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# A Simple Model of Efficient Tort Liability Rules

ALLAN M. FELDMAN

and

JOHN M. FROST

*Department of Economics, Brown University, Providence, Rhode Island, USA*
*E-mail: allan_feldman@brown.edu*

We present a simple model of tort liability in which precaution is a binary choice, and, if any party takes precaution, the probability of accidents is zero. We compare and contrast our model to other models in which precaution is a continuous variable. Our paper provides easy characterizations of the efficiency properties of a number of real and hypothetical liability rules, including no liability, Learned Hand negligence, negligence with contributory negligence as a defense, Calabresi and Hirschoff's reverse Hand, Galena, Brown's relative negligence, strict liability, and others. In a mathematical appendix we extend the model and derive efficiency propositions for dichotomous-action, multidefendant liability rules of various types: simple (in which one party pays 100% of accident costs); comparative negligence (in which accident costs may be spread among two or more parties); and punitive damages (in which some parties may pay more than 100% of accident costs). 

## I. Introduction

Judge Learned Hand's opinion in *U.S. v. Carroll Towing Co.*[1] was the first to use explicit cost-benefit analysis in assigning tort liability. It presaged a substantial body of literature in law and economics. The opinion is now 50 years old, but the type of analysis it inspires is still vital, and this paper is another descendant from it.

According to Judge Hand's well-known formula, "if the probability [of an accident] be called $P$; the injury, $L$; and the burden [of precaution], $B$; liability depends on whether . . . $B < PL$."[2] That is, whether or not a party should be liable for losses caused by an accident ought to depend on whether or not his cost of prevention is less than the expected losses from such accidents. If accidents are relatively inexpensive to prevent, they ought to be prevented, and those who could have prevented them should be liable

[1] 159 F.2d 169 (2d Cir. 1947).
[2] *Id.* at 173.

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if they are allowed to occur. This has come to be known as the Hand rule for negligence in torts. It is a great step beyond the "reasonable man of ordinary prudence" standard, because it in effect defines what is reasonable and does so in a rational, cost-benefit fashion.

The usual discussion of the Hand rule assumes that the defendant is the actor who might (at some cost) prevent accidents. In *U.S. v. Carroll Towing Co.*, however, it was not quite so simple. Judge Hand's formula was applied to the actions (or inactions) of plaintiff Connors Marine Co., owner of the barge *Anna C*. In their efforts to move another barge in New York Harbor, defendants Carroll Towing Co. and Grace Line, Inc., respectively owner and charterer of the tug *Carroll*, found it necessary to adjust the *Anna C*'s mooring lines, as no barge attendant ("bargee") was on board the *Anna C* at the time. However, they adjusted the moorings improperly, and the *Anna C* broke away. Adrift downriver, she collided with a tanker and sank, thereby harming both the Connors Co. and the owner of the cargo on board, the U.S. government. Judge Hand's formula was applied to the behavior of plaintiff Connors Co., because the defendants endeavored to show that the plaintiff was also negligent, which would have absolved them from some of the damages under the governing comparative negligence admiralty law. Judge Hand found that if plaintiff Connors Co. had had a bargee aboard the *Anna C* on the day of the accident, then Carroll Towing's negligence would have resulted in *some* damages, but not in *sinking* and the attendant loss of cargo. Plaintiff was negligent because the cost of having the bargee aboard that day was less than the expected accident costs. Plaintiff failed the cost-benefit test.

In the last 25 years a number of economists and legal scholars have constructed models of tort liability rules—including the Hand rule—with a focus on what rules are rational in the cost-benefit sense.[3] These models typically assume there are two parties: a (potential) plaintiff and a (potential) defendant, who engage in some activity that creates a risk of injury to the plaintiff. Defendant (and/or plaintiff) might take some precaution, at some cost, so as to reduce or eliminate the chance of injury. They are bound together by a legal system with a known liability rule; and in light of the costs of the accidents, the probabilities, the costs of precautions, and the legal rule, they choose their behavior. The models then allow one to answer some crucial questions: (1) What do plaintiff and defendant do? (2) Is their behavior an equilibrium in some sense?[4] and (3) Most important, is what they do efficient, in the sense of minimizing total social costs? That is, is the outcome rational for society?

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[3]This is a large literature and we can only touch upon it here. In his pathbreaking article, "Toward an Economic Theory of Liability," 2 *Journal of Legal Studies* 323 (1973), John Brown introduced the first formal economic model of torts. Brown and most of his followers assumed risk-neutral and homogeneous agents. Steven Shavell, in "Strict Liability versus Negligence," 9 *Journal of Legal Studies* 1 (1980), and A. Mitchell Polinsky, in "Strict Liability vs. Negligence in a Market Setting," 70 *American Economic Review* 363 (1980), extended Brown's analysis to consider the ramifications of parties having differential knowledge of risk (i.e., likelihood of accident) and firm entry and exit, respectively. David Haddock and Christopher Curran, in "An Economic Theory of Comparative Negligence," 14 *Journal of Legal Studies* 49 (1985), used Brown's framework to analyze two broad categories of comparative negligence: pure comparative negligence and a 50% threshold rule. Samuel A. Rea, Jr., in "The Economics of Comparative Negligence," 7 *International Review of Law and Economics* 149 (1987), extended Haddock and Curran's analysis to consider when parties took action sequentially, rather than simultaneously. Winand Emons, in "Efficient Liability Rules for an Economy with Non-Identical Individuals," 42 *Journal of Public Economics* 89 (1990), analyzed the implications of heterogeneous individuals within the Brown model. Finally, Lynda Thoman, in "Strict Liability and Negligence Rules when the Product is Information," 44 *Economics Letters* 205 (1994), analyzed the implications of the model in a principal-agent framework.

[4]In particular, is it a game-theoretic or Nash equilibrium? That is, does each party maximize his welfare, given the liability rule in force and the behavior of the other party?

The models of John Brown and those who followed him typically assume continuous cost-of-precaution functions, probability-of-accident functions, and loss functions. Solving those models then usually requires mathematical sophistication that would likely discourage even a modern Judge Hand. The purpose of this short paper is to return to an easy model very much like that inherent in Judge Hand's original inequality and to use that simple model to illustrate the properties, good and bad, of standard and proposed tort liability rules.

