APPORTIONING DAMAGES AMONG POTENTIALLY INSOLVENT ACTORS

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In this article, we study how the relative efficiency of rules for imposing liability and apportioning damages among joint tortfeasors is affected by the potential insolvency of some of the actors.1 We focus primarily on the choices between negligence and strict liability and between joint and several liability and nonjoint (several only) liability. This article extends the analysis of our prior study of multiple tortfeasors by relaxing the assumption that all actors are infinitely solvent and are therefore able to satisfy any judgment.2

Like our prior study, this article is motivated in large part by the prob-

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1 This question has been virtually neglected in the law and economics literature. The only wholly pertinent work that we have found is Note, The Case of the Disappearing Defendant: An Economic Analysis, 132 U. Pa. L. Rev. 145 (1983), which we discuss infra, note 91. The problem of injurers’ insolvency is discussed in Steven Shavell, The Judgment Proof Problem, 6 Int’l Rev. L. & Econ. 45 (1986); see also Steven Shavell, Economic Analysis of Accident Law 167–70 (1987). Shavell, however, studies a model in which, though there are many injurers and victims, each injurer interacts with a single, passive victim so that the liability for any given loss need not be apportioned among different actors. His model does not permit the study of the problems that arise when one actor may be forced to bear the unfunded share of another actor’s liability. In our article, these problems are central to Sections III and IV.

There exists an interesting literature on the relationship between remote tort risks and bankruptcy. See, for example, Mark Roe, Bankruptcy and Mass Tort, 84 Colum. L. Rev. 846 (1984); Alan Schwartz, Products Liability, Corporate Structure, and Bankruptcy: Toxic Substances and the Remote Risk Relationship, 14 J. Legal Stud. 689 (1985).


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lems of apportionment raised by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Under CERCLA, liability for the cleanup of hazardous waste sites and for damage to natural resources falls on a large number of potential defendants: the owner of a hazardous waste site, certain prior owners of the site, and transporters and generators of hazardous wastes to the site. Often, in actions to recover cleanup costs or damages under CERCLA, the plaintiff—which usually the federal government or a state—will seek extremely large sums (sometimes exceeding $100 million). As a result, at least some of the actors are likely to be unable to pay their share of the damages. Thus, CERCLA provides a good backdrop against which to study the problem of insolvency.

The surprising success of the tort reform movement in persuading state legislatures to abolish joint and several liability provides a second focus for this article. In our prior study, we concluded that negligence rules are efficient under joint and several liability as long as the standards of care for each of the actors are set at the socially optimal level but that negligence rules are not efficient in the absence of joint and several liability. We also determined that traditional strict liability rules are not efficient whether or not there is joint and several liability. We seek here to ascertain whether these conclusions hold once the assumption of infinite solvency is relaxed, and whether there is merit in the efficiency claims that have been made for the abolition of joint and several liability.

4 Id. § 9607(a) (Supp. IV 1986).
6 Actions under CERCLA are governed by strict liability; see, for example, New York v. Shore Realty Corp., 759 F.2d 1032, 1042 (2d Cir. 1985); City of Philadelphia v. Stepan Chem. Co., 544 F. Supp. 1135, 1140 n.4 (E.D. Pa. 1982), and courts have held that the imposition of joint and several liability is appropriate. See, for example, Colorado v. ASARCO, Inc., 608 F. Supp. 1484 (D. Colo. 1985); United States v. Chem-Dyne Corp., 572 F. Supp. 802, 810–11 (S.D. Ohio 1983). In this article, we analyze these rules as well as rules of negligence and of nonjoint (several only) liability.
7 See Kornhauser & Revesz, supra note 2, at 846–55.
8 See id. at 856–58.
9 See, for example, Note, 1986 Tort Reform Legislation: A Systematic Evaluation of Caps on Damages and Limitations on Joint and Several Liability, 73 Cornell L. Rev. 628, 648–49 (1988). This student commentator argues, “Joint and several liability sometimes forces an actor to pay for costs that do not result from his activity. These forced costs lead to a misallocation of resources because actors spend too much on safety. When states limit joint and several liability, however, actors’ liability corresponds more closely to activity-related costs. Thus, although limiting joint and several liability reduces the tort law’s deterrent effect, it does so in a carefully tailored manner, consistent with the efficiency limitations of deterrence.” Id. at 649.
Unlike in our prior study, we cannot draw any general conclusion about whether, on efficiency grounds, negligence is preferable to strict liability, or whether joint and several liability is preferable to nonjoint (several only) liability. The relative efficiency of these rules depends on the characteristics of the joint tortfeasors: the benefits they derive from their economic activity, the costs their activity imposes on society, and their levels of solvency. Absent very detailed information about these factors, it is not possible to rank the efficiency of the various rules. Neither can we draw any general conclusions about the relative desirability of the various legal rules with respect to two other possible goals of the legal system: the minimization of the amount of unfunded liability (that is, liability that must be borne by the victim), and the minimization of the waste dumped.

This article has two principal purposes. To economists, it provides an analysis of the various types of inefficiencies generated by the potential insolvency of joint tortfeasors. To policymakers, it provides a counterargument to efficiency-based claims in favor of particular rules.10

Section I provides an overview of the legal rules governing the allocation of damages attributable to insolvent actors. Section II describes the model that underlies our analysis. Sections III and IV discuss the types of inefficiencies that arise under negligence and strict liability, respectively, from the potential insolvency of some of the actors. Section V compares the efficiency properties of negligence and strict liability. Section VI briefly explores the implications of this article for the analysis of CERCLA, a question to which we hope to return in the future. A mathematical appendix to a companion working paper provides formal proofs to various propositions.11

I. THE LEGAL REGIME

The legal regime deals with the insolvency of joint tortfeasors12 through four principal types of rules: (1) joint and several liability without contri-

10 See Note, supra note 1; Note, supra note 9, at 648–49.
12 For the purposes of this section, “joint” tortfeasors are tortfeasors who have been held jointly and severally liable at common law. Robert A. Leflar, Contribution and Indemnity between Tortfeasors, 81 U. Pa. L. Rev. 130, 131 n.9 (1932). In general, common-law courts imposed such liability in the case of “indivisible” harms. See, for example, Restatement (Second) of Torts §§ 875, 881 (1977).

In our prior study, we argued that “indivisibility,” as interpreted at common law, did not offer a defensible basis on which to ground a rule of joint and several liability. We then suggested that multiple actors should be characterized as joint tortfeasors if and only if the harm caused by each actor increases the harm caused by the others. See Kornhauser &
bution, (2) joint and several liability with legal contribution, (3) joint and several liability with equitable contribution, and (4) nonjoint (several only) liability. We define these rules in order of historical vintage.

A. Joint and Several Liability without Contribution

The common law did not recognize the right to contribution among joint tortfeasors, and several jurisdictions still maintain this rule. Absent a right to contribution, if multiple tortfeasors are held jointly and severally liable for a single harm, the plaintiff can enforce the judgment against any single tortfeasor, or against any group of tortfeasors. The only constraint on the plaintiff is that he cannot recover more than his judgment. Under this rule, the plaintiff can recover the full judgment as long as the aggregate solvency of the defendants held jointly and severally liable is at least as large as the size of the judgment.

Under a rule of joint and several liability without contribution, the optimal strategy for a plaintiff may well be to attempt to enforce the full judgment against the defendant with the highest solvency and to turn to other defendants only if the most solvent defendant cannot satisfy the

Revesz, supra note 2, at 850–55. In the subsequent sections, we apply this criterion of interdependence.

Our previous study showed that, in the absence of insolvency, our definition of joint torts corresponds exactly to the class of cases in which a rule of joint and several liability is necessary to induce efficient outcomes under negligence (with the standards of care set optimally). In what follows, we argue that this coincidence between our criterion for joint torts and the efficiency of joint and several liability does not hold when actors are potentially insolvent.

13 While the terms “legal” and “equitable” contribution arise primarily among co-obligors, see infra note 18, we believe that they also provide a convenient shorthand in the case of contribution among tortfeasors.


15 In 1981, there were apparently eleven states that did not recognize any right to contribution among negligent tortfeasors. See Northwest Airlines, Inc. v. Transport Workers Union, AFL-CIO, 451 U.S. 77, 87 n.17 (1981); see also, for example, Gomeau v. Forrest, 176 Conn. 523, 524, 409 A.2d 1006, 1007 (1979). Moreover, the common-law rule denying contribution has generally not been modified for intentional tortfeasors. See Restatement (Second) of Torts, supra note 12 § 886A and comment j.

The federal courts have declined to fashion common-law rules of contribution except where Congress has empowered them, explicitly or implicitly, to develop a federal common law; there is, therefore, no right to contribution under the antitrust laws, Texas Indus., Inc. v. Radcliff Materials, Inc., 451 U.S. 630, 642–46 (1981); and Title VII and the Equal Pay Act, Northwest Airlines, supra, at 91–98. But where the courts have found that Congress intended the development of common-law rules, they have recognized a right of contribution among joint tortfeasors. See United States v. Reliable Transfer Co., 421 U.S. 397, 409 (1975) (admiralty); Colorado v. ASARCO, Inc., supra note 6, at 1484, 1486, 1490 (CERCLA); United States v. Chem-Dyne Corp., supra note 6, at 802, 809 (same); see also 42 U.S.C. § 9613 (f)(1) (Supp. IV 1986) (express right of contribution under CERCLA).
whole judgment. In this way, the plaintiff is likely to minimize the transaction costs of litigation.

A single defendant who must satisfy the whole judgment bears not only the share of the damage attributable to her actions but also the shares attributable to other solvent tortfeasors and the shares attributable to the insolvent tortfeasors. Similarly, when the judgment is enforced against several defendants and is satisfied in full, it is these defendants, rather than the plaintiff, who bear the shares of the insolvent defendants.

B. Legal and Equitable Contribution

Since the beginning of the century, many common-law courts have recognized a right to contribution among joint tortfeasors. Moreover, in several states, the no-contribution rule of the common law was overruled by statute. Two different sets of rules emerged. Under one rule, which we call joint and several liability with legal contribution, a tortfeasor who satisfies more than her share of the judgment can seek contribution from other tortfeasors, but only for their shares of the judgment. The tortfeasor who satisfied the judgment, however, must bear the shares of tortfeasors who are insolvent. Under the other rule, which we call joint and several liability with equitable contribution, the tortfeasor who satisfies the judgment can seek contribution from solvent tortfeasors not only for the shares attributable to such tortfeasors but also for the apportioned shares of tortfeasors who are insolvent.

