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Least-Cost Avoidance: The Tragedy of Common Safety

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This article shows that the least-cost avoider approach in tort is not necessarily the optimal way to attain least-cost avoidance when accidents can be avoided by either of two parties. When parties do not observe each other's costs of care at the time of the accident and are unable to determine which party is the least-cost avoider, they fail to anticipate the outcome of the adjudication. Under these circumstances, accident avoidance becomes a commons problem because care by each individual party reduces the prospect of liability for both parties. As a result, parties suboptimally invest in care. We show that regulation removes this problem and is superior to tort liability both when parties act simultaneously and when they act sequentially. We further examine how different liability rules perform in this respect. (*JEL* K13, K32)

1. Introduction

When accidents can be avoided by either of two parties, it seems obvious to place liability on the least-cost avoider, that is, the party who could have prevented the accident at the lowest cost.[1] This approach is unanimously

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1. See Calabresi and Hirschoff (1972:1060 ff.) and Demsetz (1972:28).

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recognized as desirable because not only does it induce parties to prevent accidents but also it forestalls wasteful caretaking by the party with the highest costs of care or, even worse, caretaking by both parties. However, in most accident contexts, parties act rapidly, do not know each other, or do not have time to communicate.[2] Thus, they may not know who the least-cost avoider is and consequently fail to anticipate the outcome of adjudication. As a result, the incentives generated by liability are distorted. In this article, we show that, in general, regulation provides better incentives than ordinary liability rules and further compare several different liability rules and regulation in terms of incentives, administrative costs, and information requirements.

The interest for least-cost avoidance typically arises in a subset of accident contexts within the standard model of bilateral accidents. In the latter, the expected accident loss is a function of both the injurer's and the victim's care. We have *joint care* when the parties' care expenditures are complements and *alternative care* in the opposite case, when care expenditures are substitutes and, hence, more care by one party makes care by the other party less productive.[3] In such general terms, this distinction has only been deemed relevant when a party fails to take appropriate care and the question arises whether the other party should respond by reducing or increasing his or her precaution.[4] By restricting the focus somewhat further, additional issues emerge. Within the alternative-care model, we can isolate those cases in which care expenditures are *perfect* substitutes: if a party takes care, the socially optimal level of care by the other party is zero. Least-cost avoidance (or cheapest cost avoidance, as it is often called) refers to those cases, in which both parties can take precaution but only one of them—the least-cost avoider—should do so.[5]

Examples abound: collisions between two parties (a diver and a swimmer in a swimming pool, two barges at sea, two cars going in the same direction, and similar cases in which it is sufficient that either party changes his or her speed or trajectory), rescue (two bystanders on opposite sides of a river where a person is drowning), the use of dangerous products (the producer can make safer products or the user can use them with some caution), or contract drafting (the drafter can make the contract language clearer or the counterpart can read it more carefully). Compared to the general model of joint care or (imperfect)

2. See Calabresi and Melamed (1972) and Kaplow and Shavell (1996).

3. In the standard model, it is usually assumed that the expected accident loss $l(x, y)$ is a strictly convex function of the parties' care expenditures x and y and that the total social loss is simply the sum $l(x, y) + x + y$, minimized by (x^*, y^*). With $l_{xy} < 0$, we have joint care; $l_{xy} > 0$ implies alternative care; $l_{xy} = 0$ yields independence of the parties' care.

4. See Wittman (1981), Shavell (1983), and Grady (1988).

5. In the standard model, this situation corresponds to either $(x^* > 0, y^* = 0)$ or $(x^* = 0, y^* > 0)$, where "least cost of care" can be interpreted as "most effective care given the same cost." Note that this is different from unilateral accident models in which we have either $l_x = 0$ or $l_y = 0$, that is, only one party can take care while the other is passive. Obviously, in this case the problem of duplicative precaution does not arise. See Landes and Posner (1987:60–1) and Shavell (1987:17–8).

alternative care, these circumstances magnify two aspects of the problem: duplicative care expenditures have the greatest negative impact on welfare and parties have the strongest incentives to free ride on each other's care.[6] These issues make least-cost avoidance of special interest to the analyst and call for further investigation, a task that we take on in this article.

The notion of least-cost avoidance has appeared before American courts in a variety of cases,[7] although at times the courts frame this concept in a different language, such as "best position to avoid the accident"[8] or "most efficient cost avoider,"[9] regularly citing Judge Calabresi's seminal contributions.[10] Some commentators have argued that the least-cost avoider approach is the key to understanding liability, emphasizing the importance of allocating liability to the best informed party.[11] Nevertheless, the literature has not emphasized that information on the probability and magnitude of the harm is not enough for a party to take socially optimal care under the least-cost avoider approach; parties also need to know each other's costs of care.[12] The cost of care to different individuals may greatly vary, and an explicit agreement between the parties about who should take care is deemed impossible by hypothesis in tort cases, due to high transaction costs. It is our objective both to elucidate how this information deficit compares to other informational shortcomings already accentuated in the literature and to examine different possible solutions to this problem.

The difficulties that arise while designing liability rules for least-cost avoidance are twofold. First of all, any rule that takes into account the parties' costs of

6. In marginal terms, least-cost avoidance simply means that the next marginal increase in care should be made by the party with the lowest cost of care compared to the benefit of care (see, for instance, Diamond and Mirrlees [1975] and Dnes [2005:133]). In such an interpretation least-cost avoidance is a mere synonym of optimal accident deterrence, without reference to whether care expenditures are substitutes or complements, which is instead crucial in our framework. Throughout the article, we will therefore adopt the more restrictive notion outlined in the text.

7. *Union Oil Co. v. Oppen*, 501 F.2d 558 (1974); *Unites States v. Tex-Tow Inc.*, 589 F.2d 1310 (1978); *Wilson v. Good Humor Corp.*, 757 F.2d 1293, 244 U.S.App.D.C. 298 (1985); *Telxon Corp. v. Hoffman*, 720 F.Supp. 657 (1989); *American Telephone and Telegraph Co. v. United Artists Payphone Corp.*, 1990 WL 200653 (S.D.N.Y.); *Employer Ins. of Wausau et al. v. Occidental Petroleum Corp. et al.*, 978 F.2d 1422 (1992); *National Union Fire Insurance Co. of Pittsburg v. Riggs National Bank of Washington, D.C.*, 5 F.3d 554, 303 U.S.App.D.C. 302 (1993); *Edwards v. Honeywell, Inc.*, 50 F.3d 484 (7th Cir. 1995); *Holtz v. J.J.B. Hilliard W.L. Lyons, Inc.*, 185 F.3d 732 (7th Cir. 1999); *Hamilton v. Accu-Tek Corp.*, 62 F.Supp.2d 802 (1999); *Extrusion Painting Inc. v. Awnings Unlimited Inc.*, 40 Fed.Appx. 97 (2002).

8. *Ryan Stevedoring Co. v. Pan-Atlantic S.S. Corp.*, 350 U.S. 124, 76 S.Ct. 232, 100 L.Ed. 133 (1956).

9. *United States v. Jackson*, 32 F.3d 1101 (1994).