In our model we assume that either plaintiff or defendant can take actions that would prevent accidents.[5] For simplicity, we assume that if *neither* party takes precaution, accidents that harm the plaintiff will occur with a given probability; if *either* party takes precaution, accidents will not occur. So the model is yes/no: either accidents happen, or they don't. To prevent accidents, at least one party must incur a fixed cost of precaution. Thus, using the terminology of Landes and Posner, this is an "alternative care" rather than a "joint care" model.[6]

Our use of a discrete model, rather than a continuous model, flies in the face of most modern economic theorizing, and we should explain why we do it. The first reason is that it is simpler and requires less mathematical apparatus. The second is that, in many contexts, it is more realistic. In defective design cases, the choice is often dichotomous: Should the gas tank have been located inside the truck frame, or outside? In medical malpractice cases, the choice is often yes or no: Should that lesion have been biopsied, or not? In many motor vehicle accident cases the issues are of a dichotomous nature: Was the driver going above the speed limit, or not? Was his blood alcohol level above 0.1%, or not? Even in *U.S. v. Carroll Towing Co.* the issue was whether Connors Co. should have had a bargee on board, or not. In fact, much of the legal system, tort law and all the rest, is of a yes/no nature: Are you guilty or innocent? Did you breach the contract, or not? Are you married, of legal age, and a citizen, or not? In short, the continuous models may be the mathematical artifacts, and the discrete, even dichotomous, models may be more natural.[7]

We also assume that the fixed costs of precaution are known to both parties, as is the legal liability rule. Both plaintiff and defendant are risk neutral, and so they care only about minimizing the expected cost of accidents. The following notation is used:

$C_D \equiv$ cost to defendant to prevent accidents.
$C_P \equiv$ cost to plaintiff to prevent accidents.
$\pi \equiv$ probability of accidents occurring if neither plaintiff nor defendant prevents.
$L \equiv$ money loss to plaintiff when an accident occurs.

The Hand rule for negligence of the defendant is now $C_D < \pi L$. If this inequality holds and a suit comes before a jurist like Judge Hand, he should find the defendant negligent and, therefore, liable, because he did not prevent an accident that cost-benefit analysis says should have been prevented. Note that we emphasize the Hand rule for negligence of the *defendant*, which is the standard usage in the law and economics literature on torts. This is what we call the Hand rule below, using the conventional

[5]In the Mathematical Appendix we allow for multiple defendants.

[6]William M. Landes and Richard A. Posner, *The Economic Structure of Tort Law* (Cambridge, MA: Harvard University Press, 1987).

[7]See also Mark F. Grady, "Legal Evolution and Precedent," 3 *Annual Review of Law & Ethics* 147 (1995), who argues that the dichotomous nature of liability may be key to understanding how common-law rules develop.

TABLE 1. The Learned Hand (1947) negligence rule and the Calabresi and Hirschoff (1972) "reverse" Hand rule under all possible cost orderings, ignoring equalities among the variables

| | *Cost ordering* | *Hand rule* | *Reverse Hand rule* |
|---|---|---|---|
| 1. | $\pi L > C_D > C_P$ | *D* liable | *P* liable |
| 2. | $\pi L > C_P > C_D$ | *D* liable | *P* liable |
| 3. | $C_D > \pi L > C_P$ | *P* liable | *P* liable |
| 4. | $C_D > C_P > \pi L$ | *P* liable | *D* liable |
| 5. | $C_P > \pi L > C_D$ | *D* liable | *D* liable |
| 6. | $C_P > C_D > \pi L$ | *P* liable | *D* liable |

$P \equiv$ plaintiff; $D \equiv$ defendant

terminology. Recall, however, that the famous part of Judge Hand's opinion in *U.S. v. Carroll Towing Co.* refers to actions (or inactions) of the plaintiff.

There are three crucial numbers in the model: $C_D$, $C_P$, and $\pi L$. To make the analysis clear and easy (and with no important loss of generality) we will assume that the three numbers are always distinct, so that there are no equalities to complicate matters. Because there are only six ways to order three numbers, in this model six simple cases tell all. Table 1 lists all the possibilities. A liability rule is simply a specification of who ultimately bears the burden of accidents (initially born by plaintiff) in each of the six cases. A Hand rule that disregards actions that the plaintiff might take to prevent accidents (that is, negligence without contributory negligence as a defense), simply says defendant *D* is liable in Cases 1, 2, and 5 (when $\pi L > C_D$) and is not liable in Cases 3, 4, and 6 (when $C_D > \pi L$).

Calabresi and Hirschoff observe that it is possible to stand Judge Hand's logic on its head and to make the defendant bear the burden of accidents *unless* it makes cost-benefit sense for the plaintiff to prevent them.[8] This is their reverse Hand rule, and it is as sensible as the Hand rule itself (again using the conventional terminology), which makes the plaintiff bear the burden of accidents unless it makes cost-benefit sense for the defendant to prevent them. The reverse Hand rule in our model makes *D* liable in Cases 4, 5, and 6 (when $C_P > \pi L$) and not liable in the rest (when $\pi L > C_P$). Table 1 shows the Hand rule for negligence of the defendant and the reverse Hand rule.[9]

To illustrate, suppose $\pi L = \$100$, $C_D = \$30$, and $C_P = \$25$. This places us on line 1 of Table 1. With these costs, the efficient outcome for society, that is, the net-cost-minimizing outcome, is for the plaintiff to prevent the accidents. Under what we call the Hand rule, the defendant will be held liable. If both parties know the costs, and know the rule, the defendant will prevent the accident (because \$100 > \$30) and the plaintiff will not (because he knows the defendant will). This is not efficient. Under the reverse Hand rule, the defendant will not prevent the accident (because he knows he is not liable) and the plaintiff will (because \$100 > \$25). This is efficient.[10]

[8]Guido Calabresi and Jon T. Hirschoff, "Toward a Test for Strict Liability in Torts," 81 *Yale Law Journal* 1055, 1059 (1972).

[9]The reverse Hand rule of Table 1 corresponds to Brown's rule of strict liability with contributory negligence. See *supra* note 3, p. 328.

[10]Note that we exclude side payments between the plaintiff and the defendant, which would guarantee efficiency

TABLE 2. Efficient outcomes and actual outcomes resulting from different liability rules

| Cost ordering | Efficient | I<br>*No liability* | II<br>*Negligence (Hand rule)* | III<br>*Neg. with cont. neg. defense* | IV<br>*Corrected neg. with cont. neg. (Galena rule)* | V<br>*Reverse Hand rule* | VI<br>*Corrected reverse Hand rule* | VII<br>*Strict liability* |
|---|---|---|---|---|---|---|---|---|
| 1. $\pi L > C_D > C_P$ | $P$ prevents | $P$ | $D^*$ | $P$ | $P$ | $P$ | $P$ | $D^*$ |
| 2. $\pi L > C_P > C_D$ | $D$ prevents | $P^*$ | $D$ | $P^*$ | $D$ | $P^*$ | $D$ | $D$ |
| 3. $C_D > \pi L > C_P$ | $P$ prevents | $P$ | $P$ | $P$ | $P$ | $P$ | $P$ | $H(D)$† |
| 4. $C_D > C_P > \pi L$ | happens | $H(P)$ | $H(P)$ | $H(P)$ | $H(P)$ | $H(D)$ | $H(D)$ | $H(D)$ |
| 5. $C_P > \pi L > C_D$ | $D$ prevents | $H(P)$† | $D$ | $D$ | $D$ | $D$ | $D$ | $D$ |
| 6. $C_P > C_D > \pi L$ | happens | $H(P)$ | $H(P)$ | $H(P)$ | $H(P)$ | $H(D)$ | $H(D)$ | $H(D)$ |

*Indicates inefficiency because the wrong party prevents accidents.
†Indicates inefficiency because accidents are wrongly allowed to happen.