These two contribution rules can be illustrated by means of a simple example. Suppose that there are three joint tortfeasors, A, B, and C, who

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16 See, for example, Ellis v. Chicago & N.W.R. Co., 167 Wis. 392, 167 N.W. 1048 (1918); Goldman v. Mitchell-Fletcher Co., 292 Pa. 354, 141 A. 231 (1928); see also Restatement (Second) of Torts § 886A comment a (1977).


18 Similar rules govern the contribution among co-obligors: in an action at law for contribution, recovery against any defendant would have been limited to the proportionate share of each, independent of the question whether any of the other contributors were insolvent or without the state. In equity, the contributor or co-surety would be liable to contribute to the payment of his proportionate share of any co-surety insolvent or beyond the reach of process. Johnson v. Tennessee Oil, Gas & Mineral Development Co., 73 A. 60, 61 (N.J. Chanc. 1909); see Moody v. Kirkpatrick, 234 F. Supp. 537, 542 (M.D. Tenn. 1964) ("[T]he law courts . . . develop[ed] the rule that each co-obligor is liable only for his aliquot portion of the common debt, no consideration being given to the insolvency of other co-obligors. The rule in equity, however, based on the maxim that equality is equity, is that the common liability must be apportioned among the solvent co-obligors.") (citations omitted).
caused 50, 30, and 20 percent of the plaintiff’s damage, respectively.19 Assume that A and B are each sufficiently solvent to bear the full loss of $1,000, but that C is wholly insolvent. Of course, under a rule of joint and several liability without contribution, if the plaintiff enforces the judgment against A, A will bear the full damage of $1,000; likewise, if the plaintiff enforces the judgment against B, B will bear the $1,000.

Under a rule of joint and several liability with legal contribution, if the plaintiff enforces the judgment against A, A can seek contribution from B for B’s share, which is $300. Thus, A would bear $700, which is her share of $500 plus C’s share of $200, whereas B would bear her own share of $300. If, instead, the plaintiff enforces the judgment against B, B could seek contribution from A for A’s share of $500. In this case, A would bear only her share of $500, whereas B would also bear $500—her share of $300 plus C’s share of $200.

In contrast, under joint and several liability with equitable contribution, C’s share would be apportioned between A and B whether or not the plaintiff enforced the judgment against A or B. If the plaintiff enforces the judgment against A, A could recover from B not only B’s own share of $300 but also B’s equitable portion of C’s share, which is determined in proportion to A’s and B’s own shares. Thus, B would also be liable for 3/8 of C’s share of $200, which is $75. Actor A would then recover $375 from B, therefore bearing $625. If, conversely, the plaintiff enforces the judgment against B, B can recover from A not only A’s share of $500 but also A’s equitable portion of C’s share, which is $125—3/8 of $200. Thus, under joint and several liability with equitable contribution, A bears $625 and B bears $375 regardless of how the plaintiff enforces the judgment.20

19 We assume, in this section, that liability is apportioned in proportion to fault, as opposed to pro rata. See text accompanying note 49. The types of rules discussed, however, would exist also under pro-rata contribution.

20 For cases adopting this approach, see, for example, Bracket v. California, 180 Cal. App. 3d 1173, 226 Cal. Rptr. 1 (1st Dist. 1986); Paradise Valley Hosp. v. Schlossman, 143 Cal. App. 3d 87, 191 Cal. Rptr. 531 (4th Dist. 1983); Coney v. J. L. G. Indus., Inc. 97 Ill. 2d 104, 454 N.E.2d 197, 206 (1983); Arctic Structures, Inc., 605 P.2d 426, 432 (Ala. 1979). For commentary favoring equitable contribution, see, for example, Glanville L. Williams, Joint Torts and Contributory Negligence § 48 (1951).

Among co-obligors, the principle of equitable contribution is now well established. See, for example, Mailliard v. Heffernen, 418 N.W.2d 85, 86–87 (Iowa App. 1987); Moody v. Kirkpatrick, supra note 18, at 542–43; Manning v. Campbell, 204 N.Y.S.2d 718 (N.Y. Sup. Ct. 1960); Lorimer v. Julius Knack Coal Co., 224 N.W. 362 (Mich. 1929).

While under a rule of equitable contribution, the shares of the various defendants are not affected by the plaintiff’s decision to enforce the judgment against one defendant, this decision affects the allocation of transaction costs. Indeed, the party against whom the plaintiff enforces the judgment must bear the transaction costs of seeking contribution.
Under either legal or equitable contribution, the plaintiff can recover the full judgment as long as the aggregate solvency of the joint tortfeasors exceeds the amount of the judgment. Thus, from the perspective of the plaintiff, the introduction of a right to contribution does not alter the fundamental characteristic of the traditional common-law rule.\textsuperscript{21} Moreover, both forms of contribution ameliorate the harshness of this rule. But as the preceding example illustrates, while under legal contribution—as under the absence of a right to contribution—the plaintiff’s decision on how to enforce the judgment affects the distribution of losses, under equitable contribution it does not. Finally, the differences between legal and equitable contribution arise only where there are more than two joint tortfeasors. With only two tortfeasors, if one is insolvent and the other is not, the solvent tortfeasor will bear the full damage regardless of the right to contribution.

During the past few decades, there has been a distinct trend toward the use of rules of equitable contribution. For example, the Uniform Contribution among Tortfeasors Act, which was promulgated in 1955 and has since been adopted by eighteen jurisdictions, was ambiguous on the question of how to apportion, among solvent tortfeasors, the shares of insolvent tortfeasors. While it stated that “principles of equity” shall control,\textsuperscript{22} it did not provide a conclusive answer on how to treat three tortfeasors subject to pro rata shares,\textsuperscript{23} where one is insolvent:

Suppose that the plaintiff is injured by the negligence of A, B, and C. A pays a judgment, and C is wholly insolvent. Should A’s right to contribution from B amount to one-third of the judgment or one-half? It has been pointed out that there are difficulties of proof of insolvency, and that the situation requires at least three tortfeasors and will seldom arise. It has also been argued that it is better to let A recover only one-third from B and take his chances on C’s insolvency, rather than litigate the issue between A and B, with further suits to follow if he turns out later to have any money. The courts in contract situations have dealt satisfactorily with such situations and it is not only difficult but unwise to try to state an express rule dealing with all the equitable situations which may arise.\textsuperscript{24}

\textsuperscript{21} Of course, there are some differences. For example, given a right to contribution, a defendant might file a third-party action and impale defendants whom the plaintiff has not sued. Several courts have faced the question whether the third-party actions under CERCLA can be tried together with the plaintiff’s primary action. See, for example, O’Neil v. Picillo, 682 F. Supp. 706, 725–26 (D.R.I. 1988) (severing actions); United States v. Stringfellow, 661 F. Supp. 1053, 1060–61 (C.D. Cal. 1987) (same).
\textsuperscript{23} See note 19 supra.
In this example, of course, A would recover from B one-third of the judgment under a rule of legal contribution and one-half of the judgment under a rule of equitable contribution.

In contrast, the Uniform Comparative Fault Act, which was approved in 1977 and amended in 1979, and which has since been adopted by two jurisdictions, provides not only a clear right to contribution for an insolvent defendant’s share but also a procedure to vindicate this right. Section 2(d) states, ‘‘Upon motion made no later than [one year] after judgment is entered, the court shall determine whether all or part of a party’s equitable share of the obligation is uncollectible from that party, and shall reallocate any uncollectible amount among the other parties . . . according to their respective percentages of fault. The party whose liability is reallocated is nonetheless subject to contribution and to any continuing liability to the claimant on the judgment.’’ Similariy, the Restatement (Second) of Torts, in a comment to a section adopted in 1977, provides that ‘‘if one tortfeasor’s equitable share turns out to be uncollectible it should be spread proportionately among the other parties at fault.’’

The distinction between legal and equitable contribution also arises in cases in which the plaintiff is liable for a portion of the damage. For example, Ambriz v. Kress posed the question whether it is ‘‘ever proper for a plaintiff, along with other solvent defendants, to share in the shortfall caused by an insolvent defendant.’’ In that case, the jury apportioned responsibility among the parties by assessing the following percentages of comparative negligence: 20 percent to the plaintiff, 70 percent to an insolvent defendant, and 10 percent to a solvent defendant. The solvent defendant argued that the plaintiff should bear two-thirds of the insolvent defendant’s shortfall, and that the solvent defendant should bear the other third, as this allocation was consistent with the relative fault of the actors. The court accepted this argument, thereby extend-

26 Restatement (Second) of Torts § 886A comment i (1977). Another comment to the same section, however, is somewhat more ambiguous: ‘‘[W]here there are three tortfeasors and one of them is clearly insolvent or is beyond the jurisdiction, the amount of contribution fairly allowable between the other two may reasonably be affected and the court may be expected to do what is fair and equitable under the circumstances.’’ Id. § 886A comment c (emphasis added).
28 Id. at 966.
29 Id. at 966–67.
30 Id. at 967.
31 Id. at 968–69, 196 Cal. Rptr. at 420–21; see also American Motorcycle Ass’n v. Superior Court, 20 Cal. 3d 578, 613–14, 146 Cal. Rptr. 182, 205, 578 P.2d 899, 922 (1978) (Clark, J., dissenting).
ing the principle of equitable contribution to cover situations in which the plaintiff is negligent. This approach is followed by the Uniform Comparative Fault Act, which states that courts “shall reallocate any uncollectible amount among the other parties, including a claimant at fault”\(^{32}\) (emphasis added).

C. Nonjoint (Several Only) Liability

One of the central platforms of the tort reform movement in the 1980s has been the statutory abolition of joint and several liability.\(^{33}\) This movement has been fueled in large part by the perceived unfairness of holding defendants, whose fault is small, liable for a large portion of the judgment where the more culpable defendants are insolvent.\(^{34}\)

Some states have eliminated joint and several liability for noneconomic damage.\(^{35}\) Other states have drawn a distinction between more culpable


\(^{33}\) See Note, supra note 9, at 635–37.

\(^{34}\) See, for example, Cal. Civ. Code § 1431 (West Supp. 1988) (“Some governmental and private defendants are perceived to have substantial financial resources or insurance coverage and have thus been included in lawsuits even though there was little or no basis for finding them at fault.”); Note, supra note 9, at 636 (“Assume that the jury finds the driver ninety-nine percent responsible for the passenger’s injuries and the municipality only one percent responsible. If the driver is insolvent, the city will have to pay the entire judgment.”).