10. Usually, Calabresi (1970) and Calabresi and Hirschoff (1972).

11. De Geest et al. (2002) argue that doctrines of misunderstanding in Belgian contract law may be interpreted as identifying the "least-cost avoider of misunderstandings." Gifford (2005:618, 663) observes that manufacturers are routinely found to be the least-cost avoiders in product liability cases. Gilles (1992) distinguishes between the least-cost avoider *test* used in Calabresi and Hirschoff (1972), referring to the party best suited to apply cost-benefit analysis, and the least-cost avoider *criterion*, referring to the party best suited to act on the basis of cost-benefit analysis.

12. Calabresi and Klevorick (1985:587) and Harel and Jacob (2002:14) note this point and suggest that liability should be allocated entirely to one party. We show below that this is not necessarily optimal.

care makes use of information that is available at the moment of adjudication but was unavailable ex ante when the parties decided whether to take care. The ex post use by the courts of information that was unavailable ex ante to the parties is known in the literature to generate inefficient results.[13] Fines are levied ex ante on the basis of information available at that time and hence are immune from this problem. However, making a finding of negligence exclusively dependent on information available ex ante, thus disregarding information available ex post, is shown below to be still inferior to regulation due to a second problem. Since the accident can be avoided by either party, any rule that conditions liability on the occurrence of accidents opens up free-riding possibilities for the parties. When a party takes care without knowing who the least-cost avoider is, he or she reduces both his or her own expected liability and the expected liability of the other party, giving rise to a *tragedy of common safety*[14] and to the consequent undersupply of safety. This outcome does not only occur when parties take care sequentially but also occurs with simultaneous decisions if parties cannot be identified ex ante. Fines are immune from this problem because they are imposed whenever an individual violates a rule of conduct, irrespective of whether this behavior results in an accident.

In these respects, our analysis yields different results from existing literature because it deals with a specific kind of information. We consider lack of information on the parties' costs of care (their *types*),[15] whereas existing literature considers lack of information on the probability and magnitude of accidents[16]; the due-care standard[17]; or the causal link between accidents, injurers, and victims.[18] In these settings, the free-riding problem described above does not appear; hence, the various solutions proposed in the literature rightly revolve around the idea of basing liability on information available ex ante. In the following, we will comment on some specific issues related to our analysis.

13. See Ben-Shahar (1998). Calabresi and Klevorick (1985) suggest that using information available ex post may induce technological advances, but Brown (1985) argues that courts are well suited to adapt the law but not the precaution technology. Rabin (1985) argues that courts rarely use information only available ex post.

14. The first economic study of this problem is Gordon (1954). The term *tragedy of the commons* was made popular by Hardin (1968). Establishing property rights through a system of tradable permits to pollute does not necessarily mitigate the problem. In cases in which two potential injurers interact only once (as it is the case in most of the examples in the text), tradable rights would not be feasible for the presence of transaction costs. Moreover, tradable rights need to be build upon an already existing regulatory framework that sets maximum emission limits and only remedy the regulator's lack of information on the injurer's costs of care. See Section 4 on this point.

15. Emons and Sobel (1991) and Ganuza and Gómez (2003) study traditional bilateral accidents with heterogeneous parties. These papers differ from our analysis in that in the former paper information on the parties' type is unavailable both ex ante and ex post, whereas in the latter paper the problem if whether the courts excuse a party's lack of information. Shavell (1980) shows that liability rules fail in the control of activity level because relevant information available ex ante is unavailable ex post, the opposite of what we assume.

16. See Brown (1985), Calabresi and Klevorick (1985), and Rabin (1985).

17. See Grady (1983), Calfee and Craswell (1984), Craswell and Calfee (1986), Edlin (1994), and Ben-Shahar (1998).

18. See Delgado (1982), Rose-Ackerman (1990), and Marino (1991).

1.1 Regulation versus Liability

Our analysis yields that imposing fines through regulation may be superior to tort liability in dealing with least-cost avoidance. To our knowledge, this issue is novel in the literature on regulation versus liability, which has mainly focused on the advantages of regulation in dealing with judgment proof injurers or disappearing defendants and in reducing the uncertainty accompanying negligence standards.[19] Our analysis emphasizes instead an advantage of regulation in an environment in which parties are timely sued, able to pay the judgment, and accurately informed on the negligence standard. Our points are independent of the relative advantages of regulators and courts in gathering information about the accident context and the parties' types; nevertheless, we will discuss in some detail the information requirements of the various policy solutions we analyze. A word of caution should be introduced here about our optimism concerning regulation. We acknowledge that other potential problems with regulation (e.g., capture by private parties) are not addressed here. Hence, we might describe our regulatory regime as the ideal public regulation framework.

1.2 Embedding the Least Cost Avoider Approach in Ordinary Liability Rules

Looking more closely at tort liability, it is important to note that not only does the least-cost avoider approach relate to the least-cost avoider doctrine but also it can be embedded into any negligence rule by reducing to zero the due level of care for the highest cost avoider party, and hence it is a rather far-reaching and general concept.[20] Consider, for example, a rule of simple negligence under which the injurer pays damages to the victim if and only if the injurer is found negligent. If, after examining the accident context it appears that the victim is the least-cost avoider, then the optimal due-care level for the injurer must be zero. Therefore, the injurer will never be found negligent and thus the victim will bear the loss.

Likewise, the same logic holds for comparative negligence, under which a negligent injurer pays compensatory damages to the victim only if the victim is found nonnegligent and only a share of them if also the victim is found negligent. If the injurer is the least-cost avoider, the optimal care level for the victim is zero and hence the victim is never found negligent. As a result the injurer is held liable for the entire harm whenever he does not take the required level of care. Similar considerations may be made for any other liability rule that makes use of the negligence inquiry.[21] We will analyze both negligence rules based on the least-cost avoider approach—determining

19. Wittman (1977) first analyzed this issue in terms of information, insurance, and transaction costs. Shavell (1984a) compared liability and regulation with respect to information, insolvency, apprehension rates, and administrative costs. Rose-Ackerman (1991) and Innes (2004) also analyzed this problem. Shavell (1984b), Kolstad et al. (1990), Burrows (1999), Schmitz (2000), and De Geest and Dari-Mattiacci (2007) deal with liability and regulation combined.

20. For a different interpretation, see Calabresi and Hirschoff (1972) and Gilles (1992), who consider the least-cost avoider approach under the heading of strict liability. For the sake of our argument, this is just another way of looking at the problem. Instead of determining whose party's level of care should have been positive, as under the negligence approach that we are describing, the legal system selects the party to be considered strictly liable.

21. See Chung (1993) noting this point.

negligence on the basis of information available ex post on the parties' costs of care—and negligence rules that only make use of information available ex ante. We will also consider the sharing of the loss irrespective of fault[22]; this approach is different from comparative negligence, under which liability is allocated upon fault. Under sharing irrespective of fault, instead, liability is shared between the parties according to some exogenous proportions, independent of the parties' costs of care. Further, we study the doctrine of last clear chance,[23] which allocates responsibility to the party who could have last taken care in order to avoid the accident, and, hence, only applies to accidents in which parties act sequentially. All of these rules generally fail our objective.

