition that might interact with the product) will exhibit a weaker version of rational optimism. Similarly, if victims are heterogeneous in the extent to which something else might have caused their harm, then victims with more alternative potential causes will exhibit a weaker version of rational optimism.

Thus, the overall picture that emerges is one wherein settlement negotiation in cases that have both IBLD and PBLD elements (e.g., IBLD causation but PBLD fault, or vice versa) will inherit properties from the mixing of the two models. As such, this article is also a contribution to the literature on settlement with externalities that has developed, with previous applications to the formation of class actions, analyses of joint and several liability, insolvency, confidential settlement, and the use of most-favored nations clauses in settlement agreements.[28] Here PBLD induces an added effect because there is settlement negotiation "in the shadow of other related harms."

7.2 Some Broader Implications

Our overall results lead to some broader implications, which we now consider. We have assumed that the costs of trial are fixed. Although one effect of the PBLD-induced increased aggression on the plaintiff's part is to increase *D*'s *ex ante* incentives for care, another effect is to increase incentives to spend resources on trials.[29] The use of PBLD in settings involving epidemiological modeling of general causation is a good example of this effect, as considerable resources appear to be spent on producing, and attacking, expert witnesses. Such an increase in the costs of trial will feed back to moderate the incentive to file suit. Along the same line is the incentive for the potential defendant to suppress information that might be of use to a plaintiff; this appeared to be the case in *Manko* discussed earlier, and has been asserted in a number of other controversial cases. To the degree that effective discovery processes can document this (or, as in *Manko*, that a court will formally recognize such behavior and adjust for it), this may or may not create a long-run inefficiency. However, as we have discussed elsewhere (Daughety and Reinganum 1999, 2002), confidentiality agreements can be effective in suppressing cases and one might expect to see this strategy employed more frequently in some PBLD cases.

Since the reliance on PBLD in the context of cause reflects science that is incomplete (in the sense of understanding and documenting cause-and-effect relationships), one way for a potential defendant to reduce future possible

28. See Daughety and Reinganum (2005) and Spier (2007), for surveys of this developing literature.

29. For a model wherein evidence costs are endogenously determined, see Daughety and Reinganum (2000b).

litigation costs is to invest in improving the science of causation associated with the product. This has two effects: it should lead to better-designed products (producing a leftward shift of F, and therefore of G) since firms may learn how to obtain the benefits with a lower likelihood of harm, and it might result in a shift of liability determination from PBLD toward IBLD, thereby shifting a potential plaintiff's analysis toward use of F rather than G.

Finally, we would note that PBLD enhances the incentives for bringing some valid cases that would fail to be brought under IBLD. This figures not only into cases involving issues of complex causation but also into issues of fault; the settlements involving the Catholic Church in cases of child abuse by priests are an example here. As previously noted, filing costs can include a disutility component, which was undoubtedly significant for some of those victims and might have deterred some valid cases. In these circumstances, PBLD is likely to generate a distinct social benefit.

On the other hand, if PBLD would result in over-deterrence, then there are policies that might be adopted by government agencies and/or the courts that would have the effect of moderating rational optimism.[30] In particular, since rational optimism arises from individual plaintiffs attempting to estimate the harm rate, this process could be short circuited (by the time of settlement negotiation, if not by the time of filing) through the public release of definitive information about the harm rate. The defendant might provide such information, but there is no reason for plaintiffs to take such disclosures at face value (i.e., to treat them as definitive). It is conceivable that a government agency might be able to enhance the credibility of disclosure by requiring that firms collect and make public information about users' experiences (with high penalties for failure to do so truthfully). This seems to be the spirit of the FDA's Phase IV drug trials program, which may require a pharmaceutical company to conduct postmarketing studies of safety and/or effectiveness, but apparently such studies are not broadly required and penalties for failure to conduct the study and report the results are weak to nonexistent (Schanz 2007).