In Gehres v. City of Phoenix, 156 Ariz. 484, 753 P.2d 174 (1987), the jury found that an insolvent defendant bore 95 percent of the fault, and that two solvent defendants bore 3 and 2 percent of the fault, respectively. The court entered a judgment of joint and several liability against all defendants. Id. at 485, 753 P.2d at 175. It rejected the argument raised by the two solvent defendants that it was unconstitutional to hold them responsible for the full damage, given their small degree of fault. Id. at 487–88, 753 P.2d at 177. The City of Phoenix, one of the solvent defendants, also challenged unsuccessfully the trial court’s ruling that the jury disregard the following argument: “If you find the City of Phoenix 1 percent at fault in this case, 1 percent, it is conceivable that we can pay the entire verdict. I give that to you only for your consideration. I ask you to apportion the fault in the way that you find it, but don’t be misled and believe that you’re apportioning the damages, because you’re not.” Id. at 486, 753 P.2d at 176.

and less culpable tortfeasors and have abolished joint and several liability for the less culpable defendants. Some states have abolished joint and several liability against only certain defendants. Other states have eliminated joint and several liability but created certain exceptions in which this rule is retained. And yet other states have gone further and abolished joint and several liability entirely.

Under nonjoint (several only) liability, it is the plaintiff, rather than the solvent defendants, who must bear the shares of the insolvent defendants. Recall the example in which the solvent defendants A and B were, respectively, 50 and 30 percent at fault, the insolvent defendant C was 20 percent at fault, and the total damage was $1,000. In the absence of joint and several liability, the plaintiff can recover $500 against A, $300 against B, and cannot be compensated for C’s share of $200.

II. The Model

We begin this section with a brief description of the model of our prior study, which did not account for the possibility of insolvency, and set forth the conclusions that we drew from it. Then, we present the modifications necessary to account for insolvency and describe the principal features of the model that underlies this article. The section concludes with a discussion of the adequacy of our model of insolvency. As in our previous study, we develop the model largely in the context of the disposal of hazardous waste, but the analysis of insolvency presented here applies more generally to any situation in which actors face potential liability in excess of their ability to pay.

36 See, for example, Alaska Stat. § 09.17.010 (Supp. 1987); Iowa Code Ann. § 668.4 (West 1987) (no joint and several liability for defendants who bear less than 50 percent of the fault); Mo. Ann. Stat. § 538.230 (Vernon Supp. 1987) (in medical malpractice cases, defendant “shall be jointly liable only with those defendants whose apportioned percentage of fault is equal to or less than such defendant”); Tex. Civ. Prac. & Rem. Code Ann. § 33.013 (Vernon 1988) (no joint and several liability for defendants less than 20 percent of fault; in some actions joint and several liability maintained if defendant’s fault is greater than plaintiff’s).

37 See, for example, Minn. Stat. Ann. § 604.02(1) (West Supp. 1988) (if fault of state or municipal defendants is less than 35 percent, “it is jointly and severally liable for an amount no greater than twice the amount of fault’’); W. Va. Code § 29-12A-7 (1986) (joint and several liability eliminated against political subdivisions).


40 In addition, the plaintiff must expend the additional transaction costs of enforcing the judgment against two defendants. Under joint and several liability, in contrast, a plaintiff can enforce the full judgment against a single defendant, provided that this defendant is sufficiently solvent.
A. The Basic Model without Insolvency

Imagine a situation in which several manufacturers dump their wastes at a single landfill. The actors benefit from this dumping because the wastes are the by-product of profitable economic activity.41 At some time in the future, these wastes will leak into the environment and cause serious damage, including, perhaps, the contamination of groundwater supplies. For ease of exposition, we think of this damage as the cost of cleaning up the landfill and the surrounding area affected by the release.

The damage caused by a release is a “social” loss because it does not fall directly on the dumpers absent a legal provision shifting the liability to them. Instead, it falls on the victim that would have legal responsibility for the cleanup, or, alternatively, that would suffer the consequences if the problem were left unattended.42 Under our model, each dumper chooses the amount of waste that she will dump; a larger amount will produce a larger benefit to the actor but will also increase the social loss.43

The optimal amounts of waste chosen by each actor are those that maximize the social objective function: the sum of the benefits derived by the actors minus the social loss.44 An economically rational dumper, how-

41 Throughout the exposition, we often refer to an actor’s level of care. In our hazardous waste context, this level is equivalent to the amount of waste that the actor dumps, where more waste implies less care.

42 Under CERCLA, the victim is often the federal government, which will undertake cleanups if “there may be an imminent and substantial endangerment to the public health or welfare or the environment because of an actual or threatened release of a hazardous substance from a facility.” 42 U.S.C. § 9606(a) (1982).

43 The analysis assumes that the release will occur for certain (though the amount of the damage might be discounted back from the date on which it will occur). See assumption 2 of the appendix to Kornhauser & Revesz, supra note 11. That analysis, however, applies also to other cases, including ones in which there is a fixed probability of a loss but where the damage depends on the amount of waste dumped. See Kornhauser & Revesz, supra note 11, n.89.

44 If we regard the actors in the model as firms, then each actor’s benefit function understates the social benefits from waste generation. Private benefits are less than social benefits because a firm’s private benefits include only its profits and ignore the consumer surplus from the activity. In the absence of the external costs of cleanup of the waste, the discrepancy between private and social benefits implies that firms will produce less than the socially optimal levels of waste. The externality of cleanup costs then might mitigate, in part, the adverse welfare effects of the discrepancy between private and social benefits. A similar discrepancy arises in the conventional model of torts if the actors are firms that choose activity levels.

A reinterpretation of the model may restore the equivalence between social and private benefits. Suppose that each of the two “actors” is an industry, each using the identical waste as an input. If each industry is competitive, the market would, absent the cleanup costs, choose the welfare-maximizing price and quantity. Put differently, competitive markets will adequately “represent” the social benefits. The presence of the joint cleanup costs would then have the distorting effects described in this article.
ever, does not decide how much waste she will dump based on the social objective function. Instead, she seeks to maximize her private objective function: the benefit that she derives from the activity that leads to the production of the waste minus whatever share of the social loss the legal regime allocates to her.

The share of the social loss borne by each dumper depends both on the liability rule and on the apportionment rule used to divide the social loss among the joint tortfeasors. We consider two liability rules: negligence and strict liability.45 Negligence rules define a standard of care; if a dumper meets her standard of care, she will bear no portion of the social loss.46 Under traditional strict liability rules, in contrast, a dumper will bear some portion of the social loss regardless of her level of care. Thus, a strict liability rule can be thought of as a negligence rule in which the standard of care is zero, so that the standard is always violated.

The second factor that determines each dumper's share of the social loss is the apportionment rule. Because any portion of the social loss that is not borne by the dumpers falls on the victim, this rule determines not only how the joint tortfeasors divide the social loss among themselves but also the victim's share of the damage, which is the total damage minus the sum of the shares of this damage that are paid by the dumpers.

In our previous study, we developed a taxonomy of eight classes of apportionment rules that resulted from three dichotomies: (i) full versus partial liability; (ii) unitary versus fractional shares; and (iii) fixed versus proportional shares. These distinctions can be summarized as follows:

i) Under a full liability rule, the maximum amount for which the negligent actors can be liable in the aggregate is the full social loss. In contrast, under a partial liability rule, this amount is reduced to take account of the loss that would have occurred even if all of the actors had been nonnegligent;47

ii) Unitary share rules correspond to rules of joint and several liability

45 To isolate the issue of apportionment among injurers, we assume that the victim cannot affect the size of that loss. Thus, we deal only with simple negligence rules (rather than negligence rules with contributory negligence) and with simple strict liability rules (rather than strict liability rules with contributory negligence or with dual contributory negligence). See Kornhauser & Revesz, supra note 2, at 871, n.135 (describing rules).

46 In general, if each actor obtains different benefits from producing the waste, each actor should also face a different standard of care. This result is consistent with Judge Learned Hand’s famous formula in United States v. Carroll Towing Co., 159 F.2d 169 (2d Cir. 1947), under which different actors face different standards of care if their burdens of taking care are different. See id. at 173.

47 See Kornhauser & Revesz, supra note 2, at 837–40.
with a right to contribution from other tortfeasors. Fractional share rules correspond to nonjoint (several only) liability; 48 and

iii) Under a fixed-share rule, the share of damages paid by a negligent actor depends only on the number of total actors or the number of negligent actors. Under a proportional shares rule, negligent actors apportion liability according not only to their numbers but also in proportion to their levels of care. 49

We then showed that, for negligence with the standards of care set at the socially optimal levels, any unitary share rule induces actors to dump the socially optimal levels of waste, but fractional share rules do not. 50 Under traditional rules of strict liability, in contrast, any share rule, unitary or fractional, induces an excessive aggregate amount of waste. 51 In addition, we studied the incentive effects of these rules when the standards of care were uncertain, though, on average, optimal, and when the standards of care were certain, though set nonoptimally. Here the relative desirability of the different types of rules proved more complex, though unitary share rules often provided superior incentives. 52

The possibility that some or all of the actors may have insufficient resources to cover the social costs caused by their actions and imposed on them by law greatly complicates the analysis. Consequently, our ambitions in this project are more limited than in our previous study. In what follows, we compare strict liability rules only to negligence rules with the standards of care set optimally. Moreover, we compare only full liability, fixed and unitary share rules to full liability, fixed and fractional share rules.

We have adopted this more narrow focus for several reasons. First, we think it important, when analyzing a legal problem, to separate it into its components. We must first understand how potential insolvency alters behavior in the simple case in which standards of care are set optimally (or at zero for strict liability) before analyzing the more complex cases. Our strategy isolates the problems caused by insolvency from the problems caused by the law’s inability to set standards optimally or with certainty. These strictures also argue for our focus on fixed rather than proportional share rules because, as we know from our prior work, pro-

48 See id. at 841–42.
49 See id. at 842–43.
50 See id. at 847–50.
51 Id. at 856–58. We also proposed an “untraditional” rule of strict liability that induced actors to dump the socially optimal levels of waste. See id. at 858–60.
52 Id. at 862–70.
portional share rules introduce an additional complication. Finally, we deal with full liability rules (rather than partial liability rules) because they have been the primary focus of the law and economics literature.

B. A Model of Apportionment with Potentially Insolvent Actors

We consider two variants of a single model. In one, the level of solvency of each actor is fixed, and each actor chooses only the amount of waste that she will dump. In the other, each actor chooses both her level of solvency and the amount of waste.

1. The Fixed-Solvency Model. In our earlier model, each actor was characterized by her benefit function, that is, by the rate at which care (or waste) was transformed into net benefits (excluding her share, if any, of the social loss). In the current model, each actor is characterized not only by her benefit function but also by her level of “solvency.” An actor’s solvency represents the total amount of assets she has available to offset her share of the social loss.