There exist, however, a way to make liability generate optimal incentives for both parties to take care. The tragedy of common safety arises, as we have stipulated, from the fact that care measures have a private cost but produce common benefits. Fines solve this problem by transforming the parties' objective from avoiding the accident loss (a common bad) to avoiding a fine (a private bad). Precaution cost liability does the opposite, since the benefit of care is accrued by both parties, and so should be the cost. Under precaution cost liability, a rule similar to those proposed by Professors Wittman[24] and Levmore[25] in contexts that are different from ours, a party is entitled to recover

22. Sharing in tort law is mainly taken into account among faulty parties; see Bar-Gill and Ben-Shahar (2003) for a recent review. Calabresi and Cooper (1996) argued that sharing irrespective of fault is in fact an increasingly common rule and that it may have an advantage over all-or-nothing arrangements. Parisi and Fon (2004) take into account the sharing of the loss among nonnegligent parties, in a framework labeled as *comparative causation*. To our knowledge, however, the application of a sharing rule to least-cost avoidance in alternative-care cases is novel in the literature. See nevertheless the related discussion in Calabresi (1970:259–61).

23. See *Davis v. Mann*, 10 M&W 546, 152 Eng.Rep. 588 (1842).

24. Wittman (1981) focuses on accidents between parties acting sequentially, in which incentives for both parties to take optimal care contrast with incentives for the second mover to make up for the first mover's possible lack of care. See also Rose-Ackerman (1989). In our framework precaution cost liability is shown to dominate other liability rules also when parties act simultaneously and our results are only related to the main goal of providing optimal incentives. Harel and Jacob (2002:36–7) argue that precaution cost liability could be a possible solution to the dilution of incentives in alternative-care cases when multiple parties are involved; however, they do not provide a formal proof of their claim. See also the discussion by Dharmapala and Hoffman (2005).

25. Levmore (1994) analyzes contractual relationships in which an unanticipated event makes it useful that one party take precaution to protect the other party, without previous agreement to do so and outside the scope of the contract, as in *Leebov v. United States Fidelity and Guaranty Co.*, 165 A.2d 82 (Pa. 1960). This is efficient in the sense that the parties would have agreed to it if they had had time to discuss the issue. Levmore asks whether the law should oblige the party to take precaution or allow that party to claim restitution of precaution costs. Levmore favors the latter arguing that obligation (the tortlike remedy) to take precaution might result in errors or in excessive precaution and hence higher contract prices ex ante. Our analysis yields that restitution coupled with tort liability is superior to the use of tort liability only, in this sense supporting Levmore's claim that restitution should be used, but it also shows that an obligation enforced by regulation is equally effective and does not require restitution. The Leboov case and similar cases are, however, different from our focus as it seems clear at the outset that a specific party was the least-cost avoider and that parties knew that ex ante. We mainly deal with cases in which this information is missing. Moreover, our framework is not well suited to ask the related question of whether restitution should follow unsuccessful attempts to prevent the accident. See also Epstein (1994).

his or her care costs from the other party. In this way, the costs of care are borne by the least-cost avoider irrespective of which party initially made those expenditures. Since the benefit of reduced liability accrues ex post to the least-cost avoider, when he or she also pays the cost of it, this liability rule produces the same optimal incentives as fines.

In sequential-move accidents, the optimal precaution cost liability rule requires instead the first mover to refund the costs of care of the second mover, irrespective of who was the least-cost avoider. Since it is always socially optimal that the second mover makes up for the first mover's lack of care, this liability rule makes the first mover perfectly internalize the costs of care by the other party and hence yields an efficient outcome. However, precaution cost liability may be difficult to apply in ordinary tort cases, as it requires compensation both when an accident occurs (compensation for harm) and when it does not occur (restitution of precaution costs).[26]

1.3 Salience

When parties do not know each other's costs, salience may help avoiding that both parties take care or that no one does: one party is somehow (even arbitrarily) singled out among the group of potential injurers. Some commentators[27] have argued that salience is, in fact, implemented in tort law. Our analysis is different from previous analysis on salience both with respect to the methodology we use, as we analyze this problem through the lens of a formal model, and with respect to the results we derive; namely, salience induces corner solutions (only one party takes care under all circumstances), whereas we show that corner solutions are not necessarily optimal and that it is generally desirable that both parties take care up to some thresholds. This is so because the need to avoid the accident must be balanced against the costs of care by the highest cost avoider.

1.4 Signaling

Another important related topic is the possibility of credible signals by the highest cost avoider in order to induce the least-cost avoider to take care. If high care costs can be credibly signaled before the accident, the information asymmetry is reduced and the least-cost avoider approach is potentially efficient. In some contexts, the government has regulated the production of these signals (e.g., ambulances, firefighters, or police cars). We could even reinterpret state immunity from liability for accidents as an example of signaling high-cost avoidance (assuming for the sake of the argument that in most

26. In insurance and contract cases, reimbursement of costs of care is easier to implement—for example, through sue-and-labor clauses. Nevertheless, when there is a contract between the parties, it is plausible to assume that parties' will reveal or otherwise discover each other's type. Therefore, such cases typically fall outside the scope of our analysis.

27. See Harel and Jacob (2002).

accidents the state is the highest cost avoider). The characteristics of some highest cost avoider cannot be easily emulated such as, for example, age (children or senior citizens), a handicap, or size (large boats in the context of international maritime law); in many other cases, however, low-cost individuals can easily imitate high-cost individuals thereby undermining the credibility and effectiveness of signaling.

1.5 Policy Makers' Incentives

A last comment concerns the policy maker's incentives to implement the optimal regime. It has been noted that the goal of efficient accident prevention may conflict with the reduction of the number of accidents.[28] Policy makers may prefer reducing the number of accidents over minimizing the total social costs as the former policy yields more visible achievements. In our model, this aspect may be relevant in two different ways. First, different policies that yield the same social cost may yield different frequencies of accidents. In this case the policy that leads to fewer accidents will be more likely to be implemented. However, there is also a second possibility: an inefficient policy may be preferred to a more efficient one. For example, attributing liability entirely to one party (a solution that can be implemented by sharing irrespective of fault with shares equal to one and zero, respectively) always yields no accidents. But this may not be the best solution for the purpose of minimizing the social cost, as our analysis shows.

The next several sections contain a formal analysis of this problem both when parties simultaneously take care and when they move sequentially; in each case, first we show that fines achieve the social optimum, then we analyze the performance of liability rules. Section 2 presents the model of parties who take care simultaneously; Section 3 contains the model of parties who take care sequentially; Section 4 discusses the information requirements of fines and of the different liability rules; and Section 5 concludes.

2. The Model with Simultaneous Moves

We consider a simple model with two risk-neutral, utility-maximizing parties who are strangers to each other: a victim, who suffers harm, and an injurer. Both of them can take care, but one party's care is enough in order to prevent an accident. Parties decide *whether or not* to take care and, if so, they incur a fixed cost that exogenously depends on their types. Note that, contrary to standard bilateral care models, in the least-cost avoidance model care is a discrete, binary variable rather than a continuous variable and if either party takes care there is no accident.