## II. Analysis of the Liability Rules

There are two principal ingredients in this tort liability model. First is the efficient outcome for any particular ordering of $C_D$, $C_P$, and $\pi L$. That is, given a particular ordering, should the defendant or the plaintiff prevent the accidents? (In our model it would be inefficient for both parties to take precaution.) Or should the accidents be allowed to happen? Second is determining, for any given liability rule (like the Hand rule), what the two parties will do. Table 2 lays all this out for seven different liability rules, including the Hand rule and the reverse Hand rule.

In Table 2, the first column on the left shows the six possible cost orderings, as in Table 1. The next column shows what is efficient for the parties to do, in terms of minimizing expected accident costs plus the costs of prevention in each of the six cases. For instance, if $\pi L > C_D > C_P$, efficiency requires that the plaintiff prevent the accidents. If $C_D > C_P > \pi L$, neither party should prevent the accidents; they should be allowed to happen.

Column 1 shows a no-liability legal rule: The defendant never has to pay for accident damages. In this column and all the remaining ones, a "$P$" entry means that, considering the costs and considering the legal rule, the equilibrium outcome is that the *plaintiff* chooses to prevent the accidents; he spends $C_P$, and the defendant does nothing. A "$D$" entry means that the *defendant* chooses to prevent the accidents; he spends $C_D$, and the plaintiff does nothing (but is not injured in accidents!). An "$H(\cdot)$" entry means that neither plaintiff nor defendant prevents the accidents; they are allowed to happen. "$H(P)$" means that the cost of accidents allowed to happen falls on the plaintiff, whereas "$H(D)$" means that the cost of accidents that are allowed to happen falls on the defendant.[11]

The no-liability rule in column 1 has two unattractive features. In line 2 (where $\pi L > C_P > C_D$) the plaintiff, knowing that the defendant will not be liable for accidents and

regardless of the liability rule. The classic statement of this result appears in R. H. Coase, "The Problem of Social Cost," 3 *Journal of Law and Economics* 1 (1960).

[11]All the outcomes shown in Table 2 are Nash equilibria. See *supra* note 4 and Proposition 1 in the Mathematical Appendix.

realizing that it makes cost-benefit sense for him to prevent them, will spend $C_P$ to prevent the accidents. But this is inefficient because he is the higher cost preventer. The asterisk denotes this kind of inefficiency: accidents are prevented, but by the wrong party. In line 5 (where $C_P > \pi L > C_D$) the plaintiff again knows that defendant will not prevent the accidents (the defendant never pays with the no-liability rule), but, although he realizes he will bear the burden, the plaintiff does not prevent the accidents himself, because $C_P > \pi L$. Thus, accidents are allowed to happen that ought not to happen (according to cost-benefit analysis, because $\pi L > C_D$). The dagger denotes this second kind of inefficiency: accidents that ought to be prevented are allowed to happen.

Next we turn to the negligence rule (without contributory negligence as a defense), or what we call the Hand rule. Column 2 shows the equilibrium outcomes. The most important thing about that column is that it shows that the Hand rule produces an inefficient outcome in line 1, where $\pi L > C_D > C_P$. In that case, the defendant knows he will be liable for accidents, and the plaintiff knows it also. Knowing that the defendant will be liable, the plaintiff does not bother to spend $C_P$. Observing this, and knowing the rule, the defendant elects to spend $C_D$. Thus the accident is prevented by the wrong party, the single-asterisk inefficiency.[12]

Column 3 represents negligence with contributory negligence as a defense. With this rule, the defendant pays for accidents if and only if he is negligent ($\pi L > C_D$) *and* if the plaintiff is not also negligent (which he would be if $\pi L > C_P$). Thus, under negligence with contributory negligence as a defense, the defendant is liable if and only if $\pi L > C_D$ and $C_P > \pi L$ (i.e., in the line 5 case), and plaintiff is liable in all other cases. In particular, the plaintiff is liable in line 2, where $\pi L > C_P > C_D$. Because both parties know the rule, the plaintiff—not the defendant—will elect to prevent accidents in line 2, because by not doing so he will be found contributorily negligent and, therefore, liable. But this is inefficient.[13]

Column 4 of Table 2 shows the corrected version of the rule of negligence with contributory negligence as a defense. The correction was suggested by Calabresi and Hirschoff.[14] It makes the defendant liable if and only if either (1) the defendant is negligent ($\pi L > C_D$) and (2) the plaintiff is not negligent ($C_P > \pi L$), or if both the defendant and plaintiff are negligent but the defendant is *more* negligent in the sense that his cost of prevention is lower. That is, the defendant is liable in the line 5 case (where the defendant is negligent but the plaintiff is not), and in the line 2 case (where both are negligent, but the defendant is more so). The great virtue of the corrected rule

[12]This contrasts with the well-known results of Brown, *supra* note 3, and others, where the cost of precaution is continuous. In the continuous model, negligence with the efficient level of precaution as the standard of care results in the efficient outcome.

It could be argued that our notion of negligence is not analogous to the continuous model notion of Brown and others, and therefore that we overstate the claim that efficiency does not carry over from the continuous to the discrete model. This is so because in a Brown-type model, negligence on the part of a defendant (or a plaintiff, if applicable) means a level of care *below* the efficient level, whereas in our model it means something different: With the numbers assumed in the last paragraph of Section I, for example, that is $\pi L = \$100$, $C_D = \$30$, and $C_P = \$25$, the efficient outcome is for the defendant to spend \$0 and for the plaintiff to spend \$25. But a level of care below the efficient level would require the defendant to spend a *negative* amount, which is impossible in the model. Therefore, one might argue that a negligence claim against the defendant, properly construed in this model, must evaporate. (A similar argument is made by Landes and Posner, *supra* note 6, p. 90.) This interpretation of negligence would lead to the efficient outcome. However, our view is that a Hand-oriented court, seeing $\pi L = \$100$ and $C_D = \$30$, should find negligence on the part of the defendant when he spends \$0.

[13]Once again this contrasts with the results of the continuous cost-of-precaution models. But cf. *supra* note 12.

[14]*Supra* note 8, p. 1058.

of negligence with contributory negligence as a defense is that it results in an efficient outcome under all possible cost orderings.