Under our formulation, the fund against which the actor’s share of the social loss may be charged does not include the benefits that she receives from engaging in the activity. We offer two interpretations of this assumption. First, one might think of an actor’s solvency as a bond that she must post in order to engage in the activity. Recourse against the actor is then restricted to the size of the bond. Alternatively, one might interpret the model as containing an implicit time structure. Benefits accrue to the actor in the present while the social loss occurs (and responsibility for it is apportioned) in the future. If current profits are distributed in the present (when they accrue), then the actor’s solvency has the traditional interpretation of the difference between her assets and her liabilities.

The socially optimal behavior for the actors is that which maximizes the sum of the benefits derived by the actors from their waste levels minus the social loss. In the fixed-solvency model, optimal behavior is independent of the actors’ levels of solvency because neither the benefits derived by the actors nor the social loss depend on the actors’ solvencies.

53 In developing our argument below, we focus on the question of when one party’s insolvency will induce the second party to become insolvent. Because we assume that costs are convex, the incentive structure under proportional share rules should be analogous to those under fixed share rules.

54 For a discussion of the controversy over whether legal theory and the common law dictate partial rather than full liability rules, see id. at 837–40; Mark Grady, A New Positive Economic Theory of Negligence, 92 Yale L. J. 799, 822 (1983); Marcel Kahan, Causation and Incentives to Take Care under the Negligence Rule, 18 J. Legal Stud. 427 (1989).

55 We concede that, on this interpretation, variation in solvencies or bond levels among otherwise identical actors might seem difficult to explain. Also, it might make more sense to consider the size of the bonds as a decision variable for a policymaker.
An economically rational actor, however, does not choose her level of waste by reference to the social objective function. Instead, she seeks to maximize her private objective function: the benefit that she derives from the activity that leads to the production of the waste minus the lesser of (1) her solvency and (2) the share of the social loss allocated to her by the legal regime. In these circumstances, it may prove rational for an actor to choose a level of dumping that will render her insolvent when the social loss is realized and apportioned in the future. Once she decides to become insolvent, the actor will generate waste until her marginal benefit from further dumping is zero, or until some technological limit is reached; we refer to this upper bound on the level of waste generated as $x^H$.

The expansion of an insolvent actor's generation of waste increases the social loss. As we discuss below, under some legal rules, this loss must be borne by other actors. These actors, in response to the insolvent actor, may either restrict their waste and bear larger damages or increase their waste and choose to become insolvent themselves. We seek, among other things, to identify the conditions that create this "domino effect."

The share of the social loss borne by each dumper depends both on the liability rule and on the apportionment rule used to divide the social loss among the actors. The introduction of solvency levels does not affect the structure of negligence rules or strict liability rules, but it does complicate the definition of unitary share rules by giving rise, where there are more than two actors, to the distinction between legal and equitable contribution. As a result, we have proved general results only in the two-actor case. For more than two actors, however, a rule of legal contribution may produce different behaviors than a rule of equitable contribution.

2. A Variable-Solvency Model. The fixed-solvency model can be criticized on the ground that actors with low solvency have a cost advantage over actors with high solvency because they face a smaller liability. Thus, either low-solvency actors would drive out high-solvency actors, or

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56 Under our model, each actor knows the other actor's solvency. This assumption is reasonably plausible in vertical relationships, such as between a generator and a transporter of hazardous wastes. But the assumption is realistic in many horizontal relationships as well. A generator of a particular hazardous waste is likely to know the identity of the other generators who dump at the same site.

57 See text accompanying notes 16–32.

58 A rule of joint and several liability with no contribution will induce behavior different from the other two rules. This behavior will depend on the actors' beliefs about the order in which the victim will levy and execute her judgment. It is plausible that she will levy and execute, first, against the "deepest" pocket and then, if necessary, proceed against the next deepest pocket, and so on. This pattern of enforcement of the judgment puts the greatest pressure on the most solvent actors either to exit the market entirely or to choose insolvency. See text accompanying notes 15–16.

59 See sec. II of appendix to Kornhauser & Revesz, supra note 11.
all actors would restructure their organizations to reduce their solvency. These problems can be addressed by a model that makes the actor’s level of solvency a decision variable. While we discuss some of the features of such a model in this section, we have not attempted to deal with it formally.

The fixed-solvency model reveals the costs to an actor of adding solvency: the possibility of higher losses. But in the fixed-solvency model there is no benefit to higher solvency. In the variable-solvency model, in contrast, higher solvency increases the current benefits derived from a given level of waste. Because higher solvency increases the probability that the actor will meet her current payments, higher solvency enables an actor to reduce her current costs and hence raise her current profits. An actor must balance this benefit against the greater exposure she suffers to future liability.

The social optimum is now characterized not only by each actor’s level of care but also by each actor’s level of solvency. Social welfare, which is the sum of the actors’ benefits less the social cost, is independent of the amount of unfunded liability. Thus, the socially optimal levels of solvency are those which maximize the sum of the benefits that the actors derive from solvency. Given the model’s interpretation of the benefits of solvency as reduced costs of production, the socially optimal level of solvency for each actor minimizes that actor’s current costs of production.60

Once again, an economically rational actor will not make her decision based on the social objective function. Instead, she will take into account the increased future exposure to liability that results by choosing a higher level of solvency, and she will balance this increased exposure against the lower production costs that result from higher solvency.61 Thus, if an actor chooses to be insolvent, she will also select a nonoptimal level of solvency. This nonoptimal choice of solvency implies that current production does not occur at the “efficient” cost.

C. The Nature of Solvency

Because, in this article, we investigate the effect of rules of liability and of apportionment on the incentives of potentially insolvent actors, our analysis rests critically on the model of solvency that we offer. Here, we consider some difficulties in elaborating a concept of solvency and some of the problems that we believe exist with our own approach.

60 See note 61 infra.

61 The actor’s choice depends on more than marginal benefits and marginal costs because she must compare her profits conditional on solvency to her profits conditional on insolvency.
The barest model of solvency would equate it to the economic value of an enterprise. On this view, a firm consists of a set of economic projects, each of which is defined by an expected future flow of costs and benefits. If the discounted present value of that flow is nonnegative, the particular project is solvent. The solvency of a firm, then, consists of the sum of the solvencies of its projects.

This model assumes that perfect capital markets permit the "smoothing" of costs and benefits over time. Consider a project with returns that are certain and have positive net present value. Suppose that costs are incurred at the outset. Perfect capital markets permit the firm to meet its current costs by issuing bonds that will be paid out of future profits.

If the firm cannot borrow against the future profits to pay its current costs, it faces a solvency (or perhaps more accurately, a liquidity) problem until the benefits begin to accrue. But under the assumption of perfect capital markets, the firm will be able to borrow the necessary money. In this simple account, a firm is neither benefited nor hindered by higher solvency.

There are at least three complications that this simple model ignores. First, a problem arises if, as in the hazardous waste context, the flow of profits precedes, rather than follows, the incursion of costs. Of course, if current profits are consumed, they will not be available to pay future costs. An insurance market that allowed current payment for future costs would, if used, smooth the flow of costs and benefits. Such a market, however, will probably not exist because actors who are not required to pay in the present for otherwise future costs, will engage in the project, distribute the current benefits, and become insolvent before the future costs arise. Moreover, there is a danger that firms will engage in projects with negative net present value but then disappear before incurring the debilitating costs. On this account, higher solvency gives rise to greater potential liability but produces no compensating benefits.

Second, projects often have uncertain streams of income. Thus, even though a project's expected net present value might be positive, the actual realization of that value could be negative. For example, a project could consist of a flow of costs that is certain followed by a flow of revenues that is uncertain. The financing of current costs out of simple bonds that are secured by the future flow of revenues will no longer work because it is possible that the future revenue streams will not cover the obligations imposed by the bonds. From this perspective, the creditor of a project would presumably prefer that its debtor own other projects as well be-

62 Alan Schwartz has recently argued that injurers will not insure if the costs attributable to their behavior will be realized only in the distant future. See Schwartz, supra note 1, at 710.
cause an owner with a diversified set of projects will receive a less variable flow of benefits and, hence, present a more desirable debtor than a one-asset debtor. The degree of solvency should thus be related to the diversity of projects in which an actor is engaged.

Third, projects with different investment "commitments" may give rise to different risks. Consider two projects, A and B, in which costs are incurred in period 1 and benefits, which are uncertain, accrue in period 2. Assume that the distribution of benefits in period 2 is identical for both projects. Similarly, assume that the costs attributable to both projects are identical but are incurred differently. In project A, the full costs are borne and consumed in period 1. In project B, however, a large capital investment must be made in period 1 but at the end of period 2 the capital investment will still have a positive value. The costs attributable to project B, therefore, are the difference between the investment made in period 1 and the value of the investment at the end of period 2. If the realization of benefits in project A is adverse, the firm loses nothing beyond the current costs incurred; it has no assets left for the creditors to reach. In contrast, if the realization of benefits in project B is adverse, the present value of the investment constitutes a financial asset that can be attached by the firm's creditors.

Unlike the first extension of the simple account of solvency, which viewed solvency solely in negative terms, the latter two extensions suggest that solvency has both desirable and undesirable characteristics. On

63 Actually, the analysis is even more complex. Arguably, a manager with more diverse projects to monitor may perform less competently on each than a manager who specializes in a single project (or in a set of related projects that have correlated outcomes). Thus, in a diversified firm, each project might have a lower net expected present value even if the firm as a whole has a higher probability of remaining solvent over time. This argument suggests that an optimal level of diversification and, hence, of solvency, exists.

A second difficulty with this explanation of the benefits of solvency must also be confronted. Why does the creditor prefer to lend to diversified debtors rather than to diversify herself and lend a small amount to each of several debtors? Consider two projects, A and B, each of them risky. Assume that they are perfectly but negatively correlated so that, if project A succeeds, project B fails, and vice versa, but that the joint return is positive with certainty. Whether projects A and B are owned jointly by a single firm or by different firms, a creditor will demand an interest rate on each project sufficient to cover the losses from the certain default of one of the two projects. This argument, when generalized to less-than-perfectly correlated projects, suggests that firm diversification has no benefits relative to creditor diversification.

The argument, however, ignores some complications. Most important, the default risk on a project depends in part on managerial conduct. Small creditors, with less at risk, will have less incentive to monitor debtor behavior. In addition, it may be more costly to monitor two projects held separately than two projects held singly.

64 This argument can be seen as a variant of the diversification argument presented in the preceding paragraph. The firm that engages in project B is diversified in that its capital investment is available for another activity at the end of the project.
the one hand, a more solvent firm can be expected to negotiate better terms with its creditors. On the other hand, such a firm will be exposed to higher liability if the outcome of its venture is poor.

Our fixed-solvency model examines exclusively the incentive problem created by a stream of income in which a large cost follows the benefits of a project. Thus, solvency plays an exclusively negative role in this model. In contrast, a variable-solvency model captures the competing effects of solvency. In such a model, higher solvency enables a firm to obtain greater benefits for each unit of waste produced. At the same time, of course, higher solvency increases the firm’s potential future liability.