Individuals' types (their costs of care) are distributed according to two probability density functions. Each party knows his or her type and both probability distributions, but he or she does not know the other party's type. The harm is

28. See Dari-Mattiacci and De Geest (2005).

assumed to be constant and positive. The law determines each party's sanction for failure to take care in terms of a fine or of a share in the harm. Let $h \in (0, \infty)$ be the harm and $c \in [0, h]$ be the cost of care,[29] which is independently distributed according to the parties' probability density functions $f_i(c)$ and cumulative distributions $F_i(c)$, with $i \in \{1, 2\}$; $f_i(c)$ is a continuously differentiable function over $0 \leq c \leq h$, positive over the same interval, and zero elsewhere, with $F_i(0) = 0$ and $F_i(h) = 1$. Note that in general the parties' density functions are not the same.

The social cost is defined as the sum of the parties' care costs and the expected harm.[30] The first-best social optimum is a state of the world in which the least-cost avoider takes care in each specific case. This article precisely deals with situations in which this is not the case because, even if the costs of care are verifiable ex post, at the time of the accident each party ignores the other party's cost of care, and hence, they cannot coordinate their actions. Thus, we are looking for a second-best policy to minimize the expected social cost. This problem is equivalent to the problem of determining two thresholds of care, c_1 and c_2, such that the parties take care if their costs are lower than or equal to those thresholds.

We begin by assuming that parties can be identified as party 1 and as party 2 ex ante[31]; thus, the thresholds can be conditioned on some salient characteristics of the parties (for instance, c_1 applies to bicyclists and c_2 to truck drivers). In addition, we assume that the parties' care costs are verifiable ex post before the court or by the regulator (although they are ex ante unobservable for the parties). Later we relax these assumptions and look at situations where parties cannot be identified ex ante (thus, c_1 and c_2 must be equal) and at situations where the costs of care are not verifiable ex post. Legal rules will be evaluated on the basis of the care choices they induce, which determine the resulting social cost.

The expected social cost may therefore be written as follows:

$$S(c_1, c_2) = \int_0^{c_1} cf_1(c)\mathrm{d}c + \int_0^{c_2} cf_2(c)\mathrm{d}c + (1 - F_1(c_1))(1 - F_2(c_2))h. \tag{1}$$

The first two terms in equation (1) are the expected costs of care when parties take care up to thresholds c_1 and c_2, respectively. The last term is the expected

29. Note that we have assumed that the costs of care are never greater than the harm. Allowing the possibility that $c > h$ would generate situations where at least one individual should not take care in addition to cases in which the accident should efficiently occur as both individuals have costs of care higher than harm. Strictly speaking, these cases are of unilateral-care type, as at most only one party can prevent the accident at a cost lower than the harm; thus, they fall outside the scope of this article. By imposing $c < h$, the focus of our study is confined to the problem of making the least-cost avoider take care. If the wrong party is picked, no accident occurs, but prevention is more expensive than optimal. If we allow for $c > h$ the focus slightly changes and encompasses situations in which the problem is indeed one of not avoiding the accident altogether.

30. On this interpretation of the social function of tort liability, see Calabresi (1970) and Brown (1973), who were somewhat anticipated by Holmes (1881). For a more general perspective, see Shavell (1987).

31. For example, they might be a motorist and pedestrian in a traffic accident context or a doctor and a simple bystander in a rescue case.

accident cost and is calculated as the magnitude of the accidental loss, h, times the probability that an accident occurs, which is given by the product of the probabilities that each party does not take care, that is, the probability mass associated with costs of care greater than thresholds c_1 and c_2, respectively. Note that this formulation portrays the case in which duplicative effort is wasteful.

If parties move simultaneously, the socially optimal thresholds of care minimize equation (1). The first-order conditions for equation (1) with respect to c_1 and c_2 yield that the socially optimal thresholds depend on the shape of the distributions and satisfy[32]:

$$c_1^* = (1 - F_2(c_2^*))h,$$
$$c_2^* = (1 - F_1(c_1^*))h. \tag{2}$$

The economic interpretation of the interior solution described by equation (2) is straightforward. The marginal increase in expected prevention costs from setting a higher threshold should equal the marginal benefit from reducing the probability of accidents. At least one solution to equation (2) exists by direct application of Brouwer's fixed-point theorem. However, there is no guarantee that such a solution is unique. In fact, we can easily show that the set of solutions to equation (2) is not necessarily a singleton: simply consider the corner solutions $(c_1^* = 0, c_2^* = h)$ and $(c_1^* = h, c_2^* = 0)$, both satisfying equation (2). Finally, a symmetric solution $c_1^* = c_2^*$ might be possible.[33]

To illustrate, consider the simplest case in which the parties' costs of care are uniformly distributed. In this case, $f_1(c) = f_2(c) = 1/h$, and $F_1(c) = F_2(c) = c/h$. The solution to the minimization problem is given by any c_1^* and c_2^* such that $c_1^* + c_2^* = h$, since the social cost in expression (1) becomes $S(c_1, c_2) = \frac{c_1^2}{2h} + \frac{c_2^2}{2h} + \left(1 - \frac{c_1}{h}\right)\left(1 - \frac{c_2}{h}\right)h = h/2$.[34] If the distribution is skewed to the left or to the right, the optimal thresholds will also change, and different local minima might yield different levels of the social cost. For example, if party 2's costs are uniformly distributed between 0 and $h/2$, it can be shown

32. The first-order conditions of equation (1) are $\frac{\partial S}{\partial c_1} = f_1(c_1)[c_1 - (1 - F_2(c_2))h] = 0$ and $\frac{\partial S}{\partial c_2} = f_2(c_2)[c_2 - (1 - F_1(c_1))h] = 0$, from which equation (2) follows. The second-order sufficient conditions should be verified to make sure that the interior solution to equation (2) is a minimum and not a maximum or a saddle point. They are satisfied as long as $f_1(c_1)f_2(c_2)h^2 < 1$. An interior solution satisfying equation (2) will be optimal and preferred to corner solutions as long as $S(c_1^*, c_2^*) \leq \min\{\int_0^h cf_1(c)\mathrm{d}c; \int_0^h cf_2(c)\mathrm{d}c\}$.

33. The necessary condition for a symmetric solution is that $F_2[(1 - F_1[c_1^*])h] = F_1[(1 - F_2[c_1^*])h]$, which is trivially satisfied when the distributions are the same.

34. Alternatively, suppose the costs for party 2 are uniformly distributed between $[\beta h, (1 - \beta)h]$, with $\beta \in [0, 1/2)$, $f_2(c) = \frac{1}{(1-2\beta)h}$, and $F_2(c) = \frac{c - \beta h}{(1-2\beta)h}$. It is the case that party 1's distribution is a mean-preserving spread of party 2's distribution, that is, both have the same expected value, but the variance of the distribution is strictly greater for party 1 than for party 2. Simple computation shows that, besides the two corner solutions, there is only an interior solution given by $c_1^* = c_2^* = h/2$ for any $\beta \in (0, 1/2)$. In the limit case such that $\beta = 0$, we are back to the first example where costs of care are symmetrically distributed.

that the optimal solution is the corner solution $(c_1^* = 0, c_2^* = h)$, since the costs for party 2 are expected to be lower than those for party 1.