Since victims are likely to learn of their harm (and file suit) during the same time period as information about the extent of harm is being collected and disclosed, it seems that public information release is likely to be most feasible and effective during the settlement negotiation phase. However, if the government were able to collect and disseminate information about the fraction of users harmed in advance of plaintiffs' filing suit, then this would blunt the rational optimism that arises when plaintiffs try to estimate this fraction, and thus reduce the number of suits filed. This is in contrast to the finding of Che and Earnhart (1997), who provide a model in which a plaintiff is uncertain about whether her harm was accidental or caused by the defendant. In addition to the plaintiff's private signal, there is regulatory information (e.g., data collected by a government agency) that could be brought to bear on the issue, either before or after the plaintiff files suit. They show that relying on

30. We thank an anonymous referee for encouraging us to explore these issues.

and providing this information prior to filing can induce some plaintiffs to sue when they otherwise would not.

An alternative to the release of information by a government agency would be court certification of a class action early in the process. Arguably, this would allow the vast majority of cases to be identified and collected (see the discussion of *Schwab v. Philip Morris* below). Since this is also likely to lower litigation costs for plaintiffs, it still seems likely to result in more cases being filed, but settlement negotiations would occur under more symmetric information conditions, leading to a lower likelihood of trial. We discuss the issue of class actions in more detail below.

7.3 Possible Extensions: PBLD and the Incentives to Form a Class

We have focused on the underlying incentives for suit and settlement that arise simply because part or all of the liability determination process depends on population-based information. This creates a rational basis for an individual victim to update her assessment of the defendant's likelihood of being found liable in a way that encourages a form of aggressiveness reflected in higher settlement demands and an increased incentive to file suit. One could imagine a dynamic extension of the basic model in which a victim updates on the fact that others have also filed suit. Under PBLD, this potentially further enhances the value of her suit, and it also has the potential to encourage class formation (so as to improve the statistical analysis that would be used in showing general causation or to distill pattern-of-behavior similarities in asserting and proving fault).

Notice that such a dynamic process could generate a "bank run" phenomenon (here on a defendant corporation rather than a bank) if individual claimants (upon observing the rising tide of lawsuits) fear that the defendant's solvency might be at risk, thereby initiating a race in an attempt to establish the priority of their claims (or a least a viable stake in being part of an early settlement).

Thus, a further spinoff would be to understand the conditions under which it is socially beneficial to allow class actions, whether the drivers are cost efficiencies so that individual meritorious, but negative-expected value, suits could be aggregated and adjudicated, or whether the only way to acquire the information needed is through using the aggregate class characteristics to distill the likelihood of the defendant's actions being the important source of the harm the plaintiffs have borne. As an illustration of this latter point, consider a recent lawsuit against the tobacco industry charging that the marketing of "light" cigarettes was a fraud, as smokers who bought the cigarettes were told via advertising that such cigarettes were safer than regular cigarettes, when (it is alleged) they were not and the tobacco companies knew this. This suit was certified by a 2nd Circuit District Court as a class (*Schwab v. Philip Morris*, 449 F. Supp. 2d 992 [ED NY, 2006]), partly in order to ascertain the fraction of such smokers who would not have purchased light cigarettes at the prevailing price but for the defendants' (allegedly) fraudulent claims. Such information would then contribute to a jury's assessment of the industry's liability. In

Schwab (at 1022), Judge Weinstein indicates this as one of the reasons for certifying the class:

> In the American legal system, whose watchword has been, as already noted, 'no right without a remedy,' the answer is that modern civil procedure, scientific analysis, and the law of large numbers used by statisticians provide a legal basis for a practical and effective remedy. The plaintiffs are entitled to the chance to prove their allegations.

Upon appeal to the 2nd Circuit, the class was decertified on the basis that individual issues of reliance, injury, and damages predominated, thereby requiring that a class action does not proceed on a PBLD basis, but allowing individual cases to potentially proceed on an IBLD basis.[31] However, it is still to be seen whether PBLD evidence in this case (such as concerning cause or fault) will appear in any such individual cases.

Our fundamental point remains that it is the nature of the harms incurred, and the relevant available means for demonstrating cause and/or fault (such as direct tracing in some cases, but statistical analysis of causality and risk in others), that shifts liability determination between the two basic schemes of IBLD and PBLD. Then the incentives engendered may (in either case) lead to individual actions or class actions.