At first glance, one might wonder why, under the fixed-solvency model, firms would have any solvency at all. Solvency is explainable, however, because even though the model explicitly accounts for only one type of cost—the liability for the dumping—there are, in fact, other inputs to the production of the benefits. Indeed, in the formal model, the benefits are described as net benefits: total benefits minus input costs. But to the extent that input costs must be borne before the benefits accrue, higher solvency might result in better terms for these inputs.

Both models raise the question why firms would not take advantage of

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65 We have discussed the choice of “solvency” in terms of a comparison of its costs and benefits to the firm. One might alternatively have considered the question as one of choosing the optimal capital structure of the firm. The interpretation of solvency in our model as optimal capital structure, however, presents some difficulties which we have not yet completely resolved.

The Modigliani-Miller theorem set out conditions under which the capital structure of the firm has no effect on the firm’s decisions. Franco Modigliani & Merton H. Miller, The Cost of Capital, Corporation Finance, and the Theory of Investment, 48 Am. Econ. Rev. 261–97 (1958). The “irrelevance result” suggests that the level of debt should not alter the expected payments that the firm must make to its creditors; on this account, a firm cannot receive “better terms” from its creditors by reducing its ratio of debt to equity.

Two general responses to the irrelevance result bear directly on our argument. First, if the firm or the creditors have risk or time preferences that the market cannot arbitrage, then the capital structure may matter. Much of our discussion in the text suggests that these factors matter for two types of creditors: suppliers of real goods and services and the residual bearer of the cleanup costs. Second, as discussed in, for example, Michael Jensen & William Meckling, The Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure, 3 J. Fin. Econ. 305 (1976), the capital structure of the firm may affect both managerial incentives and the beliefs about the firm’s profitability to potential capital suppliers. Our discussion, cited in note 63 supra, raises these considerations as well.

More important, in our model, the firm “forcibly” issues debt to the residual bearer of the cleanup costs. In a world with perfect foresight, this prospective debt would determine the terms on which the firm received credit. If all creditors were to be paid at once, large cleanup costs would close the credit market as bankruptcy would be certain. If payments occur periodically and bankruptcy were not sure to occur, the credit terms on market-issued debt would serve to price the periodic payments the firm should make to the residual bearer of cleanup costs. The analysis becomes more complex if firms can adjust their solvencies over time.
the benefits of solvency and then sell off their assets and distribute the proceeds among their shareholders before the liability attaches.\textsuperscript{66} Several impediments to such a sell-off strategy exist. First, one may usefully distinguish a firm’s cash flow or liquidity from its “sunk” capital; the cash flow consists of its flow of current benefits that are easily adjustable to changes in potential liability. In our models, the actors never retain cash flow. Sunk capital, alternatively, consists of assets embodied in physical plant. These assets cannot easily be distributed as current benefits.\textsuperscript{67} It is possible, nonetheless, that an actor could sell the physical capital before she must bear the liability and consume the proceeds (or distribute them to shareholders).\textsuperscript{68} The incentive a firm faces to dissipate its solvency is somewhat mitigated by doctrines permitting the piercing of the corporate veil to reach assets distributed to shareholders, and by doctrines of successor liability.\textsuperscript{69}

Second, it may take time and involve significant costs for a firm to

\textsuperscript{66} For a discussion of the various forces that reduce the probability that a firm will liquidate to avoid future liability, \textsuperscript{66} Mark Roe, Corporate Strategic Reaction to Mass Tort, 72 Va. L. Rev. 1, 7–30 (1986).

\textsuperscript{67} As the discussion in the text suggests, solvency is a complex issue. Even the question of retention of current benefits is more complex than the text suggests. Retained earnings may offer a firm a lower cost of capital than other financing devices. Thus, in the short run, the firm may have an incentive to retain those earnings for short-run investment purposes.

Our discussion also suggests, however, that firms that face potentially crushing liabilities in the future should, other things equal, distribute more of their current profits than those firms that do not face these threats. In the CERCLA context, certain industries, such as the chemical industry, face greater exposure to liability than other industries, such as the film industry. After the introduction of CERCLA, we would expect dividend policies in the two industries to have adjusted differently.

\textsuperscript{68} If an asset can be used only in the activity to which the liability attaches, however, the sale price of the asset will be discounted. First, if the potential purchaser uses the asset to engage in the same activity as the seller, she will face the possibility of liability stemming from her own actions. Second, it is possible that the sale of the asset will be characterized as a merger, and that the purchaser will also be responsible for the seller’s liability under principles of corporate successor liability. See, for example, Smith Land & Improvement Corp. v. Celotex Corp., 851 F.2d 86, 91 (3d Cir. 1988).

\textsuperscript{69} Although courts have been reluctant to pierce the corporate veil in CERCLA actions, they have broadly defined the class of defendants that can be reached as current or past “owner[s] and operator[s]” for the purposes of 42 U.S.C. § 9607(a) (Supp. IV 1986). See, for example, New York v. Shore Realty Corp., 759 F.2d 1032, 1052 (2d Cir. 1985) (“an owning shareholder who manages the corporation” is personally liable); United States v. Northeastern Pharm. & Chem. Co., 810 F.2d 726, 743–45 (8th Cir. 1986).

Our legal regime also places other constraints on an actor’s ability to distribute her solvency before her liability has attached. For example, New Jersey’s Environmental Cleanup Responsibility Act, 13 N.J. Rev. Stat. 13:1K-6, \textit{et seq.} requires sellers of commercial real estate to perform a cleanup of hazardous substances before the sale can go forward. Alternatively, the buyer can undertake to perform the cleanup and must place a performance bond.
reduce its solvency. Consistent with this account, to realize a current cost reduction, an actor must commit to a given solvency for a certain period. If the liability attaches during that period, the actor has no opportunity to dissipate its solvency.

Third, a more sophisticated model would look at sequential decisions on the part of the actors. In each period, actors would determine how to adjust their solvencies given the future stream of benefits and the future liability. Actors would have to balance the benefits in the current period of greater solvency against the additional cost that the solvency imposes if the liability attaches during that period. Such a model is an important subject for further research, but we have not undertaken to study it here.

III. THE INEFFICIENCIES OF STRICT LIABILITY

In our previous study, we investigated the incentives created by strict liability rules when all actors are infinitely solvent. In that context, we described two sources of inefficiency, one that is always present and another that depends on the characteristics of the actors and of the apportionment rules. First, and most important, we noted that, under strict liability, the total amount of waste dumped will exceed the socially optimal amount. The intuition behind this result is most clear for an apportionment rule that allocates the loss equally among identical actors. Under such a rule of apportionment, an actor who contemplates dumping more than the socially optimal level, given that all other actors are dumping at the socially optimal level, bears not the full increase in the damage but only a fraction of that increase. This divergence between the social cost and the actor’s private cost gives the actor an incentive to dump more than the socially optimal level.

The second potential inefficiency in the infinite-solvency case concerns the distribution of the waste among the various actors. The question here is whether a given amount of waste is divided among the actors in the manner that maximizes the sum of the benefits derived by the actors. Often, though not always, total benefits would increase if some waste

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70 See Kornhauser & Revesz, supra note 2, at 856–57.
71 Rules of apportionment that allocate the loss differently than per capita require a more complicated analysis. For certain fixed-share rules, for example, some actors will restrict their output below their (individual) socially optimal level while others will increase their production above this level. Suppose, for example, that one actor must bear the entire loss while the others bear none. The actors free of liability will dump until marginal benefits are zero (or until they reach some technological limit). The loss bearer will restrict her output to below what she should dump at the social optimum but by less than the aggregate increase in the output of the other actors.
were reallocated among the dumpers.\textsuperscript{72} For example, if all of the actors have equal benefit functions but face different fixed shares of the total liability, actors with lower shares will dump more than actors with higher shares, because the dumping imposes lower costs on them. But if the actors are identical, for a given level of wastes, social welfare is maximized if each actor dumps the same amount. Thus, the apportionment rule in this example produces a misallocation among the actors of the total amount of waste dumped.

When actors have finite solvencies, these two inefficiencies may be exacerbated and two additional sources of potential inefficiency may also arise. First, and most obviously, an actor may choose to dump at a level at which she will be unable to bear her share of the social loss. Her insolvency increases the incentive to overproduce waste as she continues to accrue benefits from dumping but does not bear any further costs.\textsuperscript{73} If she were infinitely solvent, she would (in most cases) have borne some fraction of the additional costs imposed by her increased level of waste; once she becomes insolvent, she bears none of the loss. Moreover, as we describe below, one actor’s decision to dump at a level that induces her insolvency may trigger a similar decision on the part of other actors.

Another related source of inefficiency arises when actors choose their levels of solvency as well as their levels of waste. Here, we should view solvency as an input to the production of benefits. When an actor chooses to be insolvent, she distorts her input choice, and the benefits that result from the generation of waste are not derived in the most efficient manner.

\textbf{A. Equal Solvencies}

We begin the study of these types of inefficiencies with the simplest case, one in which two actors have equal benefit functions and equal, fixed solvencies.\textsuperscript{74} We further assume that the rule of apportionment assigns equal shares of the loss to each actor, as long as both are solvent.

There are two possible equilibria to this symmetric problem. Under one, the actors will each dump at the same level that they would have if they had been infinitely solvent; we denote this level as \(x(\infty)\). We refer to

\textsuperscript{72} If infinitely solvent actors have identical benefit functions and face a per capita rule of apportionment, each actor will dump an identical amount of waste. This division will maximize the sum of the benefits derived from dumping the resulting total amount of waste.

\textsuperscript{73} As a shorthand, we sometimes say that an actor chooses to become insolvent. Stated more precisely, we mean that the actor chooses to dump a level of waste that is so high that the actor does not have sufficient solvency to pay for her share of the liability.

\textsuperscript{74} We make the assumption of equal benefit functions solely for ease of exposition. As we show in the appendix to Kornhauser & Revesz, \textit{supra} note 11, none of the qualitative conclusions in this section depends on the assumption.
the resulting equilibrium as the “infinite-solvency” equilibrium and describe it as \( (x(\infty), x(\infty)) \) to indicate that each actor dumps \( x(\infty) \). It follows from the inefficiency of the strict liability rule that \( x(\infty) \) is greater than the socially optimal level, which we call \( x^* \).\(^75\) It also follows, by definition, that the equilibrium \( (x(\infty), x(\infty)) \) is socially less desirable than the equilibrium \( (x^*, x^*) \).