It is easy to see that, under any distribution, the second-best socially optimal thresholds of care can always be implemented by regulation, even if the parties' costs of care cannot be verified ex post by the police or by a regulatory body. In fact, a fine set equal to these thresholds induces parties to take care if care costs less than the fine and to bear the fine otherwise and only requires the enforcer to verify whether or not parties have taken care but not their costs. Formally, a fine of magnitude ϕ_i will induce party i to take care for any $c \leq \phi_i$. Hence, fines $\phi_i = c_i^*$, for $i = 1, 2$ will induce the second-best outcome.[35] A similar approach is often referred to as a strict-liability type of enforcement, as fines are levied irrespective of the parties' costs of compliance. The same result may be reached by a fault-based type of enforcement, under which parties pay the fine only if compliance costs less than the fine.[36]

Finally, note that our approach applies not only to accidents with an injurer and a victim, both of whom can take care, but also to accidents with two injurers, who can take care, and a third party, a passive victim, who cannot take any care but suffers harm. Under the liability rules discussed below, both interpretations of the model are equivalent. The regulatory approach, instead, requires that parties face the possibility to pay fines but do not bear the harm resulting from the accident. This implies that injurers should not be liable in tort, and victims, if active, should have first-party insurance.

2.1 The Least Cost Avoider Approach with Simultaneous Moves

The least-cost avoider approach requires that liability be allocated entirely to the party with the lowest cost of care, and thus, the courts must be able to verify ex post the parties' costs of care. Since such costs are not observable ex ante, the parties do not know each other's costs of care at the time of the accident and they will decide whether to take care according to their expectations to pay damages, as in a traditional Nash-Cournot setting.

When parties move simultaneously without observing each other's decisions, a party will take care if his or her care costs are lower than or equal to the expected liability costs; that is, a party will take care if his or her cost of care is below a certain threshold $\hat{c}_i$ and will not take care otherwise. The thresholds for party 1 and party 2 are such that:

$$\hat{c}_1 = (1 - F_2(\hat{c}_2))(1 - F_2(\hat{c}_1))h,$$
$$\hat{c}_2 = (1 - F_1(\hat{c}_1))(1 - F_1(\hat{c}_2))h. \tag{3}$$

The right-hand sides of equation (3) describe the expected liability of a party. Party 1 is liable only under two conditions: party 2 does not take care

35. As usual, we assume that fines are costless to enforce. If not, the second-best levels of care would have to be determined taking into account enforcement costs.

36. Concerning the economic theory of strict liability versus negligence, see Shavell (1980) on tort law and Polinsky and Shavell (2000) on public enforcement of law.

(otherwise there is no accident), which occurs with probability $1 - F_2(c_2)$, and party 2's cost of care c_2 is greater than or equal to party 1's cost c_1, which occurs with probability $1 - F_2(c_1)$.[37] The same applies to party 2.

By comparing equations (2) and (3), we can note that $\hat{c}_i$ will typically be less than c_i^* for both $i = 1, 2$, as $1 - F_i(c) < 1$; hence, the least-cost avoider approach does not attain the second-best optimum. It also impedes corner solutions discussed previously.[38] Therefore, we can unambiguously say that the liability approach cannot yield the second-best outcome.[39]

2.2 Sharing Irrespective of Fault with Simultaneous Moves

Another possibility under liability is to share the loss between the parties according to shares σ and $1 - \sigma$ for party 1 and party 2, respectively. The shares depend neither on whether parties were at fault nor on who is the least-cost avoider. As we explained in Section 1, sharing the loss among the parties upon fault according to a comparative negligence rule necessarily embeds a least-cost avoider approach.

On the contrary, here we examine the effects of sharing that does not take into account the costs of the parties' care and, thus, the shares are determined ex ante and applied ex post irrespective of the parties' behavior. Similar to the previous section, parties will take care as long as their costs are lower than or equal to their expected liability. In a sense, this approach resembles fines but it is more constrained because the sum of the parties' shares always amounts to 1 and thus the sum of the costs up to which parties are willing to take care cannot be greater than h.[40] This restriction is not present in a regulatory approach. Therefore, as our results will show, sharing irrespective of fault is inferior to fines. When parties move simultaneously, their reaction functions are as follows:

$$\hat{c}_1 = (1 - F_2(\hat{c}_2))\sigma h,$$

$$\hat{c}_2 = (1 - F_1(\hat{c}_1))(1 - \sigma)h. \tag{4}$$

37. We can disregard the instance of the two costs being equal as it does not affect the result.

38. Moreover, we can also see that the least-cost avoider approach will ensure $\hat{c}_1 = \hat{c}_2$ when costs are symmetrically distributed which was shown not to be necessarily optimal in the previous section.

39. Consider the example with a symmetric uniform distribution introduced earlier. Easy calculations show that $\hat{c}_1 = \hat{c}_2 = h(3 - \sqrt{5})/2$ which is clearly less than the second-best solution.

40. This is clearly not true if liability is decoupled, that is, if the damages paid by the injurer and the compensation received by the victim diverge. Decoupling liability consists of adding fines or subsidies to damages and in fact amounts to a (partially) regulatory solution. In our model, perfectly set decoupled liability would yield the same outcome as a regulatory approach. Polinsky and Che (1991) advocate decoupling in relation to the incentives to take care and to litigate; Kahan and Tuckman (1995) discuss the decoupling of punitive damages under "special levy" statutes and extend the conclusions reached by Polinsky and Che (1991) for the case in which litigation effort varies with litigation stakes; Choi and Sanchirico (2004) reach an opposite result and revise the desirability of decoupling liability; Lewis and Sappington (1999) relate decoupling to the judgment proof problem.

The right-hand sides to equation (4) describe the expected cost of liability. Each party is liable for only a fraction of the harm and in only those cases in which the other party does not take care (otherwise there is no accident). It is easy to see that $\hat{c}_i$ will generally be lower than c_i^*, for both $i = 1, 2$, because we cannot have $\sigma = 1$ and $1 - \sigma = 1$ simultaneously, except when corner solutions are optimal. By setting $\sigma = 1$, we would have $\hat{c}_1 = h$ and $\hat{c}_2 = 0$. The other possible corner solution will result when $\sigma = 0$. In fact, sharing irrespective of fault only works if courts do not have to make comparisons and can make one of the parties fully liable for the accident.[41] Putting aside this situation that is contrary to the notion of sharing, we can say that the second-best solution is not achieved.[42]

2.3 Precaution Cost Liability with Simultaneous Moves

Under precaution cost liability, the least-cost avoider is not only liable for the harm he fails to prevent (if an accident occurs) but also for the care costs incurred by the other party (if no accident occurs). When parties move simultaneously, their decisions whether or not to take care may be formalized as follows. Let us first consider the cost of not taking care. The expected costs party 1 and party 2 bear if they do not take care are, respectively, given by:

$$(1 - F_2(c_1))(1 - F_2(\hat{c}_2))h + (1 - F_2(c_1))F_2(\hat{c}_2)\frac{\int_{c_1}^{h} c\mathrm{d}F_2(c)}{1 - F_2(c_1)},$$

$$(1 - F_1(c_2))(1 - F_1(\hat{c}_1))h + (1 - F_1(c_2))F_1(\hat{c}_1)\frac{\int_{c_2}^{h} c\mathrm{d}F_1(c)}{1 - F_1(c_2)}.$$