The corrected rule of negligence with contributory negligence shown in column 4 is essentially equivalent to the Galena rule, as expressed in *Galena and Chicago Union Railroad Co. v. Jacobs.*[15] In that 1858 case, according to Professor Keeton, the Illinois court attempted to "modify the rigors of contributory negligence by classifying negligence into degrees, and providing that if the plaintiff's negligence was 'ordinary' or 'slight,' while that of the defendant was 'gross,' the plaintiff might recover."[16] Keeton indicates that the Galena remedy proved unsatisfactory because it shifted the entire burden to the defendant when both parties were still partly at fault, and because it was "extremely difficult to assign any definite meaning to 'gross' negligence or to furnish the jury with any satisfactory guide."[17] As a result the rule was abandoned in Illinois by the 1890s, and the Galena rule is "now entirely discarded at common law."[18] What common law discards, we pick up, because it is one of the efficient rules in this model.

Column 5 of Table 2 shows the outcomes with the Calabresi and Hirschoff reverse Hand rule, which makes $P$ or $D$ liable according to the last column of Table 1. As with the Hand rule, the reverse Hand rule also results in an inefficiency, this time if $\pi L > C_P > C_D$, when the plaintiff must bear the burden of accidents.[19] Knowing the rule, the defendant will not prevent the accidents; knowing this, and knowing the rule, the plaintiff will prevent the accident. But he is the higher cost preventer of accidents, and we have another instance of inefficiency.

Column 6 of Table 2 shows the outcomes of a corrected version of the reverse Hand rule. The correction is to make the defendant liable in the line 2 case; that is, the corrected rule says the defendant is liable if and only if either it does not make cost-benefit sense for the plaintiff to prevent the accidents ($C_P > \pi L$, which gives lines 4, 5, and 6), or it does make cost-benefit sense for the plaintiff to prevent the accident but makes even better sense for the defendant to prevent the accident ($\pi L > C_P > C_D$, or line 2). Like the corrected negligence with contributory negligence rule, the corrected reverse Hand rule is efficient under every possible cost ordering.

The last liability rule to be surveyed here is the strict liability rule, shown in column 7. This rule makes the defendant *always* liable. It is the flip side of the no-liability rule, which makes the defendant never liable. And as Table 2 shows, it creates both types of inefficiencies. In the line 1 case, where $\pi L > C_D > C_P$, strict liability results in the plaintiff not preventing the accidents. The defendant, knowing the rule and knowing that the plaintiff will not prevent the accidents, decides to prevent the accidents himself (because $\pi L > C_D$). But because he is the higher cost preventer, accidents are prevented by the wrong person. In line 3, where $C_D > \pi L > C_P$, the plaintiff will again not prevent the accidents. The defendant sees this, sees that he is liable, but also sees that $C_D > \pi L$. Therefore, he does not prevent the accidents, and accidents happen that ought to be prevented.

[15] 20 Ill. 478 (1858).

[16] W. Page Keeton, Dan B. Dobbs, Robert E. Keeton, and David G. Owen, *Prosser and Keeton on the Law of Torts*, 5th ed., p. 470 (1984).

[17] *Id.*

[18] *Id.*

[19] Recall that this rule makes the defendant bear the burden unless it makes cost-benefit sense for the plaintiff to do so. In line 2, it does make cost-benefit sense for the plaintiff to prevent the accident $\pi L > C_P$, and therefore under the reverse Hand rule plaintiff bears the burden.

It is useful, we think, to emphasize the symmetry between the no-liability rule (absurd to think about in the United States), and the strict liability rule (of some practical significance, especially in product liability cases).[20] If it is plausible that both plaintiffs and defendants might take steps to prevent accidents, and if it is plausible that their costs of preventing accidents are of similar magnitude, then one rule is just as bad as the other: If you think no liability is absurd, you should feel the same about strict liability.[21]

### III. Calabresi and Klevorick Rules

In extending Calabresi and Hirschoff's analysis, Calabresi and Klevorick consider several issues that complicate the rules analyzed in Section II.[22] The first major complication they examine is the notion that a liability rule should depend *not only* on expected accident costs and of costs of prevention, *but also* on which party "is in a better position" to do the cost-benefit analysis. The second complication has to do with *when* the expected accident costs and costs of prevention are to be figured: Should it be before the accident, or should it be years later after new information is available, perhaps around the time of trial? We will not deal explicitly with the second complication here, other than to say that it creates difficult problems in the analysis of the behavior of the plaintiff and the defendant. But we will attempt to formalize the first complication.

Assume therefore that either party, plaintiff or defendant, can in principle do some kind of cost-benefit analysis to decide, in Calabresi and Klevorick's words, "whether avoidance costs would have been lower than the accident cost itself."[23] In other words, the $\pi L$, $C_D$, and $C_P$ of the model as outlined above are not freely available information. The plaintiff and the defendant may have some inkling of what they are (or may have Bayesian priors), but to discover their true values costs money. We use the following notation:

$X_D \equiv$ cost to defendant of discovering the true values of $\pi L$, $C_D$, and $C_P$.
$X_P \equiv$ cost to plaintiff of discovering the true values.

For simplicity, assume that cost-benefit analysis is a "package deal": If you pay $X_D$ or $X_P$, respectively, you discover the values of all three parameters; otherwise, you stay in the dark. Of course it might be more realistic to assume that there are separate costs of discovering $\pi L$, $C_D$, and $C_P$, for both the plaintiff and the defendant. But this would greatly complicate the analysis. Our formalization of the Calabresi and Klevorick notion that Party 1 "is in a better position to decide" than Party 2, is that Party 1 has a lower $X$ than Party 2. Also, as with the magnitudes $\pi L$, $C_D$, and $C_P$, we will assume that the $X$s are never equal: Either $X_D > X_P$ or $X_P > X_D$. Finally, to avoid infinite regress, we assume $X_D$ and $X_P$ are known to both parties.

Our assumption that being in a "better position to decide" really means being a

[20]Brown, *supra* note 3, pp. 328–329, emphasized this symmetry.

[21]In practice, what is commonly called strict liability is usually some offshoot of negligence, and it rarely means liability on the part of the injurer in every possible case. In fact, the rules we discuss in Section III are called strict liability rules by Guido Calabresi and Alvin Klevorick in "Four Tests for Liability in Torts," 14 *Journal of Legal Studies* 585 (1985), although we do not refer to them as such. Stephen G. Gilles, in "Negligence, Strict Liability, and the Cheapest Cost-Avoider," 78 *Virginia Law Review* 1291, 1293 (1992), notes that what we call strict liability is "tantamount to absolute liability," and that it is "inefficient, except in unusual cases." Table 2 illustrates exactly when strict liability is efficient, when it is inefficient, and why.

[22]See Calabresi and Klevorick, *supra* note 21.