Alternatively, the actors will each dump at the level defined by the technological limit \( x^H \); we assume that \( x^H \) is greater than \( x(\infty) \).\(^76\) We refer to this equilibrium as the “technological-limit” equilibrium \( (x^H, x^H) \). The \( (x^H, x^H) \) equilibrium is socially less desirable than the \( (x(\infty), x(\infty)) \) equilibrium, as it is further from the social optimum.

If the liability that is apportioned to each actor when both actors are dumping \( x(\infty) \) is more than each actor’s solvency, it is clear that the equilibrium will be at \( (x^H, x^H) \). Indeed, by expanding their output from \( x(\infty) \) to \( x^H \), each of the actors will accrue additional benefits but will not be liable for any additional costs, as their solvency will already have been exhausted.

If, in contrast, each actor has sufficient solvency to bear her share of the liability even if both actors were to dump \( x^H \), it is clear that the \( (x(\infty), x(\infty)) \) equilibrium will result. Indeed, in this case, the actors behave as if they were infinitely solvent.

The actors will depart from the \( (x(\infty), x(\infty)) \) equilibrium not only when they would be insolvent if they each dumped \( x(\infty) \) but in other instances as well. Indeed, suppose that the actors expand their output beyond \( x(\infty) \) and become insolvent at some point before reaching \( x^H \). Each actor’s share of the additional liability that results from dumping more than \( x(\infty) \) is higher—up to the point at which each actor becomes insolvent—than the corresponding additional benefit. But beyond this point of insolvency, each actor’s benefits continue to increase but their share of the liability does not.

For some solvency, which we refer to as the critical solvency \( s_* \), given that one actor chooses \( x(\infty) \), the other actor will be indifferent between \( x^H \) and \( x(\infty) \); for any lower solvency, she will prefer \( x^H \) to \( x(\infty) \). But if one actor chooses \( x^H \), the other actor will choose \( x^H \) as well. Indeed, both actors have the same benefit functions and levels of solvency. Thus, suppose that actor 1 prefers \( x^H \) to \( x(\infty) \) when actor 2 chooses \( x(\infty) \). It

\(^75\) As we have stated, the total amount dumped under strict liability is more than the socially optimal aggregate level. Therefore, each actor will dump more than the level that is socially optimal for that actor.

\(^76\) While we refer to this level as a technological limit, an alternative interpretation is the level at which marginal benefits become zero. See text accompanying notes 55–56.
follows, a fortiori, that actor 1 will prefer $x^H$ when actor 2 has chosen $x^H$ rather than $x(\infty)$.\textsuperscript{77}

B. Different Solvencies

We now turn to situations in which the two actors have different, fixed solvencies.\textsuperscript{78} For the purposes of this article, we look only at the particular case in which actor 1’s solvency is zero and examine the properties of strict liability for different values of actor 2’s solvency.\textsuperscript{79} Of course, because actor 1’s solvency is less than the critical solvency $s_x$, actor 1 will dump $x^H$.

We restrict our inquiry in this fashion because it is sufficient to generate our central conclusions: that it is not possible to make general comparisons between unitary share rules and fractional share rules under strict liability, or between strict liability and negligence. Thus, a more general inquiry would in no way affect these conclusions. Moreover, the full analysis is sufficiently complex to require a mathematical treatment, rather than a verbal one.

When the actors have different solvencies, the problem differs from the case of equal solvencies just considered in two important respects. First, the insolvency of one actor can drive to insolvency an actor who otherwise would be solvent. This “domino” effect has important implications for the choice among legal rules.

Second, unitary share rules produce different results than fractional share rules. In the equal-solvency case, we did not need to differentiate between unitary share and fractional share rules because no actor would ever be responsible for a harm attributable to the other. Indeed, either both actors are solvent and each pays her equal apportioned share, or both are insolvent and each pays her equal solvency. But where the solvencies are not equal, it is possible that only one actor (actor 1 in our discussion) is insolvent and, therefore, that under a unitary share rule, actor 2 would have to pay a portion of actor 1’s liability. Under a fractional share rule, in contrast, actor 2 would not be liable for any portion of

\textsuperscript{77} There is a range within which each actor has a solvency greater than $s_x$ in which, in addition to the equilibrium at $(x(\infty), x(\infty))$ there is also an equilibrium at $(x^H, x^H)$. For even larger solvencies, however, the equilibrium at $(x(\infty), x(\infty))$ is unique. See corollaries 1 and 3 of the appendix to Kornhauser & Revesz, supra note 11. In the range within which there are two equilibria, $(x(\infty), x(\infty))$ is Pareto superior to $(x^H, x^H)$. Thus, in the text, we refer primarily to the equilibrium at $(x(\infty), x(\infty))$.

\textsuperscript{78} They continue to have equal benefit functions. See note 74 supra.

\textsuperscript{79} The appendix to Kornhauser & Revesz, supra note 11, provides a comprehensive analysis of the equilibria for all possible pairs of solvencies, and all possible concave benefit functions.
the liability attributable to actor 1. Even under a fractional share rule, however, actor 1’s decision to operate at \(x^H\) will increase the total liability and, therefore, actor 2’s share of this liability.

1. Unitary Share Rules. Recalling that actor 1’s solvency is zero, consider first a case in which actor 2 is infinitely solvent. Under a unitary share rule, actor 2 will be responsible for the whole liability. If actor 1 were dumping \(x^*\), actor 2 would dump \(x^*\) as well, as she would incur the full social cost of departing from \(x^*\). But because actor 1 is dumping \(x^H\), which is more than \(x^*\), actor 2 will dump less than \(x^*\)—an amount that we call \(a\). Therefore, the resulting equilibrium is \((x^H, a)\).

If actor 2 is not infinitely solvent, there are two possible equilibria: \((x^H, a)\) or \((x^H, x^H)\). It is clear that the equilibrium is at \((x^H, a)\) if actor 2 has sufficient solvency to pay for the liability attributable to her if she dumped \(x^H\), which is the full damage caused by dumping a total of \(2x^H\). In contrast, it is clear that the equilibrium is at \((x^H, x^H)\) if actor 2 does not have sufficient solvency to pay for the liability attributable to her if she dumped \(a\), which is the full damage caused by dumping a total of \((x^H + a)\).

But by analogy to the discussion in the case of symmetric solvencies, the equilibrium can be at \((x^H, x^H)\) even if actor 2 has sufficient solvency to pay the liability that results from the equilibrium \((x^H, a)\). Actor 2’s additional liability caused by dumping more than \(a\) is greater than her corresponding additional benefit, up to the point at which she becomes insolvent. But beyond her point of insolvency, she continues to accrue benefits, and her liability does not increase.

We define actor 2’s critical solvency under a strict liability, unitary share rule, given that actor 1 is insolvent, as \(s_{2su}\). This critical solvency is greater than \(s_s\), the critical solvency when both actors have equal solvencies. Indeed, for a given level of dumping, actor 2 must bear a higher liability when actor 1 has zero solvency and is therefore dumping \(x^H\) than where actor 1 is solvent and is dumping \(x(\infty)\). First, for any level of dumping by actor 2, the total liability is greater where actor 1 is dumping \(x^H\) than where she is dumping \(x(\infty)\). Second, when actor 1 has zero solvency, actor 2 is responsible not only for her own share of the liability but for actor 1’s share as well.

Thus, actor 2 exhausts a given solvency at a lower level of dumping when actor 1 is insolvent, leaving actor 2 with a greater range in which she can continue to expand her output with no corresponding increase in lia-

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\(^{80}\) This notation indicates that actor 1 dumps \(x^H\) and actor 2 dumps \(a\). In the text, we deal only with the situation where \(a > 0\); in the appendix to Kornhauser & Revesz, supra note 11, we provide the condition under which this relationship will hold.
bility. As a result, there are instances in which actor 2 would not become insolvent and would not expand her output to $x^H$ if actor 1 were solvent, but where actor 2 becomes insolvent and expands her output to $x^H$ if actor 1 is insolvent. Under this "domino effect," the insolvency of actor 1 is the but-for cause of actor 2's insolvency.

2. **Fractional Share Rules.** Under a fractional share rule, actor 2 will be responsible for half the liability caused by the dumping of the two actors. Whereas under a unitary share rule actors 1 and 2 pay, between them, the full liability, except in cases in which actor 2 becomes insolvent, under a fractional share rule, they do not pay, in the aggregate, the full liability. Because, in both cases, actor 1 pays nothing since her solvency is zero, actor 2 faces, for a given level of dumping, a smaller liability under a fractional share rule than under a unitary share rule.

Even under a fractional share rule, however, actor 1's insolvency affects actor 2's incentives. Where actor 1 is insolvent and dumps $x^H$, actor 2 faces higher costs than where actor 1 is solvent and dumps $x(\infty)$ because $x^H$ is larger than $x(\infty)$. Consequently, if actor 2 were infinitely insolvent, she would, in response to the insolvency of actor 1, restrict her dumping to a level of waste $b$ that is less than $x(\infty)$.

By analogy to the analysis performed for a unitary share rule, it follows that, under a fractional share rule, there is either an equilibrium at $(x^H, b)$, where actor 2 remains solvent, or at $(x^H, x^H)$, where actor 2 is insolvent. Given that for a given level of dumping, actor 2 bears less liability under a fractional share rule than under a unitary share rule, it follows that $b$ is greater than $a$.

We define actor 2's critical solvency under a strict liability, fractional share rule, given that actor 1 is insolvent, as $s_{2sf}$. This critical solvency is greater than $s_s$, the critical solvency when both actors have equal solvencies. The "domino effect" discussed in the context of unitary share rules is therefore also present here; the insolvency of actor 1 can be the but-for cause of actor 2's insolvency.

The critical solvency $s_{2sf}$ is smaller than $s_{2su}$, actor 2's critical solvency under a strict liability unitary share rule, given that actor 1 is insolvent. The critical solvency under a fractional share rule is smaller because, given that actor 1 is insolvent and actor 2 is solvent, actor 2 faces a smaller liability under fractional share rules, and the prospect of remaining solvent is correspondingly more attractive. Thus, there is a range of solvencies—the range between $s_{2sf}$ and $s_{2su}$—in which actor 2 would choose to remain solvent under a fractional share rule but would become insolvent under a unitary share rule.