The first term is the same as under the least-cost avoider approach: party 1 (who does not take care) pays the harm if and only if he or she turns out to be the least-cost avoider and if party 2 does not take care either. In addition, as indicated by the second term, party 1 may be held liable for the care costs borne by party 2 if party 1 is the least-cost avoider, with probability $1 - F_2(c_1)$, and party 2 has taken care, with probability $F_2(\hat{c}_2)$; the expected care costs borne by party 2 are calculated as the average costs of care for party 2 conditional on the fact that such costs are higher than the costs of care for party 1

41. Bar-Gill and Ben-Shahar (2003:438) seem to make a similar point, but they refer to the ordinary use of the comparative negligence doctrine, under which the parties' shares are functions of their levels of care. As we have already noted, in this case the optimal share of the least-cost avoider is always equal to one (thus, the other party's share is equal to zero) and in fact sharing does not take place. We have examined this approach in the previous section. In this section, we refer instead to a different use of the principle of sharing and note that it only replicates the outcome assured by regulation in the case of optimal corner solutions, a point not made in the literature.

42. Consider the example with a uniform distribution discussed previously. The solution is given by $\hat{c}_1 = \frac{\sigma^2}{1-\sigma(1-\sigma)}h$ and $\hat{c}_2 = \frac{(1-\sigma)^2}{1-\sigma(1-\sigma)}h$. Clearly, their sum is less than h for $0 < \sigma < 1$, and hence, they are not socially optimal. The magnitude of the underprevention will be most significant when $\sigma = 1/2$.

(as party 1 is the least-cost avoider). The same reasoning applies to party 2. Consider now the situation where a party takes care. The expected costs party 1 and party 2 bear if they take care are, respectively, given by:

$$(1-F_2(c_1))c_1+(1-F_2(c_1))F_2(\hat{c}_2)\frac{\int_{c_1}^{h} c\mathrm{d}F_2(c)}{1-F_2(c_1)},$$

$$(1-F_1(c_2))c_2+(1-F_1(c_2))F_1(\hat{c}_1)\frac{\int_{c_2}^{h} c\mathrm{d}F_1(c)}{1-F_1(c_2)}.$$

Contrary to the previous cases, on the one hand, party 1 does not always bear his or her cost, this cost is refunded by party 2, if party 2 is the least-cost avoider, and hence is borne by party 1 only with probability $1 - F_2(c_1)$ and, on the other hand, he or she might also bear the care costs of party 2, if party 1 is the least-cost avoider, with the same probability seen before, and if party 2 has taken care, with probability $F_2(\hat{c}_2)$. Again, the same applies to party 2.

The decision whether or not to take care is taken by comparing the two previous expressions. It is instructive to note that liability for the other party's care costs appears in both expressions. This is because, say, party 1 is held liable for party 2's care costs only on the basis of whether party 1 is the least-cost avoider and party 2 took care. Thus, precaution cost liability occurs irrespective of whether party 1 took care and thus appears on both sides of the expression (and, consequently, cancels out). Simplifying, we have:

$$\hat{c}_1=(1-F_2(\hat{c}_2))h,$$

$$\hat{c}_2=(1-F_1(\hat{c}_1))h. \tag{5}$$

By comparing equations (2) and (5) it is easy to see that parties under precaution cost liability take care up to the socially (second best) optimal thresholds. The intuition behind this result is as follows. The shortcoming of the least-cost avoider approach is that a party's care has a positive external effect on the other party's liability; this positive effect is not internalized and thus reduces the parties' willingness to take care. Precaution cost liability perfectly internalizes such externalities, by obliging the least-cost avoider to pay either the accident cost or the other party's care costs. This way, the parties' private incentives to take care are aligned with the social goal of minimizing the total accident cost.

2.4 Ex Ante Optimal Negligence Rule with Simultaneous Moves

Under the least-cost avoider approach described above, the liability rule is based on information available ex post to the court; the outcome does not coincide with the second best because this information was not available ex ante to the parties. One might expect that an efficient outcome could be reached by implementing a negligence only based on the information available ex ante. Let c_i^d be the due-care standard for party i. As it typically happens in a negligence rule, the parties will comply with the negligence standards only if the cost of doing so is lower than their expected liability. To calculate the expected liability costs, note that each party knows that if the other party's costs are above the negligence standard, that party will not be liable and hence will not take care. In this case, failure to take care results in full liability for the accident. However, if the other party's costs are below the negligence standard and neither of them takes care, the harm will be shared, according to a general rule, γ and $1-\gamma$, for party 1 and party 2, respectively. Obviously, no party has an incentive to take care beyond the negligence standard.[43] Define $\bar{c}_1$ and $\bar{c}_2$ to be the thresholds above which party 1 and party 2, respectively, do not take care aiming at free riding on the other party's care. The parties' reaction functions are:

$$\bar{c}_1 = (1 - F_2(c_2^d))h + (F_2(c_2^d) - F_2(\bar{c}_2))\gamma h,$$

$$\bar{c}_2 = (1 - F_1(c_1^d))h + (F_1(c_1^d) - F_1(\bar{c}_1))(1-\gamma)h. \tag{6}$$

The first terms on the right-hand sides depict the cost of unilateral negligence, that is, the cost borne by a negligent party when the other party is nonnegligent because his or her costs of care were above the negligence standard. In this case, the negligent party pays the full harm. The second terms depict instead the cost born by a party when also the other party is negligent. In this case the loss will be shared. By rearranging the terms, the parties' reaction functions can be expressed as follows:

$$\bar{c}_1 = (1 - F_2(\bar{c}_2))h - (F_2(c_2^d) - F_2(\bar{c}_2))(1-\gamma)h,$$

$$\bar{c}_2 = (1 - F_1(\bar{c}_1))h - (F_1(c_1^d) - F_1(\bar{c}_1))\gamma h.$$

It is easily shown that the equilibrium in equation (6) is similar to that in equation (2) when the negligence standards are set equal to the second-best standards, c_1^* and c_2^*. Thus, a negligence rule that only makes use of information that was available ex ante mimics the outcome of regulation. Note also that this result holds true for any value of γ, confirming a well-known theorem in the economic analysis of tort law.[44]

43. Note that varying γ from 0 to 1 covers simple, comparative, and contributory negligence. Similar considerations can be made for negligence rules based on strict liability. It is easy to verify that the allocation of the residual burden—that is, the liability for accidents that occur when no party is negligent because both parties' costs are above the negligence standards—does not affect the results proven in the text if the negligence standards are optimally set. This is because, when a party takes due care, the other party, who is bearing the residual burden, will take care up to $\bar{c}_i = (1 - F_j(c_j^d))h$, which is similar to equation (2) if $c_j^d = c_j^*$. In the setting with two injurers, simple, comparative, and contributory negligence allocate the residual burden to the passive victim, whereas strict-liability rules with some negligence defense result in the residual burden being shared among the injurers. In the setting with an injurer and a victim instead the residual burden necessarily falls on either of them.

44. Namely, that all negligence rules are equivalent with respect to the incentives to take care. See Landes and Posner (1980).