[23]*Id.* at 591.

cheaper cost-benefit analyzer has several ramifications. Consider first the issue of whether or not it is even *possible* for one party to do the analysis. If it is impossible for the plaintiff to do the analysis because he has no access to the necessary information or expertise, we simply assign $+\infty$ to $X_P$. This might be the case, for example, in some product liability cases or in some medical malpractice cases. Second, suppose there is one potential defendant (e.g., a large corporation producing a potentially hazardous product) and a large number of potential plaintiffs. If the costs of assessing $\pi L$, $C_D$, and $C_P$ are roughly comparable for the corporation, on the one hand, and for any one potential plaintiff, on the other hand, and if there is no mechanism to costlessly disseminate the information among potential plaintiffs, then on a per accident basis it will be cheaper for the one corporation to do the analysis. Clearly, the costs of precaution should be figured per accident. Third, suppose that the numbers of potential plaintiffs and defendants are roughly the same, and that neither the $P$ side nor the $D$ side has an overwhelming advantage in terms of knowledge and expertise, but that one party is rich and the other is poor. Suppose, for instance, that $X_P = \$5$, $X_D = 10$, but that the plaintiff has wealth of \$50 whereas the defendant has wealth of \$10,000. In this case some might say that the defendant is in a better position to do the cost-benefit analysis, but we would opt for the plaintiff. Our view is consistent with the standard wealth maximization—rather than utility maximization—orientation of normative law and economics. Fourth, and finally, suppose in the above case that $X_P = \$55$ and $X_D = \$60$. Now, although the plaintiff is the cheaper cost-benefit analyzer, he doesn't have the resources to do the analysis. He is like a "shallow pocket" defendant. We will not consider the ramifications of this particular problem.[24]

We make three further assumptions. First, if either party discovers the true values of $\pi L$, $C_D$, and $C_P$, that information can be costlessly discovered by a court. Second, the cost of doing cost-benefit analysis for at least one party, i.e., $X_D$ or $X_P$, is small compared to the magnitudes of $\pi L$, $C_D$ and $C_P$. And third, if an actor is potentially liable because of his lower $X$, he will definitely choose to do the cost-benefit analysis to discover $\pi L$, $C_D$, and $C_P$.

Now let us attempt to formalize what Calabresi and Klevorick call liability Rules 2a and 4a, which we lump together as Rule $A$, according to which "loss lies on the victim unless the injurer is in a better position to decide whether avoidance of the accident would be cheaper than the cost of the accident," and "to act on the analysis once made." This might be viewed as a Hand rule with a who-can-do-the-cost-benefit-analysis-cheaper overlay. We would translate this somewhat obscure rule by saying it means that the plaintiff is liable unless $X_P > X_D$ (i.e., if the defendant can do the cost-benefit analysis cheaper), and $C_P > C_D$ (i.e., if the defendant is better able to act on the analysis). In short, the Calabresi and Klevorick Rule $A$ (C&K $A$) is interpreted by us to mean that the plaintiff is liable *if and only if not* ($X_P > X_D$ and $C_P > C_D$). This in turn is equivalent to: The defendant is liable if and only if ($X_P > X_D$ and $C_P > C_D$). As we understand them, Calabresi and Klevorick's Rules 2b and 4b (which we merge into C&K Rule $B$) are mirror image rules that replace $P$ with $D$ and $D$ with $P$. That is, the plaintiff is liable if and only if ($X_D > X_P$ and $C_D > C_P$).

In Table 3 we illustrate the 12 possible cases (six possible orderings of $\pi L$, $C_D$, and $C_P$ $\times$ two possible orderings of $X_D$ and $X_P$), C&K Rules $A$ and $B$, plus a hybrid rule. The

[24]See Steven Shavell, "The Judgment Proof Problem," 6 *International Review of Law and Economics* 45 (1986), for an analysis of this problem.

TABLE 3. Analysis of three liability rules: Calabresi and Klevorick strict liability rules A and B (C&K A and C&K B), and the rule of relative negligence

| Cost ordering | *Efficient* | | *C&K A* | | *C&K B* | | *Relative negligence* | |
|---|---|---|---|---|---|---|---|---|
| | *C/B Analyzer* | *Outcome* | *Liability* | *Outcome* | *Liability* | *Outcome* | *Liability* | *Outcome* |
| $X_D > X_P$, and: | | | | | | | | |
| 1. $\pi L > C_D > C_P$ | *P* | *P* prevents | *P* | *P, P* | *P* | *P, P* | *P* | *P* |
| 2. $\pi L > C_P > C_D$ | *P* | *D* prevents | *P* | *P, P** | *D* | *P, D* | *D* | *D* |
| 3. $C_D > \pi L > C_P$ | *P* | *P* prevents | *P* | *P, P* | *P* | *P, P* | *P* | *P* |
| 4. $C_D > C_P > \pi L$ | *P* | happens | *P* | *P, H(P)* | *P* | *P, H(P)* | *P* | *H(P)* |
| 5. $C_P > \pi L > C_D$ | *P* | *D* prevents | *P* | *P, H(P)*† | *D* | *P, D* | *D* | *D* |
| 6. $C_P > C_D > \pi L$ | *P* | happens | *P* | *P, H(P)* | *D* | *P, H(D)* | *D* | *H(D)* |
| $X_P > X_D$, and: | | | | | | | | |
| 7. $\pi L > C_D > C_P$ | *D* | *P* prevents | *P* | *D, P* | *D* | *D, D** | *P* | *P* |
| 8. $\pi L > C_P > C_D$ | *D* | *D* prevents | *D* | *D, D* | *D* | *D, D* | *D* | *D* |
| 9. $C_D > \pi L > C_P$ | *D* | *P* prevents | *P* | *D, P* | *D* | *D, H(D)*† | *P* | *P* |
| 10. $C_D > C_P > \pi L$ | *D* | happens | *P* | *D, H(P)* | *D* | *D, H(D)* | *P* | *H(P)* |
| 11. $C_P > \pi L > C_D$ | *D* | *D* prevents | *D* | *D, D* | *D* | *D, D* | *D* | *D* |
| 12. $C_P > C_D > \pi L$ | *D* | happens | *D* | *D, H(D)* | *D* | *D, H(D)* | *D* | *H(D)* |

orderings column of Table 3 is self-explanatory. In the efficiency column the first entry (*P* or *D*) identifies who should do the cost-benefit analysis, and the second indicates what is efficient in terms of accident prevention. For the liability rules, the left-hand column (under "liability") shows who is liable for the costs of the accidents. For C&K Rules *A* and *B*, the right-hand columns (under "outcome") have pairs of entries. The first identifies who will choose to do the cost-benefit analysis. The second indicates what happens in terms of accident prevention, with the same notation as in Table 1.