3. **Comparison between Unitary and Fractional Share Rules.** Table
APPORTIONING DAMAGES

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TABLE 1

EQUILIBRIA UNDER STRICT LIABILITY

<table>
<thead>
<tr>
<th>REGION</th>
<th>ACTOR 2’S SOLVENCY</th>
<th>UNITARY SHARE</th>
<th>FRACTIONAL SHARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0 – s_{2,uf}</td>
<td>(x^H, x^H)</td>
<td>(x^H, x^H)</td>
</tr>
<tr>
<td>B</td>
<td>s_{2,uf} – s_{2,uf}</td>
<td>(x^H, x^H)</td>
<td>(x^H, b)</td>
</tr>
<tr>
<td>C</td>
<td>s_{2,uf} – ∞</td>
<td>(x^H, a)</td>
<td>(x^H, b)</td>
</tr>
</tbody>
</table>

1 summarizes the equilibria generated by unitary and fractional share rules. Recall that actor 1’s solvency is zero. The table defines three regions, for different ranges of actor 2’s solvency.

Table 1 reveals that, in region A, the two rules perform identically, yielding an equilibrium at (x^H, x^H). In region B, a unitary share rule produces an equilibrium at (x^H, x^H), whereas a fractional share rule does so at (x^H, b). Finally, in region C, the equilibrium under a unitary share rule is at (x^H, a), whereas under a fractional share rule it is at (x^H, b).

We use three measures to compare the performance of the two rules. We determine, first, which rule leads to higher social welfare; second, which rule results in less unfunded liability; and, third, which rule leads to the dumping of less waste.

In region C, we ascertain whether an equilibrium at (x^H, a) under a unitary share rule is preferable to an equilibrium at (x^H, b) under a fractional share rule. From a social welfare perspective, (x^H, a) is preferable. Where one actor is dumping x^H, a unitary share rule makes the other actor see the full social cost of her actions, whereas a fractional share rule does not. Thus, a is the optimal response by actor 2 to actor 1’s choice of x^H.

The unitary share rule also results in less unfunded liability. When the equilibrium is at (x^H, a), actor 2 is solvent and pays the full liability, leaving no unfunded liability. At (x^H, b), actor 2 is also solvent, but under a fractional share rule, she pays only half the liability, leaving the other half unfunded.

Finally, the (x^H, a) equilibrium results in an amount (x^H + a) of waste, whereas the (x^H, b) equilibrium results in (x^H + b) of waste. Because a is smaller than b, a unitary share rule is preferable to a fractional share rule. Thus, in region C, a unitary share rule is preferable under all three criteria.

The comparison between the equilibria in region B follows by analogy. From a social welfare perspective, (x^H, b) is preferable to (x^H, x^H) be-
cause, as we have indicated, given that actor 1 has chosen $x^H$, the socially optimal response by actor 2 is $a$; of course, $b$ is closer to $a$ than is $x^H$. In terms of amount of waste dumped, the $(x^H, b)$ equilibrium is also preferable, as $(x^H + b)$ is smaller than $2x^H$.

With respect to unfunded liability, if actor 2’s solvency is only $s_{2sf}$, which is the lower bound of the range defined in region $B$, the $(x^H, b)$ equilibrium will result in less unfunded liability. Indeed, as actor 2 expands her production of waste from $b$ to $x^H$, the total liability increases, but actor 2’s contribution to that liability does not, as her full solvency is consumed at the $(x^H, b)$ equilibrium. Where actor 2 has a solvency higher than $s_{2sf}$, however, it is not possible to make any general comparison between the rules: the $(x^H, b)$ equilibrium will result in less unfunded liability for certain benefit and loss functions but in more unfunded liability for other functions.\(^81\)

In summary, neither rule dominates the other. In region $C$, a unitary share rule is always preferable under all three criteria. In region $B$, a fractional share rule is always preferable under two criteria—social welfare and waste dumped—but is only sometimes preferable under the criterion of unfunded liability. Table 2 summarizes these results.

### IV. The Inefficiencies of Negligence

We showed in our previous article that, for infinitely solvent actors, unitary share rules under negligence induce the efficient equilibrium, provided that the standards of care are set at the socially optimal level.\(^82\) We also explained that fractional share rules under negligence have this prop-

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\(^{81}\) See proposition 8 of the appendix to Kornhauser & Revesz, supra note 11.

\(^{82}\) See Kornhauser & Revesz, supra note 2, at 847–49.
property for certain benefit and loss functions but not for others. We focus here only on unitary share rules. Insolvency creates the same types of inefficiencies for unitary share rules under negligence as it produces under strict liability. When one or more actors are insolvent, too much waste will be produced, and this waste might be inefficiently distributed among the actors. Similarly, when actors can choose their levels of solvency, they might select their input levels inefficiently.

Once more, we begin our inquiry with the simple case in which two actors have equal benefit functions and equal, fixed solvencies. There are two possible equilibria under unitary share rules: \((x^*, x^*)\) or \((x^H, x^H)\). At the \((x^*, x^*)\) equilibrium, each actor derives the benefits that accrue from dumping \(x^*\); the actors are insulated from any liability by virtue of meeting the standard of care. In contrast, at \((x^H, x^H)\), each actor derives the benefits that accrue from dumping \(x^H\) but must pay the lesser of her apportioned share of the liability or her solvency.

Whether or not actor 1 is dumping at \(x^*\) or \(x^H\), actor 2 will dump at \(x^H\) rather than \(x^*\) only if two conditions are met. First, actor 2 would have to be insolvent at \(x^H\) because if she were solvent, she would see the full cost of departing from \(x^*\) and therefore would pick \(x^*\). Second, the benefit that actor 2 would derive from dumping at \(x^H\) minus her solvency would have to be greater than the benefit she derives from dumping \(x^*\).

We define the critical solvency \(s_n\) as the solvency at which each actor is indifferent between dumping \(x^*\) and \(x^H\). For solvencies lower than this critical solvency, there is a \((x^H, x^H)\) equilibrium; for higher solvencies, there is a \((x^*, x^*)\) equilibrium.

We now turn to situations in which the two actors have different, fixed solvencies. As in our discussion of strict liability, we assume that actor 1’s solvency is zero and examine the properties of unitary share rules under negligence for different values of actor 2’s solvency.

Because actor 1’s solvency is less than the critical solvency \(s_n\), she will dump \(x^H\). But, as we have explained above, given that actor 1 dumps \(x^H\), actor 2 will dump \(x^H\) only if her solvency is less than \(s_n\); she will dump \(x^*\)

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83 See id. at 849–50.

84 We demonstrate that where fractional share rules do not produce the efficient equilibrium, they are likely to produce either multiple equilibria or no equilibria in pure strategies. It is not practical to discuss these rules within the nonmathematical constraints of this section. See propositions 10 and 11 of the appendix to Kornhauser & Revesz, supra note 11.

85 They continue to have equal benefit functions. The results presented in this section arise also where the benefit functions are different. See appendix to Kornhauser & Revesz, supra note 11.
for larger solvencies. Thus, where actor 2’s solvency is smaller than $s_n$, the equilibrium is at $(x^H, x^H)$; when actor 2’s solvency is greater than $s_n$, the equilibrium is at $(x^H, x^*)$.

Unlike in the case of strict liability, for unitary share rules under negligence, actor 2’s optimal strategy is independent of whether actor 1 is insolvent—there is no “domino effect” here. More generally, the insolvency of one actor is never the but-for cause of another actor’s insolvency.  

V. COMPARING NEGLIGENCE AND STRICT LIABILITY

We now compare the performance of three rules: unitary and fractional share rules under strict liability, and unitary share rules under negligence.  

We do so according to the three measures applied in Section III. Thus, we determine, first, which rule leads to higher social welfare; second, which rule results in less unfunded liability; and, third, which rule leads to the dumping of less waste. As before, actor 1’s solvency is zero, and the two actors have the same benefit functions.

Before making the comparisons, it is necessary to define the equilibria that will occur for different ranges of actor 2’s solvency. In Table 1, we set out the ranges in which different equilibria occur under strict liability. To include negligence in our inquiry, we need to determine how $s_n$, the critical solvency under negligence, compares with $s_{2sf}$ and $s_{2su}$, the critical solvencies for actor 2, given that actor 1 is insolvent under strict liability, fractional, and unitary share rules, respectively. Where the two actors have identical benefit functions, $s_n$ is smaller than $s_{2sf}$; consequently, it follows that it is also smaller than $s_{2su}$. Table 3 sets out the equilibria under the various rules for different ranges of actor 2’s solvency.

Table 3 reveals that in region $A$, the three rules perform identically, yielding an equilibrium at $(x^H, x^H)$. In region $B$, the two strict liability rules produce an equilibrium at $(x^H, x^H)$, whereas the negligence rule produces an equilibrium at $(x^H, x^*)$. From a social welfare perspective, the equilibrium generated by the negligence rule is preferable. Recall that when one actor is dumping $x^H$, the socially optimal response by the other actor is $a$. Of course, because $a$ is smaller than $x^*$, $x^*$ is closer to $a$ than is $x^H$. Also, because $x^*$ is smaller than $x^H$, the $(x^H, x^*)$ equilibrium results in less waste.

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86 See lemma 21 and proposition 9 of the appendix to Kornhauser & Revesz, supra note 11.

87 As we have stated in Section IV, it is not practical to deal in the text with fractional share rules under negligence.

88 See corollary 4 of the appendix to Kornhauser & Revesz, supra note 11.
TABLE 3
EQUILIBRIA UNDER STRICT LIABILITY AND NEGLIGENCE

<table>
<thead>
<tr>
<th>Region</th>
<th>Actor 2’s Solventy</th>
<th>Strict Liability</th>
<th>Negligence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Unitary Share</td>
<td>Fractional Share</td>
</tr>
<tr>
<td>A</td>
<td>$0 - s_n$</td>
<td>$(x^H, x^H)$</td>
<td>$(x^H, x^H)$</td>
</tr>
<tr>
<td>B</td>
<td>$s_n - s_{2sf}$</td>
<td>$(x^H, x^H)$</td>
<td>$(x^H, x^H)$</td>
</tr>
<tr>
<td>C</td>
<td>$s_{2sf} - s_{2su}$</td>
<td>$(x^H, x^H)$</td>
<td>$(x^H, b)$</td>
</tr>
<tr>
<td>D</td>
<td>$s_{2su} - \infty$</td>
<td>$(x^H, a)$</td>
<td>$(x^H, b)$</td>
</tr>
</tbody>
</table>

From the standpoint of unfunded liability, however, it is not possible to make a general comparison. Under the strict liability rules, the victim suffers a damage resulting from the dumping of $2x^H$ and recovers actor 2’s solvency. Under negligence, in contrast, the victim suffers a smaller damage, since the total dumping is $(x^H + x^*)$, but he does not recover anything because actor 1 has no solvency and actor 2 meets her standard of care. Which rule produces less unfunded liability depends on the benefit functions of the actors and on the loss function.