Appendix

Proof of Proposition 1. By definition (Mas-Collel, Whinston, and Green 1995: 195), $G(\bullet)$ FOSD $F(\bullet)$ if and only if $G(\alpha) \leq F(\alpha)$ for all $\alpha \in [0, 1]$ (with $G(\alpha) < F(\alpha)$ on a set of positive measure). Applying integration by parts to $G(\alpha) = \int_0^{\alpha} tf(t)\mathrm{d}t/\mu_F$ yields $G(\alpha) = (1/\mu_F)[\alpha F(\alpha) - \int_0^{\alpha} F(t)\mathrm{d}t]$. Then $G(\alpha) \leq F(\alpha)$ if and only if $(1/\mu_F)[\alpha F(\alpha) - \int_0^{\alpha} F(t)\mathrm{d}t] \leq F(\alpha)$; that is, if and only if $\Delta(\alpha) \equiv (\alpha - \mu_F)F(\alpha) - \int_0^{\alpha} F(t)\mathrm{d}t \leq 0$. It is clear that $\Delta(\alpha) < 0$ for all $\alpha \leq \mu_F$. For $\alpha > \mu_F$, the function $\Delta(\alpha)$ is increasing since $\Delta'(\alpha) = (\alpha - \mu_F)f(\alpha)$. Moreover, $\Delta(1) = 1 - \mu_F - \int_0^1 F(t)\mathrm{d}t = 0$. Therefore, $G(\alpha) < F(\alpha)$ for all $\alpha \in (0, 1)$, whereas $G(0) = F(0)$ and $G(1) = F(1)$, and thus $G(\bullet)$ FOSD $F(\bullet)$. To see that this implies $\mu_G > \mu_F$, simply note that $\mu_G - \mu_F = 1 - \int_0^1 G(t)\mathrm{d}t - [1 - \int_0^1 F(t)\mathrm{d}t] = \int_0^1 [F(t) - G(t)]\mathrm{d}t > 0$. QED.

P's Credible Commitment to Trial Following Rejection

It was claimed in footnote 20 that *P* could achieve a credible commitment to trial following rejection of her settlement demand by using a contingent-fee contract with her attorney that allocated the choice of settlement demand and the decision to proceed to trial to *P* and the filing and any litigation costs to the attorney. Moreover, it was claimed that such a contract would lead *P* to choose

31. *McLaughlin v. Philip Morris*, Docket No. 06-4666-cv, 2008 U.S. App. Lexis 7093 (2nd Cir.). "In sum, because we find that numerous issues in this case are not susceptible to generalized proof but would require a more individualized inquiry, we conclude that the predominance requirement of Rule 23 has not been satisfied." (at 39).

the settlement demand that maximizes the *interim* expected value of the suit and that suit would be filed whenever the *interim* expected value of the suit was positive. We will first prove these claims for the case of IBLD.

Suppose that P discusses with her attorney (PA) her intention to select λ as the marginal type for settlement purposes. Then (assuming a competitive market for attorneys) PA will require a share of the award or settlement, denoted $\sigma(\lambda)$, that solves the following break-even constraint: $\int_0^{\lambda}(\sigma t\delta - c_P)f(t)\mathrm{d}t + \sigma(\lambda\delta + c_D)(1 - F(\lambda)) - K = 0$. This leaves P with the payoff $(1 - \sigma(\lambda))[\int_0^{\lambda} t\delta f(t)\mathrm{d}t + (\lambda\delta + c_D)(1 - F(\lambda))]$. Substitution from the break-even constraint implies that P's payoff is equal to $Z(\lambda; F) - K = \int_0^{\lambda}(t\delta - c_P)f(t)\mathrm{d}t + (\lambda\delta + c_D)(1 - F(\lambda)) - K$, which is the *interim* expected value of the suit. Thus, P will choose the marginal type that maximizes $Z(\lambda; F)$, resulting in the contingent-fee share $\sigma(\lambda^*)$ for PA. As long as $Z(\lambda^*; F) - K > 0$, the share $\sigma(\lambda^*)$ will allow PA to break even and still yield a positive share of the award or settlement for P, and thus the case will be filed whenever $Z(\lambda^*; F) - K > 0$. If P's demand is rejected, P will choose to proceed to trial since she receives a fraction of any award while her attorney absorbs the litigation costs.