Now consider C&K Rule *A*. Note first that it induces the right party to do the cost-benefit analysis (because under the strong assumptions laid out above the party with the lower $X$ will do it). Note also that when the defendant is the cheaper analyzer (i.e., $X_P > X_D$), the rule produces efficient outcomes in terms of actual accident prevention. However, if the plaintiff is the cheaper analyzer (i.e., $X_D > X_P$), then it is unsatisfactory in terms of efficient accident prevention. In fact, its shortcomings are identical to the no-liability (for the defendant) rule discussed above, because that is what it reduces to when $X_D > X_P$!

Next consider C&K Rule *B*, which might be viewed as a reverse Hand rule with a who-can-do-the-cost-benefit-analysis-cheaper overlay. Like Rule *A*, and given the strong assumptions listed above, it induces the right party to do the cost-benefit analysis. And in the realm where the plaintiff is the cheaper analyzer (i.e., $X_D > X_P$), it produces efficient outcomes in terms of accident prevention. But if the defendant is the cheaper analyzer, it has all the inefficiencies of the strict liability rule.

These observations suggest hybridizing the two rules. That is, when $X_P > X_D$, use Rule *A*, and when $X_D > X_P$, use Rule *B*. More formally: if $X_P > X_D$, then the defendant is liable if and only if ($X_P > X_D$ and $C_P > C_D$); and, if $X_D > X_P$, then the plaintiff is liable if and only if ($X_D > X_P$ and $C_D > C_P$). However, this is logically equivalent to a wonderfully simple rule: The defendant is liable if and only if $C_P > C_D$. This rule, somewhat similar but not identical to the Galena rule, is the discrete analog of what Brown calls the rule of relative negligence.[25] The relative negligence rule is really comparative negligence subject to an all-or-nothing constraint. The court decides which party was more negligent (in the sense of having a lower cost of prevention), and then it apportions damages not in proportion to degree of fault, but entirely to the party more at fault.[26]

The relative negligence rule has several virtues. Number one is its simplicity: It only requires examination of the prevention costs of the two parties. Expected losses from the accident can be ignored. Two, it assigns liability in the obvious way: to the party with the lower prevention costs. Three, it is efficient in terms of accident prevention under all possible cost orderings. Its first vice, in the present context of Calabresi and Klevorick rules, is that it entirely submerges the *X*s. They are now irrelevant to liability. Its second vice is that, as far as we know, it is not used anywhere.

## IV. Concluding Remarks and Possible Extensions

We can make a few final observations. First, is the discrete yes/no nature of this tort liability model more or less realistic than the continuous models of Brown and his followers? The answer is: It depends. It is easy to imagine scenarios in which the plaintiff and the defendant can spend continuously varying amounts of money on precaution. In the *U.S. v. Carroll Towing Co.* case, for example, Connors Co. might arguably have varied the wages of its bargee, making precaution expenditures continuous. On the other hand, what mattered most to Judge Hand was whether or not the bargee was aboard—a dichotomous variable. As we indicated at the beginning of this paper, there are many other cases one can conceive of where it is crucial that a defendant decides to do, or not do, one thing.[27]

Second, in the discrete model of this paper we find certain rules to be inefficient, rules that seem to be efficient in the continuous models. In particular, both simple negligence and negligence with contributory negligence as a defense are inefficient under certain cost orderings in our model, whereas they are efficient in Brown-type models.[28] The implication is that efficiency or nonefficiency of a negligence rule depends on whether or not variables like precaution are continuous or discrete.

Third, the model of this paper allows us to make some observations about the universe of all conceivable liability rules. Insofar as a liability rule in the Section II model is simply a specification of who, between two parties, must bear the burden of accidents under each of the six possible cost orderings shown in Table 2, the number of possible liability rules is $2^6 = 64$. We analyzed just seven of them in Section II. We can determine also the number of liability rules that result in the *efficient* outcome under all possible cost orderings: It is clear that efficiency requires that the plaintiff be liable on line 1 of Table 2, where $\pi L > C_D > C_P$, and that the defendant be liable on line 2, where $\pi L > C_P > C_D$, because otherwise accidents would be prevented by the higher cost preventer. On line 3, where $C_D > \pi L > C_P$, it is clear that *P* must be liable, because otherwise the accidents will not be prevented, although they should be prevented. Similarly, on line 5, where $C_P > \pi L > C_D$, it is clear that *D* must be liable, because otherwise accidents that

[25] Brown, *supra* note 3, p. 329.

[26] For an analysis of other comparative negligence rules, see the Mathematical Appendix.

[27] Mark F. Grady, in "Untaken Precautions," 18 *Journal of Legal Studies* 139 (1989), observed that rather than perform complicated cost-benefit calculations on a continuum of potential actions, judges identify a limited number of specific precautionary actions that the parties could have taken and then apply the Hand formula to determine liability. He emphasized, *id.* p. 139, that "[t]he key question the courts ask is what particular precautions the [plaintiff or] defendant could have taken but did not."

[28] But cf. *supra* note 12.

should be prevented will happen. In the cases of lines 4 and 6, however, the accidents should happen, and making either $P$ or $D$ liable will not induce either to (inappropriately) prevent them. Hence, there are exactly $2^2 = 4$ efficient liability rules.

In Section II we examined two of the efficient liability rules, corrected negligence with contributory negligence (also known as the Galena rule), and the corrected reverse Hand rule. A third, the rule of relative negligence, was revealed in Section III. The reader is invited to examine the remaining one, which we would name the *perverse efficient rule*. It makes $D$ liable on line 4 of Table 2 and $P$ liable on line 6.

Fourth, this model could be easily expanded to deal with punitive damages (set at, say, a multiple of compensatory damages $L$). The introduction of punitive damages would allow a third type of inefficiency, that of the defendant preventing accidents that ought to be allowed to happen. The reverse Hand rule of Calabresi and Hirschoff, and the strict liability rule, would be especially likely to show this inefficiency. For instance, assume that $L = \$1{,}000{,}000$ and $\pi = 1/100{,}000$, so $\pi L = \$10$. (These are numbers that are of appropriate orders of magnitude for some fatal risks.) Suppose that $C_P = \$100$ and $C_D = \$20$. The efficient outcome is for the defendant (and, of course, potential plaintiffs) to let the accidents occur, and that is the outcome under the reverse Hand and strict liability rules. But if punitive damages are added to compensatory damages at, say, a multiple greater than 1, the defendant will see expected damages (compensatory plus punitive) in excess of \$20. Therefore, under those rules, he will prevent accidents that ought to be allowed to occur. This is an inefficiency of type 3. Note that punitive damages only can be imposed on the defendant under Anglo-American law, so that it is only possible for the defendant to overspend on precaution.