Nevertheless, somewhat anticipating considerations that we will make in section 4, this is no longer true when parties are not identifiable ex ante in the sense that they may look identical at the outset. Think, for example, of an accident between two cars. It is easy to allocate liability entirely to one party after the accident according to some predefined criterion. The problem, however, is that such a criterion should be predictable by the parties before the accident takes place. If, for example, liability is allocated to the party that suffers the larger loss, parties may be uncertain about the relative size of their future loss. Likewise, if liability is allocated to the one with the lower costs of care, parties may only have probabilistic expectations on the other parties' costs. The fact that parties are identifiable ex post is evidently not enough as they take care decisions before the accident. In this case, not only should the negligence standards be set at the same level c_u^d for both parties but also the sharing of the loss will also be equal because any unequal nominal sharing will anyway amount to $\gamma = \frac{1}{2}$ in expectation, as parties do not know on which side they will be ex post.[45] When parties are unidentifiable ex ante, their care decision in equation (6) can be rewritten as:

$$\bar{c}_1 = (1 - F_2(\bar{c}_2))h - (F_2(c_u^d) - F_2(\bar{c}_2))\frac{1}{2}h,$$

$$\bar{c}_2 = (1 - F_1(\bar{c}_1))h - (F_1(c_u^d) - F_1(\bar{c}_1))\frac{1}{2}h.$$

By comparing the former expression to equation (13) in Section 4, it will be easy to verify that an equilibrium $\bar{c}_1 = \bar{c}_2 = c_u^*$ will not occur if $c_u^d = c_u^*$ and damages equal to harm. In principle, incentives could be corrected by noncompensatory damages, in the case of two injurers and a passive victim, or decoupled liability, in the case of an injurer and an active victim. However, the tailoring of damages might require complex calculations in each individual case and ultimately reproduce the identification problem that makes it impossible to set individual negligence standards at the outset.

3. The Model with Sequential Moves

If parties move sequentially, the second mover observes whether or not the first mover has taken care.[46] Recall, however, that costs of care are not observable. Social policy can be improved by exploiting this information in order to avoid that an accident occurs or that both parties take care. In the course of this analysis we will constantly assume that party 1 moves first and party 2 second, being evident that the roles can be reversed without prejudice to our results.

45. This is assuming the probability of being on each side is the same. Things change very little if we relax this assumption.

46. If parties move sequentially but the second mover does not observe the first mover's move, we are back to the simultaneous-move model.

Using backward induction, we begin by analyzing the socially optimal decision of party 2, given the move of party 1.

It is immediately evident that the socially optimal strategy for party 2 is to take care if party 1 did not take care (in fact, by assumption the cost for party 2 is lower than the harm) and not to take care if party 1 has already taken care (in fact, the accident will not occur and additional care would only increase the social cost). In other words, party 2's care is a function of party 1's previous decision. We can now define the socially optimal care decision of party 1, given the reaction function for party 2 described above. Since party 2 always takes care whenever party 1 fails to do so, there will never be an accident. Thus, the social cost is as follows

$$S(c_1) = \int_0^{c_1} c\mathrm{d}F_1(c) + \int_{c_1}^{h} \left[\int_0^{h} c\mathrm{d}F_2(c)\right]\mathrm{d}F_1(c). \tag{7}$$

The social cost minimization problem is one of deciding whether the care costs should be borne by party 1 or by party 2, subject to the condition that party 2 will always do the opposite of party 1. In turn, party 1's optimal decision consists of taking care if his or her cost is less or equal to the *expected* cost for party 2. From the first-order condition for the minimization of equation (7) with respect to c_1, we find that the socially optimal thresholds for c_1 and c_2 depend again on the shape of the distribution functions and satisfy[47]:

$$c_1^{*s} = \int_0^h cf_2(c)\mathrm{d}c,$$
$$c_2^{*s} = \begin{cases} 0 & \text{if } c_1 \leq c_1^{*s} \\ h & \text{if } c_1 > c_1^{*s} \end{cases}. \tag{8}$$

It is evident that a solution exists and is unique for any distribution function. Furthermore, a corner solution is never efficient for party 1, but could be efficient for party 2.[48] As we have shown for the simultaneous-move model, also in this case fines $\phi_i = c_i^{*s}$ for $i = 1, 2$ will induce the second-best outcome. The other considerations already made also apply.

3.1 The Least Cost Avoider Approach with Sequential Moves

Under the least-cost avoider approach it is evident that if party 2 observes that party 1 has taken care, party 2 will not take any care, and this is optimal. Nevertheless, if party 2 has observed that party 1 has not taken care, party 2 will not always take care, but will do so only if the costs of care are lower than or equal

47. The first-order condition for the minimization of equation (7) with respect to c_1 yields $\frac{\partial S}{\partial c_1} = f_1(c_1)\left[c_1 - \int_0^h cf_2(c)\mathrm{d}c\right] = 0$, from which the first line in equation (8) is derived. The second-order condition is clearly satisfied at the optimum.

48. Take the example developed in the previous subsection with symmetric uniform distribution of care costs, we have $c_1^{*s} = h/2$ and c_2^{*s} is h if $c_1 > h/2$ and zero otherwise, where equation (7) becomes $S(c_1) = \frac{c_1^2}{2h} + \frac{h}{2} - \frac{c_1}{2}$.

to the expected liability, which depends on the probability to be the least-cost avoider. Unlike under simultaneous moves, the fact that party 1 has not taken care is a signal of his or her true costs of care. Thus, party 2 takes this fact into consideration when calculating his or her expected liability. Party 1, in turn, will anticipate party 2's reaction while deciding on his or her care. In a sense, party 1 is a Stackelberg leader taking into account the follower's reaction function. Party 1, thus, will compare the costs of care with the expected liability as already in equation (3), whereas party 2 will react to that choice, after observing party 1's behavior. Thus:

$$\hat{c}_1^s = (1 - F_2(\hat{c}_2^s))(1 - F_2(\hat{c}_1^s))h,$$
$$\hat{c}_2^s = \begin{cases} 0 & \text{if } c_1 \leq \hat{c}_1^s \\ \frac{1-F_1(\hat{c}_2^s)}{1-F_1(\hat{c}_1^s)}h & \text{if } c_1 > \hat{c}_1^s \end{cases}. \tag{9}$$

Party 2 never takes care if party 1 has already done so. Instead, if party 2 observes that party 1 has not taken care, he or she knows that the actual costs of care borne by party 1 are necessarily higher than $\hat{c}_1^s$. Otherwise, party 1 would have taken care. By incorporating the signal sent by party 1, party 2 recognizes that his or her probability of being liable is higher than otherwise, since it is the conditional probability of $c_1 > \hat{c}_2^s$ given that $c_1 > \hat{c}_1^s$.