The argument for the PBLD case is completely analogous, once it is verified that PA will have the same *interim* distribution $g(\alpha)$. Suppose that there is population of attorneys of measure M. When a client who has been harmed arrives at PA's office (assume that the probability of more than one such client arriving is negligible), PA is interested in estimating α, since this will affect the likelihood of winning the case. If there are αN victims who randomly seek out attorneys, then the conditional probability that a victim walks into PA's office (given that αN are harmed) is $\alpha N/M$. The probability (density) that αN users are harmed is given by $f(\alpha)$. Thus, the unconditional probability (density) of a victim arriving at PA's office and αN users being harmed is given by $(\alpha N/M)f(\alpha)$. Finally, the unconditional probability that a victim arrives at PA's office is given by $\int_0^1(tN/M)f(t)\mathrm{d}t$. Combining these expressions using Bayes' rule, PA has an *interim* density over α that is given by $(\alpha N/M)f(\alpha)/\int_0^1(tN/M)f(t)\mathrm{d}t = \alpha f(\alpha)/\mu_F = g(\alpha)$.

Proof of Proposition 2. The derivative of the joint payoff is: $Z'(\lambda; F) = \delta(1 - F(\lambda)) - Cf(\lambda)$. Thus, $\mathrm{sgn}(Z'(\lambda; F)) = \mathrm{sgn}(\delta/C - f(\lambda)/(1 - F(\lambda)))$. Since $f(0) < \delta/C$, it follows that $Z'(0; F) > 0$; moreover, $\lim_{\lambda\to 1} Z'(\lambda; F) < 0$ since $f(\lambda)/(1 - F(\lambda))$ goes to infinity as λ goes to 1. Finally, the expression $\delta/C - f(\lambda)/(1 - F(\lambda))$ changes sign only once (since the hazard rate is strictly increasing). Thus, the function $Z(\lambda; F)$ is single peaked in λ and reaches its peak at the unique value λ^* that satisfies $Z'(\lambda^*; F) = 0$ or, equivalently, $f(\lambda^*)/(1 - F(\lambda^*)) = \delta/C$. QED.

Proof of Proposition 3. The derivative of the joint payoff is: $Z'(\alpha; G) = \delta[1 - G(\alpha)] - Cg(\alpha)$. Thus, $\mathrm{sgn}(Z'(\alpha; G)) = \mathrm{sgn}(\delta/C - g(\alpha)/(1 - G(\alpha)))$. Since $g(0) = 0 < \delta/C$, it follows that $Z'(0; G) > 0$; moreover, $\lim_{\alpha\to 1} Z'(\alpha; G) < 0$ since $g(\alpha)/(1 - G(\alpha)) = \alpha f(\alpha)/[\mu_F - \alpha F(\alpha) + \int_0^{\alpha} F(t)\mathrm{d}t]$ goes to infinity as α goes to 1. Thus, the function $Z(\alpha; G)$ is first increasing and eventually decreasing; that is, there exists at least one $\alpha^* \in (0, 1)$ that is a maximizer of $Z(\alpha; G)$; moreover α^* satisfies $g(\alpha^*)/(1 - G(\alpha^*)) = \delta/C$. QED.

Proof of Proposition 4. $g(\alpha)/(1 - G(\alpha)) = \alpha f(\alpha)/[\mu F - \alpha F(\alpha) + \int_0^\alpha F(t)\mathrm{d}t] < f(\alpha)/(1 - F(\alpha))$ if and only if $\Phi(\alpha) \equiv \alpha - \mu_F - \int_0^\alpha F(t)\mathrm{d}t \leq 0$. It is clear that $\Phi(\alpha) < 0$ for all $\alpha \leq \mu_F$. For $\alpha > \mu_F$, the function $\Phi(\alpha)$ is increasing since $\Phi'(\alpha) = 1 - F(\alpha)$. Moreover, $\Phi(1) = 1 - \mu_F - \int_0^1 F(t)\mathrm{d}t = 0$. Therefore, $g(\alpha)/(1 - G(\alpha)) < f(\alpha)/(1 - F(\alpha))$ for all $\alpha \in [0, 1)$. QED.

Proof of Proposition 5. Recall that α^* maximizes $Z(\alpha; G)$ and thus satisfies $g(\alpha^*)/(1 - G(\alpha^*)) = \delta/C$, whereas λ^* maximizes $Z(\lambda; F)$ and thus satisfies $f(\lambda^*)/(1 - F(\lambda^*)) = \delta/C$. But then $f(\lambda^*)/(1 - F(\lambda^*)) = \delta/C = g(\alpha^*)/(1 - G(\alpha^*)) < f(\alpha^*)/(1 - F(\alpha^*))$, where the last inequality follows from Proposition 4. Since the hazard rate $f(\bullet)/(1 - F(\bullet))$ is strictly increasing, it follows that $\alpha^* > \lambda^*$. QED.