Fifth, and finally, the model could be expanded without too much difficulty to allow for two or more defendants. This would allow analysis of joint and several liability, deep and shallow pockets among defendants, and similar interesting complications.[29]

## Mathematical Appendix

Here we generalize the model in the text. Let $i = 1, 2, \ldots, n$ be the parties to a suit. As before, parties are risk neutral and know the liability rule costlessly enforced by the courts. Party $n$ is the plaintiff; the rest are defendants. Each party may take precaution, incurring a cost $c_i > 0$, or do nothing, incurring 0. Denote these alternatives as elements $a_i$ from the set $A_i = \{c_i, 0\}$. The cross-product $A_1 \times A_2 \times \cdots A_n = \mathcal{A}$, is the set of possible strategies.

The plaintiff faces an expected money loss function, $L\colon \mathcal{A} \to \Re_+$, where $\Re_+$ is the nonnegative real line. As before, if any party chooses to take precaution, plaintiff's expected losses are zero. If no party takes precaution, expected losses are positive. Denote expected losses when no party takes precaution by $\ell$.[30] Then the expected loss function takes the form

$$L(a_1, a_2, \ldots, a_n) = \begin{cases} \ell > 0 & \text{when } a_i = 0 \text{ for } i = 1, 2, \ldots, n, \\ 0 & \text{when } a_i = c_i \text{ for some } i. \end{cases} \tag{1}$$

Combining $\ell$ with each party's cost of precaution $(c_1, c_2, \ldots, c_n)$ results in an $n+1$-dimensional cost vector $c = (\ell, c_1, c_2, \ldots, c_n)$. Without significant loss of generality, assume, as before, that the $c_i$ and $\ell$ are distinct. There are $(n + 1)!$ ways to order the

[29] The Mathematical Appendix deals with some of these complications.

[30] Note that $\ell$ corresponds to $\pi L$ in the text. We drop the redundant notation here.

entries in $c$. Let $\mathbb{O}$ denote the set of these cost orderings. An element $o$ in $\mathbb{O}$ is an $n+1$-vector of indices ($\ell$ is indexed by 0). For example, in the two-party model of the text $\mathbb{O} = \{(0, 1, 2), (0, 2, 1), (1, 0, 2), (1, 2, 0), (2, 0, 1), (2, 1, 0)\}$, as illustrated in Table 1. That is, in line 1 the ordering is (0, 1, 2), and in line 6 it is (2, 1, 0). $\mathbb{O}$ has six elements, because $n = 2$ and $(2 + 1)! = 6$.

### *Liability Rules, Equilibria and Efficiency*

When assigning liability in a tort case the court in effect decides how to distribute the plaintiff's losses among the $n$ parties. A *liability assignment* is thus a vector $x$ in $\Re^n$, with the restriction that the entries in $x$ sum to 1. Let $X$ be the set of all possible liability assignments, i.e., $X = \{x \in \Re^n \mid \sum_{i=1}^{n} x_i = 1\}$. Each entry $x_i$ in the vector $x$ corresponds to the fraction of the loss borne by party $i$. For example, if $n = 2$ and $x = (½, ½)$, then the plaintiff and the defendant each bear 50% of the losses originally borne by plaintiff. If $x = (1, 0)$, then the defendant bears 100%.

In theory nothing prevents some of the individual liability assignments from taking negative values or values greater than 1. For example, if $n = 3$ and $x = (1, 1, -1)$, defendants (Parties 1 and 2) each pay full damages to the plaintiff (Party 3). The plaintiff is compensated twice, and therefore gains from the accident. Alternatively, if $x = (2, 0, -1)$, Defendant 1 pays compensatory damages plus punitive damages in the amount 1× compensatory damages. Defendant 2 is not liable, and the plaintiff is again compensated twice.

The court takes into account the cost ordering $o$ when making a liability assignment. A *cost-ordering-based liability rule* (or *liability rule* for short) is a vector-valued function $r: \mathbb{O} \to X$. (We write $r(o) = x$.) That is, given a cost ordering $o$, a liability rule $r$ distributes the losses from an accident among the parties according to the liability assignment $x = (r_1(o), r_2(o), \ldots, r_n(o))$. If no one takes precaution to avoid accidents, the losses to party $i$ are $r_i(o)\ell$; and by the definition of a liability assignment, $\sum_{i=1}^{n} r_i(o) = 1$.

There are several different types of liability assignments. The most general definition of a liability assignment, with $x \in X$, allows for both fractional liabilities and liabilities greater than 1, and so allows for both comparative negligence and punitive damages. In the text, however, all liability assignments put 100% of accident losses on a single party. Here we refer to such assignments as *simple liability assignments*. These are vectors $x \in X_s = \{x \in X \mid x_i = 1 \text{ and } x_{-i} = 0, \text{ for some } i\}$.[31]

To allow for splitting losses, but to disallow punitive damages, we define *comparative negligence liability assignments*. These are vectors $x \in X_c = \{x \in X \mid 0 \leq x_i \leq 1 \text{ for all } i\}$. Note that $X_s \subset X_c \subset X$.

If a liability rule $r$ maps $\mathbb{O}$ into $X_s$, we call it a *simple liability rule*; if it maps $\mathbb{O}$ into $X_c$, we call it a *comparative negligence liability rule*. Otherwise, we just call it a *liability rule*, and when appropriate, we note the implications of punitive damages (i.e., $x_i > 1$ for some $i$).

We assume that each party $i$ chooses an action $a_i$ to minimize its expected accident costs plus prevention costs. That is, given the liability rule $r$, the ordering $o$ of the cost vector, *and* the actions of the other parties $a_{-i}$, party $i$ chooses $a_i^*$, which satisfies

$$a_i^* = \arg\min_{a_i \in A_i} \{r_i(o)\, L(a_i, a_{-i}) + a_i\} \tag{2}$$

We assume for simplicity that if $r_i(o)\ell = c_i$, party $i$ chooses $a_i = 0$. The function "argmin" refers to the value of $a_i$ that minimizes the criterion function in braces. A *Nash*

[31] $x_{-i} = 0$ means $x_j = 0$ for all $j \neq i$. In general, $-i$ means all $j \neq i$.

*equilibrium* is an outcome $a^*$ in $\mathcal{A}$ where each party minimizes its costs given the actions of every other party. That is, a Nash equilibrium is an outcome in which equation (2) is satisfied for all parties simultaneously. We can now state:

PROPOSITION 1: *A Nash equilibrium exists for every liability rule.*

The proof is simple. Let $I$ = {all parties $i$ for which $r_i(o)\ell > c_i$}. If $I$ is empty, the equilibrium involves everyone taking no action ($a_i^* = 0$ for all $i$). This is a unique equilibrium. On the other hand, if $I$ is nonempty, and if any one person in $I$ takes action while all the rest take no action, the result is a Nash equilibrium. Note that there are as many Nash equilibria as there are members of $I$.