In region C, we need to compare the equilibrium at $(x^H, b)$ produced by a strict liability fractional share rule with the negligence equilibrium of $(x^H, x^*)$. For some benefit and loss functions $b$ is greater than $x^*$, but for other functions it is smaller. Thus, from the perspectives of social welfare and amount of waste dumped, a strict liability, unitary share rule is preferable when $b$ is smaller than $x^*$, but a negligence rule is preferable when it is larger.89

In this region, too, it is not possible to make a general comparison about unfunded liability. When $b$ is smaller than $x^*$, the damage caused under a strict liability fractional share rule is smaller than that resulting from a negligence rule. Moreover, under a strict liability fractional share rule, the victim recovers half the damage, whereas under a negligence rule she does not recover anything. But where $b$ is greater than $x^*$, as in region B, the relative amounts of unfunded liability will depend on the benefit and loss functions.

Finally, in region D, the equilibrium at $(x^H, a)$ produced by a strict liability unitary share rule is preferable, under all three measures, to the equilibrium at $(x^H, x^*)$ produced by a negligence rule. From a social welfare perspective, we have already indicated that $a$ is actor 2’s best

89 See proposition 14 of the appendix to Kornhauser & Revesz, supra note 11.
response to actor 1’s choice of $x^H$. In terms of the amount of waste dumped, $a$ is smaller than $x^*$, so less waste is dumped under a strict liability unitary share rule. Finally, under a strict liability unitary share rule, the victim recovers his whole damage, whereas under a negligence rule she does not recover anything.

For each range of actor 2’s solvency, the best rule is indicated in Table 4. Note that on the measures of social welfare and amount of waste dumped, neither rule is categorically superior to the others. And it is perhaps surprising that, given the traditional argument that strict liability

\[90\] In this region, unitary share strict liability rules induce higher levels of welfare than negligence because the standard of care for actor 2 under negligence is set at $x^*$. This standard of care for actor 2 is socially optimal only if actor 1 dumps $x^*$ as well but is not optimal where, as here, actor 1 dumps $x^H$. In a model of fixed solvency, one might consider a rule in which the standard of care of actor 2 is conditional on the solvency of actor 1. If actor 1 has zero solvency, the court could set actor 2’s standard of care at $a$ rather than $x^*$. Negligence would then be preferable to strict liability with unitary shares because the critical solvency of actor 2 under these conditions would be lower. Indeed, under negligence, actor 2 does not face any liability if she dumps no more than $a$, and, therefore, it is relatively less desirable for actor 2 to become insolvent. The legal strategy of making actor 2’s standard of care contingent on actor 1’s decisions is less easy to analyze in a model of variable solvency, where actor 1 decides not only the amount she dumps but also the solvency at which she operates.

The preceding paragraph was a focus of the discussion of our article at the Conference on the Law and Economics of Risk at the University of Virginia. We pointed out that a negligence rule in which the standard of care for actor 2 is set at $a$ when actor 1 is insolvent, does not dominate a negligence rule in which the standard of care is set at $x^*$. (Note that the level that we term $a$ is equivalent to the level that Landes terms $y$; see William Landes, Insolvency and Joint Torts: A Comment, in this issue.) Because actor 2 will derive greater benefits when it operates at $x^*$ and the standard of care is set at $x^*$ than when she operates at $a$ and the standard of care is set at $a$, insolvency will be a comparatively less attractive alternative in the former case. There is a range of solvencies for which a standard of care set at $x^*$ will lead to an equilibrium at $(x^H, x^*)$, whereas a standard of care set at $a$ will lead to an equilibrium at $(x^H, x^H)$. As we point out in the text, the former equilibrium is more desirable from the perspective of social welfare than the latter. Thus, our conclusion that efficiency comparisons among alternative liability rules yield indeterminate outcomes is not affected by a recharacterization of the standard of care under negligence.

Making the standard of care for actor 2 a function of actor 1’s level of solvency (and hence of actor 1’s level of dumping) is consistent with Mark Grady’s suggestion that perhaps one actor’s negligence should result in a more stringent standard of care for the other actor. At the time of this decision, each actor knows the solvency of the other actor, see supra note 56, and therefore knows the equilibrium choice of care of the other actor. We are not implicitly assuming, as Grady suggests, “that each dumper cannot observe whether its fellows are breaching the negligence standard” (Mark F. Grady, Multiple Tortfeasors and the Economy of Prevention, in this issue). In our model, however, each actor faces only one choice, rather than a “preparation” choice and a “reaction” choice.

Grady is mistaken that defining the standard of care for one actor as a function of the other actor’s level of solvency “would throw a monkey wrench into [our] equations” (id.). In this footnote, we have discussed the properties of such a rule where one of the actors has a solvency of zero; it is not conceptually difficult to modify the analysis to treat the more general problem for such a negligence rule.
fully compensates the victim, negligence is sometimes preferable from the perspective of unfunded liability.

VI. Conclusion

From the perspective of a policymaker, this article has two central conclusions. First, when the liability of joint tortfeasors is potentially greater than their solvency, one cannot make any general statements about whether negligence is more desirable than strict liability, or about whether joint and several liability is more desirable than nonjoint (several only) liability. For neither pair of choices does one rule dominate the other in terms of its effects on social welfare, on unfunded liability, or on the amount of waste generated.91 Second, the potential insolvency of joint

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91 Both our analysis and our conclusions differ significantly from those in Note, supra note 1, the only prior work to formulate a model of the problem of insolvency with multiple tortfeasors. The Note’s model diverges from ours principally in how it represents the problem of potential insolvency. The Note does not explicitly impute a solvency to the actors; rather, it assumes that each actor faces a probability that she will be unable to meet her obligation. Moreover, this probability is independent of the decisions of the actors. See id. at 173. Thus, under this model, one actor’s insolvency cannot increase the probability that the other actor will become insolvent, even though it imposes additional costs on the other actor. Primarily for this reason, we do not believe that the Note offers an adequate model of solvency.

Proposition 4 in the Note’s appendix asserts that a rule of negligence with joint and several liability is superior to a rule of negligence with nonjoint liability. Id. at 182. It is not clear that the result holds in the Note’s model, as the proof to proposition 4 is incorrect. The inequality in the Note’s eq. (48) does not follow from the inequalities in eqq. (46) and (47). See id. at 184.

In the text, the Note asserts that, under strict liability, joint and several liability is superior to nonjoint liability (see id. at 169), but the Note’s appendix offers no proof for this assertion. The Note also intimates that negligence with joint and several liability is superior to strict liability, see id. at 169, but, again, no proof is offered. Neither of these claims is true in our model.
tortfeasors creates various kinds of inefficiencies that common-law rules simply cannot eliminate.

The first conclusion bears directly on the question of whether the abolition of joint and several liability—a central tenet of the tort reform movement—can be justified on grounds of social welfare. Our article stands as a counterargument to any justification that is framed in general terms. Though, for particular benefit and loss functions, nonjoint (several only) liability will be preferable on welfare criteria to joint and several liability, in other circumstances, as we have indicated in Section III, the converse will be true. Thus, a claim in favor of one rule over the other must rest on an empirical judgment about the characteristics of all possible actors and must hold that the relative desirability of one rule in certain instances outweighs its relative undesirability in other instances. Common-law courts seem unlikely institutions to which to delegate this empirical judgment, in part because no social institution (or individual) is likely ever to have sufficient facts to confirm or deny its truth.

Moreover, the conclusion that welfare concerns do not justify the abolition of joint and several liability emphasizes the distributional consequences of the choice. Presumably, the advocates of tort reform must bear the burden of explaining the preference to hold plaintiffs, rather than defendants, responsible for the shares of the liability attributable to insolvent actors.

Our second conclusion—that common-law rules cannot eliminate the inefficiencies caused by the potential insolvency of joint tortfeasors—suggests the desirability of regulatory solutions. We intend to look at this question in a subsequent study, in which we will perform an economic analysis of CERCLA. We are prepared, however, to make some initial remarks.

First, the existence of these inefficiencies suggests that an ex post liability system should perhaps be coupled with an ex ante regulatory system. Traditional law and economics analyses have generally held that economically efficient incentives can be transmitted to the relevant actors either through ex ante regulation or through the imposition of ex post liability; consequently, the choice between ex ante and ex post regulation should turn on the relative costs of enforcement. In light of this article, potential insolvency should be viewed as an "enforcement cost" that dramatically constrains the ability of ex post liability to transmit appropriate incentives.

Moreover, an ex ante scheme alone is unlikely to be desirable either. Assume, for example, that some regulation prevents actors from dumping more than the socially optimal amount of waste. Assume, in addition, that such a regulation would be universally obeyed if infinite resources were
spent on enforcement. Obviously, such an expenditure is not socially optimal. But to the extent that some actors will choose to violate the ex ante standard, it may be desirable to retain a scheme of ex post liability. A dual approach appears particularly desirable where the mechanisms for evasion of the ex ante and ex post approaches are different.

To a certain extent, the current legal regime in the hazardous waste area can be viewed as fitting within such a model. Indeed, actors dumping hazardous waste must contend not only with ex post liability imposed through CERCLA but also with ex ante regulation imposed by the Resource Conservation and Recovery Act (RCRA),92 which includes waste minimization requirements.93 We intend to study several questions raised by the dual approach, including whether compliance with ex ante regulation should play a role in the determination of ex post liability.94

A second policy option suggested by this article is the replacement of the ex post liability system with a scheme of ex ante taxation. If, instead of imposing liability on an actor after a damage occurs, an actor’s expected liability were taxed at the outset, the inefficiencies of potential insolvency would disappear, as each actor would have to pay the expected liability at the outset, or could be precluded from dumping.95

Our final set of observations concern CERCLA’s effects on industry structure. For example, the incentives caused by potential insolvency would appear to make it preferable for high-solvency firms to dump only with other high-solvency firms, perhaps through the formation of joint ventures. These incentives would also appear to make vertical integration desirable. For example, a high-solvency generator should not want to dump its waste through low-solvency transporters, as it might be liable for the share attributable to the transporter, if the transporter becomes insolvent. We hope to investigate questions such as these in our next study, and to consider their implications for environmental regulation.96

93 Each generator of hazardous waste must certify that she “has a program in place to reduce the volume or quantity and toxicity of such waste to the degree determined by the generator to be economically practicable.” Id. § 6922(b)(1).
94 Under CERCLA, for example, an actor can raise a particular defense only if “he exercised due care with respect to the hazardous substance concerned.” 42 U.S.C. § 9607(b)(3).
95 Here, too, enforcement considerations, particularly uncertainty over actual benefit and loss functions, might make it desirable to proceed both ex ante and ex post.
96 Our discussion of the nature of solvency also suggests that firms exposed to potentially large cleanup costs will not diversify outside their industry. In fact, they may seek to divest themselves of activities that do not carry this exposure. In a similar vein, it might be an effective defense against takeovers to become exposed to large liabilities under CERCLA.