Proof of Proposition 6. In the IBLD model, P's payoff conditional on a defendant of type t can be written as $z(t; \lambda^*) = t\delta - c_P$ if $t \leq \lambda^*$ and $z(t; \lambda^*) = \lambda^*\delta + c_D$ if $t > \lambda^*$; notice that $z(t; \lambda)$ is a nondecreasing function of t, with portions that are strictly increasing if $\lambda^* > 0$. Moreover, P's *interim* expected payoff in the IBLD model is given by $Z(\lambda^*; F) = \mathrm{E}_F(z(t; \lambda^*))$. Also, define $Z(\lambda^*; G) \equiv \mathrm{E}_G(z(t; \lambda^*))$. Since $G(\bullet)$ FOSD $F(\bullet)$, $Z(\lambda^*; G) \geq Z(\lambda^*; F)$ because $z(t; \lambda^*)$ is a nondecreasing function of t. First, assume that $\lambda^* > 0$. Since $z(t; \lambda^*)$ is strictly increasing on a subinterval, then using integration by parts yields $Z(\lambda^*; G) - Z(\lambda^*; F) = \int_0^1 z'(t; \lambda^*)[F(t) - G(t)]\mathrm{d}t > 0$, where $z'(t; \lambda^*)$ is the derivative of $z(t; \lambda^*)$ and $F(t) > G(t)$ for $t \in (0,1)$. If $\lambda^* = 0$, then $Z(\lambda^*; G) = Z(\lambda^*; F)$. In either case, note that $Z(\alpha^*; G) > Z(\lambda^*; G)$ because α^* maximizes $Z(\alpha; G)$, whereas λ^* does not. Combining these two inequalities yields $Z(\alpha^*; G) > Z(\lambda^*; F)$. QED.

Proof of Proposition 7. First, note that $K_G \equiv Z(\alpha^*; G, \delta) > Z(\lambda^*; F, \delta) \equiv K_F$, where the inequality follows from Proposition 6. Second, inspection of the payoff functions $Z(\lambda^*; F, \delta)$ and $Z(\alpha^*; G, \delta)$ and application of the envelope theorem implies that both are increasing functions of δ. If $Z(\lambda^*; F, \underline{\delta}) - K \geq 0$, then $\delta_G = \delta_F = \underline{\delta}$. If $Z(\lambda^*; F, \underline{\delta}) - K < 0$, then since $Z(\alpha^*; G, \delta_F) - K > Z(\lambda^*; F, \delta_F) - K = 0$, it follows that $\delta_G < \delta_F$. QED.

Proof of Proposition 8. Conditional on a suit being filed, the defendant's payoff if he is of type t is given by $w(t; \lambda^*) = t\delta + c_D$ if $t < \lambda^*$ and $w(t; \lambda^*) = \lambda^*\delta + c_D$ if $t \geq \lambda^*$ for the IBLD model, and as $w(t; \alpha^*) = t\delta + c_D$ if $t < \alpha^*$ and $w(t; \alpha^*) = \alpha^*\delta + c_D$ if $t \geq \alpha^*$ for the PBLD model. Since $\alpha^* > \lambda^*$, it follows that $w(t; \alpha^*) = w(t; \lambda^*)$ for $t \leq \lambda^*$ and $w(t; \alpha^*) > w(t; \lambda^*)$ for $t > \lambda^*$. The last claim follows directly from Proposition 5. QED.

Proof of Remark following Proposition 8.

In the text following Proposition 8, it was claimed that the defendant's *ex ante* expected expenditure, taking into account litigation costs and settlement bargaining (but assuming that filing costs $K = 0$ and δ is the same for all plaintiffs), are higher under PBLD than under IBLD. To see this, let this expenditure be denoted by $V^I(\lambda^*)$ under IBLD and by $V^P(\alpha^*)$ under PBLD. Then:

$$V^I(\lambda^*) \equiv \int_0^1 N\alpha[\int_0^{\lambda^*} (\lambda\delta + c_D)f(\lambda)\mathrm{d}\lambda + \int_{\lambda^*}^1 (\lambda^*\delta + c_D)f(\lambda)\mathrm{d}\lambda]f(\alpha)\mathrm{d}\alpha$$