We are most interested in liability rules that always produce efficient outcomes. We call such liability rules *efficient rules*. An *efficient outcome* is an element $\hat{a}$ of $\mathcal{A}$ that minimizes the *ex ante* social cost of accidents. The *ex ante* social cost of accidents is the sum of the plaintiff's expected loss [equation (1)] plus the costs of precaution taken by any of the parties. So $\hat{a}$ is given by

$$\hat{a} = \arg\min_{a \in \mathcal{A}} \left\{ L(a_1, a_2, \ldots, a_n) + \sum_{i=1}^{n} a_i \right\}. \tag{3}$$

For each ordering $o \in \mathbb{O}$, let $m$ denote the minimum cost party, i.e., that party for which $c_m = \min\{c_1, c_2, \ldots, c_n\}$. Then the solution to equation (3) is

$$\hat{a} = (\hat{a}_1, \ldots, \hat{a}_{m-1}, \hat{a}_m, \hat{a}_{m+1}, \ldots, \hat{a}_n) = \begin{cases} (0,\ldots,0,\ c_m,\ 0,\ldots,0) & \text{when } \ell > c_m, \\ (0,\ldots,0,\ 0,\ 0,\ldots,\ 0) & \text{otherwise.} \end{cases} \tag{4}$$

If accidents should be prevented ($\ell > c_m$), they should be prevented by exactly one party (because additional preventers are redundant), and that party should be the minimum cost party. Note that for each $o \in \mathbb{O}$, $\hat{a}$ is unique.

### *Alternative Liability Rules and Efficiency*

*Simple liability.* Recall that a simple liability rule is a mapping $r: \mathbb{O} \to X_s = \{x \in X | x_i = 1$ and $x_{-i} = 0$, for some $i\}$. It turns out that the Nash equilibria resulting from simple liability rules are always unique, and they involve the liable party $i$ taking precaution if and only if $\ell > c_i$, while everyone else does nothing. Thus, given $o$ in $\mathbb{O}$, the unique Nash equilibrium under a simple liability rule is $(a_i^*, a_{-i}^*) = (c_i, 0)$ if $\ell > c_i$, and $(a_i^*, a_{-i}^*) = (0, 0)$ otherwise (where $i$ is the liable party). Note that this equilibrium looks very similar to $\hat{a}$ in equation (4). The only difference is the party taking precaution is the liable party, not necessarily the minimum-cost party. Proposition 2 follows from the previous discussion and the definition of $\hat{a}$:

PROPOSITION 2: *The simple liability rule* $r(o) = \begin{cases} r_i(o) = 1 & \text{for } i = m, \\ r_i(o) = 0 & \text{otherwise,} \end{cases}$ *is efficient.*[32]

Note that when accidents should occur ($c_m > \ell$) it does not matter which party is liable, and, consequently, there are many different efficient liability rules. In fact, it can be shown that there are $n^{n!}$ possible efficient simple liability rules. This quickly becomes

[32]This is the rule of relative negligence referred to in Section III.

a large number, but not nearly so large as the number of *possible* (efficient plus nonefficient) simple liability rules, which is $n^{(n+1)!}$.

*Comparative negligence.* We now consider comparative negligence liability rules. Recall that comparative negligence liability assignments may be fractions between 0 and 1. Thus, in cases where accidents should be allowed to occur, arbitrarily assigning parties fractional liability does not alter their actions (if $c_m > \ell$, then $c_m > x_m\ell$ for $0 \leqslant x_m \leqslant 1$). The unique Nash equilibrium outcome will be a vector of zeros, and it will be efficient.

However, if accidents should be prevented ($\ell > c_m$), arbitrarily assigning fractional liability is not generally efficient ($c_m$ may be larger than $x_m\ell$). For efficiency, we require the minimum cost party to take precaution and the rest to not take precaution. Parties $i \neq m$ will find it not worthwhile to prevent accidents if and only if $c_i \geqslant x_i\ell$ (or $c_i/\ell \geqslant x_i$). If all the $x_i$, $i \neq m$, are thus assigned, and if, in contrast, party $m$'s assignment satisfies $x_m > c_m/\ell$, then the unique Nash equilibrium will be $(a_i^*, \ldots, a_{m-1}^*, a_m^*, a_{m+1}^*, \ldots, a_n^*) = (0, \ldots, 0, c_m, 0, \ldots, 0)$, and it will be efficient.[33]

It will prove useful to partition $\mathbb{O}$ into two mutually exclusive sets. Let $\mathbb{O}_\ell$ contain all those orderings for which accidents should be allowed to occur; and let $\mathbb{O}_{\ell'}$ contain the remaining orderings. The preceding two paragraphs prove the following proposition:

PROPOSITION 3: *On the domain $\mathbb{O}_{\ell'}$, all comparative negligence liability rules are efficient. On the domain $\mathbb{O}_{\ell'}$, any comparative negligence liability rule satisfying the following property is efficient:*

$$r(o) = \begin{cases} r_i(o) > c_i/\ell & \text{for } i = m, \\ r_i(o) \leqslant c_i/\ell & \text{otherwise.} \end{cases}$$

For example, consider the $n = 2$ case. Let $c_1 = 10$, $c_2 = 20$, and $\ell = 100$. Because accidents should be prevented, by restricting liability assignments in accordance with Proposition 3 we can achieve efficiency. Note, however, that the assignments $x_1$ and $x_2$ are not independent (because they must sum to 1). In particular, note that $x_1 > c_1/\ell$ and $x_2 = 1 - x_1 \leqslant c_2/\ell$ imply $x_1 \geqslant \max\{c_1/\ell, 1 - c_2/\ell\}$. In the present example, $x_1 \geqslant \max\{0.1, 0.8\} = 0.8$. Thus assigning, say, 90% liability to the defendant suffices for efficiency (defendant prevents, plaintiff does nothing). Now, suppose $c_2 = 200$. Then $x_1 \geqslant \max\{0.1, -1\} = 0.1$. In this case assigning only 11% liability to the defendant suffices for efficiency.

*Allowing punitive damages.* When punitive damages are allowed, so $x \in X$ rather than $x \in X_c$, further restrictions on liability rules are needed to ensure efficiency. In particular, it is necessary to guarantee that no one prevents accidents that should occur, i.e., when $o \in \mathbb{O}_\ell$. This observation plus the remarks above lead to

PROPOSITION 4: *Let* r *be an arbitrary negligence rule (possibly allowing punitive damages). Then* r *is efficient if it satisfies the following:*

$$\text{When } o \in \mathbb{O}_\ell,\ c_i/\ell > r_i \text{ for all } i.$$

$$\text{When } o \in \mathbb{O}_\ell{}',\ r(o) = \begin{cases} r_i(o) > c_i/\ell & \text{for } i = m, \\ r_i(o) \leqslant c_i/\ell & \text{otherwise.} \end{cases}$$

[33]Contrast this result with the models of Rea, and Haddock and Curran, *supra* note 3, where precaution is a continuous variable for both the plaintiff and the defendant, and *any* arbitrary assignment of comparative liability leads to the efficient amount of care.