Similarly,

$$V^P(\alpha^*) \equiv \int_0^{\alpha^*} N\alpha(\alpha\delta + c_D)f(\alpha)\mathrm{d}\alpha + \int_{\alpha^*}^1 N\alpha(\alpha^*\delta + c_D)f(\alpha)\mathrm{d}\alpha$$

Then $V^P(\alpha^*) - V^I(\lambda^*) > 0$ if and only if (using the fact that $\alpha f(\alpha) = \mu_F g(\alpha)$ and using t as the variable of integration in both integrals):

$$H(\alpha^*;\lambda^*) \equiv \int_0^{\alpha^*} tg(t)\mathrm{d}t + \int_{\alpha^*}^1 \alpha^* g(t)\mathrm{d}t - \int_0^{\lambda^*} tf(t)\mathrm{d}t - \int_{\lambda^*}^1 \lambda^* f(t)\mathrm{d}t > 0.$$

Since $\int_{\lambda^*}^1 \lambda^*[g(t) - f(t)]\mathrm{d}t = -\int_0^{\lambda^*} \lambda^*[g(t) - f(t)]\mathrm{d}t$ (since these integrals must add up to zero), we can write $H(\lambda^*;\lambda^*) = \int_0^{\lambda^*}(t - \lambda^*)[g(t) - f(t)]\mathrm{d}t = -\int_0^{\lambda^*}[G(t) - F(t)]\mathrm{d}t > 0$, upon integrating by parts. Moreover, since $\partial H(\alpha^*;\lambda^*)/\partial\alpha^* = \int_{\alpha^*}^1 g(t)\mathrm{d}t > 0$, it follows that $H(\alpha^*;\lambda^*) > 0$ for all $\alpha^* > \lambda^*$. QED.

Effect of Background Harm Rate on Posterior Density of Product Harm Rate

As before, the density for the product-related harm rate α is $f(\alpha)$; the mean of this density is denoted as μ_F and N people have acquired and used the product. Furthermore, let β be the "background rate," which is the chance of harm arising from other sources. Since it is possible that someone gets harmed by both sources simultaneously (smokes and is exposed to industrial smokestack product), the probability of harm within the user (i.e., exposed to the product) population, given that αN people are harmed by the product, is:

$$\Pr\{\text{harm} \mid \alpha N\} = \alpha + \beta - \alpha\beta,$$

where the subtraction of the $\alpha\beta$ term adjusts for the potential of over-counting. Thus, the posterior density, $g(\alpha)$, is:

$$g(\alpha) = (\alpha + \beta - \alpha\beta)f(\alpha)/(\mu_F + \beta - \mu_F\beta).$$

As with the simpler (no background harm) model discussed in the main text, $g(\alpha)$ down-weights values below μ_F and up-weights those above μ_F. Comparing with the simpler story, this down- and up-weighting is less in magnitude, but it still occurs, so G still first-order stochastic dominates F.

Signaling Model of Settlement Bargaining Under IBLD and PBLD

We assume that P is committed to going to trial if she rejects D's offer via a contract with P's attorney (PA), which allocates the decision to reject the offer and proceed to trial to P and the filing and litigation costs to PA. PA will require a share of the award or settlement that allows her to break even in expectation. It is in P's interest to establish such a commitment for, if there were an offer that would induce P to drop the case, then every defendant type would make this offer and P could not recover anything.

As will become apparent, the analysis of the bargaining subgame does not depend on the liability regime, but for concreteness we will proceed under IBLD. Let σ_F denote the share of the award or settlement that PA receives; then P receives the share $(1 - \sigma_F)$ of either the award or the settlement. Thus, P will accept a settlement offer of s if and only if $(1 - \sigma_F)s \geq (1 - \sigma_F)b(s)\delta$, where $b(s)$ represents P's belief about λ, based on the settlement offered (note that if P rejects the offer s, she will find it optimal to proceed to trial since she anticipates receiving $(1 - \sigma_F)b(s)\delta$). In a separating equilibrium, P will randomize between accepting and rejecting D's offer; thus a strategy for P is a probability of rejection function, denoted $r(s)$. Let $(s^*(\lambda), r^*(s), b^*(s))$ be the strategies and beliefs in a separating perfect Bayesian equilibrium. Then it must be that: (1) $s^*(\lambda)$ minimizes D's expected payment $s(1 - r(s)) + r(s)(\lambda\delta + c_D)$; (2) P must be willing to randomize between acceptance and rejection; and (3) the beliefs $b^*(s)$ must be correct; that is, $b^*(s^*(\lambda)) = \lambda$.

Differentiating D's expected payoff yields the first-order condition $1 - r(s) + r'(s)(\lambda\delta + c_D - s) = 0$. Given consistent beliefs, P will only be willing to randomize if $s^*(\lambda) = \lambda\delta$. Substituting this into the first-order condition yields a differential equation for $r^*(s)$: $1 - r(s) + r'(s)c_D = 0$. Solving this equation and applying the boundary condition that the highest equilibrium offer δ will never be rejected yields the solution $r^*(s) = 1 - \exp\{-(\delta - s)/c_D\}$ for $s \in [0, \delta]$. D's offer function is $s^*(\lambda) = \lambda\delta$ for $\lambda \in [0, 1]$, and the consistent beliefs are $b^*(s) = s/\delta$. Thus, the equilibrium probability of trial against a defendant of type λ is given by $r^{**}(\lambda) = r^*(s^*(\lambda)) = 1 - \exp\{-(1 - \lambda)\delta/c_D\}$.

When considering filing suit, the plaintiff's side anticipates receiving the amount $\lambda\delta$ from the defendant of type λ whether the case is settled or tried, and PA anticipates paying trial costs with probability $r^{**}(\lambda)$. Thus, PA's share must satisfy the following *interim* break-even constraint: $\int_0^1(\sigma_F\lambda\delta - r^{**}(\lambda)c_P)f(\lambda)d\lambda - K = 0$. P's *interim* expected payoff is $\int_0^1(1 - \sigma_F)\lambda\delta df(\lambda)d\lambda$; substituting from PA's break-even constraint, P's *interim* expected payoff is $V(F, K) \equiv \int_0^1(\lambda\delta - r^{**}(\lambda)c_P)f(\lambda)d\lambda - K$, and thus a case is filed whenever $V(F, K) \geq 0$.

Note that the bargaining subgame equilibrium did not depend on the distribution F; thus, it is immediate that the equilibrium strategies under PBLD simply involve replacing λ with α; that is, P's equilibrium rejection function is still $r^*(s) = 1 - \exp\{-(\delta - s)/c_D\}$ for $s \in [0, \delta]$, D's offer function is now $s^*(\alpha) = \alpha\delta$ for $\alpha \in [0, 1]$, and the consistent beliefs are $b^*(s) = s/\delta$. The equilibrium probability of trial against a defendant of type α is given by $r^{**}(\alpha) = r^*(s^*(\alpha)) = 1 - \exp\{-(1 - \alpha)\delta/c_D\}$.

However, when considering filing suit, the plaintiff's side now employs the distribution G rather than the distribution F. Thus, PA's share (denoted σ_G) must satisfy the *interim* break-even constraint: $\int_0^1(\sigma_G\alpha\delta - r^{**}(\alpha)c_P)g(\alpha)d\alpha - K = 0$.

P's *interim* expected payoff is $\int_0^1 (1-\sigma_G)\alpha\delta g(\alpha)\mathrm{d}\alpha$; substituting from PA's break-even constraint implies that P's *interim* expected payoff is $V(G,K) \equiv \int_0^1 (\alpha\delta - r^{**}(\alpha)c_P)g(\alpha)\mathrm{d}\alpha - K$, and thus a case is filed whenever $V(G, K) \geq 0$. Since the function $t\delta - r^{**}(t)c_P$ is an increasing function of t, the fact that G FOSD F implies that $V(G, K) = \mathrm{E}_G(t\delta - r^{**}(t)c_P) - K > V(F, K) = \mathrm{E}_F(t\delta - r^{**}(t)c_P) - K$. Thus, more cases will be filed under PBLD than under IBLD.

Generalization of the Probability of Liability Function

Let ℓ denote the probability that the defendant will be held liable, and suppose that ℓ is given by $L(\alpha)$, where $L(\bullet)$ is a differentiable and strictly increasing function with $L(0) = 0$ and $L(1) = 1$. For future reference, let $h(\ell) \equiv L^{-1}(\ell)$; then $h(\ell)$ is also differentiable and strictly increasing with $h(0) = 0$ and $h(1) = 1$.

To maintain comparability with the IBLD model, we assume that ℓ is distributed according to $F(\ell)$ on [0, 1]. We are interested in deriving $g(\ell)$, which is the probability (density) of ℓ, given that P has been harmed. To calculate this using Bayes' rule, we need $\Pr\{P \text{ is harmed} \mid \ell\}$. As before, $\Pr\{P \text{ is harmed} \mid \alpha\} = \alpha$; conditional on ℓ, the associated value of α is given by $h(\ell)$, and therefore $\Pr\{P \text{ is harmed} \mid \ell\} = h(\ell)$. This yields: $g(\ell) = h(\ell)f(\ell)/T_F$, where $T_F \equiv \int_0^1 h(t)f(t)\mathrm{d}t$. For future reference note that, by construction, $0 = \int_0^1 [h(t) - T_F]f(t)\mathrm{d}t$. Since h is strictly increasing with $h(0) = 0$ and $h(1) = 1$, it follows that there exists a unique value $\ell_m \in (0, 1)$ such that $h(\ell)$ $(<\,=\,>)$ T_F as ℓ $(<\,=\,>)$ ℓ_m. Finally, we can write $G(\ell) = \int_0^\ell h(t)f(t)\mathrm{d}t/T_F$. Notice that this G distribution is not the same as the one derived in Section 3, due to the transformation $\ell = L(\alpha)$. Nevertheless, it shares all the properties derived for the G distribution in Sections 3, 4 and 5.

Proposition 1′. G first-order stochastic dominates F.

Proof. Recall that the distribution G FOSD the distribution F if $G(\ell) \leq F(\ell)$ for all ℓ, with a strict inequality on at least a subset of [0, 1]. First note that $G(0) = F(0) = 0$ and $G(1) = F(1) = 1$, since both are probability distributions. We now show that $G(\ell) < F(\ell)$ for $\ell \in (0, 1)$, and therefore G FOSD F. To see this, observe that $G(\ell) < F(\ell)$ if and only if $\Delta(\ell) \equiv \int_0^\ell h(t)f(t)\mathrm{d}t - T_F F(\ell) < 0$. It is clear that $\Delta(0) = 0$ and $\Delta(1) = 0$. Differentiation yields $\Delta'(\ell) = [h(\ell) - T_F]f(\ell)$ $(<\,=\,>)$ 0 as ℓ $(<\,=\,>)$ ℓ_m. Thus, $\Delta(\ell)$ starts at 0, declines to a minimum at ℓ_m, and then rises back to 0, establishing that $\Delta(\ell) < 0$ for $\ell \in (0, 1)$. QED.

Proposition 4′. Both hazard rates go to infinity as ℓ goes to 1; otherwise, $g(\ell)/(1 - G(\ell)) < f(\ell)/(1 - F(\ell))$ for all $\ell \in [0, 1)$.

Proof. Recall that $g(\ell) = h(\ell)f(\ell)/T_F$. Since both $h(\ell)$ and $f(\ell)$ are bounded, whereas $G(1) = F(1) = 1$, both hazard rates go to infinity as ℓ goes to 1. To verify the second claim, note that $g(\ell)/(1 - G(\ell)) = h(\ell) f(\ell)/[T_F - \int_0^\ell h(t)f(t)\mathrm{d}t] < f(\ell)/(1 - F(\ell))$ if and only if $\Phi(\ell) \equiv h(\ell)[1 - F(\ell)] - T_F + \int_0^\ell h(t)f(t)\mathrm{d}t < 0$. Observe that $\Phi(0) = -T_F$ and $\Phi(1) = 0$.

Differentiation yields $\Phi'(\ell) = h'(\ell)[1 - F(\ell)] > 0$. Thus, $\Phi(\ell) < 0$ for all $\ell \in [0, 1)$. QED.

We handle multiple optima in the same manner as discussed in Section 4 and label the PBLD marginal type that maximizes $Z(\ell; G)$ as ℓ^*. Since the (new) distribution $G(\ell)$ satisfies these two properties, the analysis of Sections 4 and 5 follows directly, subject to the substitution of ℓ (and ℓ^*) for α (and α^*).

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