From equation (9), it is quite clear that $\hat{c}_1^s < \hat{c}_2^s$.[49] The economic rationale is that player 2 knows that if player 1 did not take care it is because his or her care costs are reasonably high, thus player 2 is more willing to take care since there is a higher-than-otherwise probability of being liable for the accident. The same logic explains why also $\hat{c}_2 < \hat{c}_2^s$ must be true, that is, party 2 is more willing to take care if he or she has observed party 1's move than if both parties move simultaneously. Conversely, we have $\hat{c}_1 > \hat{c}_1^s$, that is, party 1 is less willing to take care when parties move sequentially than when they move simultaneously, since in the former case he or she can rely to some extent on the fact that party 2 will take care in his or her place and hence there will be no accident to pay for.[50]

3.2 Sharing Irrespective of Fault with Sequential Moves

If liability is allocated according to fixed shares, the parties' care decisions are as follows:

49. Note that if $\hat{c}_1^s \geq \hat{c}_2^s$ were true, then we would have $\frac{1-F_1(\hat{c}_2^s)}{1-F_1(\hat{c}_1^s)} \geq 1$ and thus, from equation (9), $\hat{c}_2^s \geq h$; $\hat{c}_2^s > h$ is evidently impossible; $\hat{c}_2^s = h$ would imply $\hat{c}_1^s = 0$ which is in turn incompatible with the premise that $\hat{c}_1^s \geq \hat{c}_2^s$. Therefore $\hat{c}_1^s \geq \hat{c}_2^s$ is impossible and thus the opposite must always hold true.

50. Consider again the uniform distribution case. Easy computations will show that $\hat{c}_1^s = (1 - \sqrt{1/2})h$ and $\hat{c}_2^s = 2(1 - \sqrt{1/2})h$ if $c_1 > (1 - \sqrt{1/2})h$ and zero otherwise. The private care decision by party 1 is less than the second-best solution; however, the private choice by party 2 could actually be above the second-best solution. In fact, expressions (8) and (9) are generally different. Also, note that with the least-cost avoider approach there is the possibility that an accident actually takes place.

$$\hat{c}_1^s = (1 - F_2(\hat{c}_2^s))\sigma h,$$
$$\hat{c}_2^s = \begin{cases} 0 & \text{if}\, c_1 \leq \hat{c}_1^s \\ (1-\sigma)h & \text{if}\, c_1 > \hat{c}_1^s \end{cases}. \tag{10}$$

If party 2 has observed that party 1 has not taken care, he or she will take care only if its costs are below his or her share in the harm. Party 1 will therefore take this reaction into account ex ante and discount the probability of party 2's care from his expected liability. As under simultaneous moves, sharing fails to achieve the second-best outcome. Note that an accident can actually take place.[51]

3.3 Last Clear Chance

Under this doctrine the party who has the last chance to avoid the accident bears the accident loss. Therefore, the doctrine only refers to accident contexts in which parties move sequentially. In this case, the second mover bears the whole cost if an accident takes place. Party 1 anticipates party 2's decision and will compare the costs of care with the expected liability given the probability that party 2 does not take care times zero compensation (since party 2 is fully liable). As to party 2, the observation that party 1 has not taken care is irrelevant, since he or she knows that, if there is an accident, he or she will be fully liable. Therefore, trivially, we have:

$$\hat{c}_1^s = 0,$$
$$\hat{c}_2^s = h. \tag{11}$$

This rule is not efficient since equation (11) is clearly different from equation (8). In fact, the last clear chance doctrine will simply implement a highly inefficient solution due to the moral hazard behavior by party 1. However, it should be recognized that no accident takes place.

3.4 Precaution Cost Liability with Sequential Moves

In this section we study a different version of the precaution cost liability that we analyzed in the case of simultaneous moves. In this case, we need to take into account the fact that the move of party 1 is observed by party 2. The optimal precaution cost liability rule requires that if party 1 does not take care, he or she refunds the costs of care eventually borne by party 2. Party 2, in turn, is liable for the accident loss.

Under this rule, when party 2 observes party 1's move, it is easy to see that the optimal reaction for party 2 is to take care if party 1 has not taken care and

51. By making use of our example with uniform distribution, we can see that the solution is given by $\hat{c}_1 = \sigma^2 h$ and $\hat{c}_2 = (1-\sigma)h$ if $c_1 > \sigma^2 h$ and zero otherwise. We cannot achieve the second-best solution under sharing; we can fix $\sigma = \sqrt{1/2}$, thus achieving an efficient solution for party 1 or we can fix $\sigma = 0$ and achieve an efficient solution for party 2.

not to take care otherwise. In fact, care costs will be refunded by party 1, whereas the harm would be borne by party 2; therefore, if party 1 has not taken care, it is optimal for party 2 to take care. On the contrary, if party 1 has already taken care, care by party 2 comes at a private cost to party 2 but yields no benefit, since the accident will not occur due to party 1's care; thus, if party 1 has already taken care, it is not convenient for party 2 to do the same. Party 1, in turn, anticipates party 2's decision and hence knows that if he or she does not take care, he or she will have to reimburse party 2's costs. Therefore, we have that the parties' decisions of whether to take care are as follows:

$$\hat{c}_1^s = \int_0^h c f_2(c) \mathrm{d}c,$$
$$\hat{c}_2^s = \left\{ \begin{array}{ll} 0 & \text{if} c_1 \leq \hat{c}_1^s \\ h & \text{if} c_1 > \hat{c}_1^s \end{array} \right\}. \tag{12}$$

It is easy to see that equation (12) is as in the social optimum in equation (8). Therefore, as in the simultaneous-moves case, precaution cost liability reaches the second-best socially optimal outcome, by making both parties internalize costs and benefits of their care.

3.5 Ex ante Optimal Negligence Rule with Sequential Moves

As we have discussed above, under a negligence rule that implements second-best standards, c_1^* and c_2^*, the parties will comply only if the cost of doing so is lower than their expected liability. The problem here is that the second-best standard for party 2 is h, that is, party 2 should take care if party 1 fails to do so. Party 1 will obviously anticipate that party 2 takes care and will not take care. Hence, second-best negligence standards will not succeed. This result is not surprising because the second-best solution balances two conflicting goals. One is the provision of optimal incentives, and the other is the optimal mitigation of losses. Party 2 should always take care when party 1 fails to do so in order to fulfill the latter task, but this upsets the former. A standard negligence rule cannot optimally balance these two goals.[52]

4. On the Feasibility of Optimal Least Cost Avoidance

In the previous sections we analyzed the incentive properties of fines and of different liability rules in a theoretical setting. In this section we will ask the question of whether the rules proposed can actually be implemented in practice and what kind of information the regulator or the courts need to acquire. In particular, we will first discuss two different information requirements: knowledge of the parties' cost distributions ex ante and verifiability of the parties' actual costs of care ex post. We also comment on the incentives to obtain information about the care costs borne by the other party.

52. See note 24 above on this issue.

Under fines, the regulator needs to know the distributions of the parties' costs in order to be able to set the fines optimally and he or she also needs to verify whether or not parties took care. It is evident that the strict-liability approach (under which a fine is levied whenever a party fails to take care) does not require the enforcer to verify ex post the costs of care for individual parties. Parties will individually choose whether or not to comply with the rule depending on whether their care costs are greater or less than the expected fines, also considering the probability of apprehension. Fault-based fines, which are levied only if a party's costs are less than the expected fine, instead require regulators to verify also the parties' costs and hence might not always be feasible, or, at least, will involve some additional administrative costs.

Also under sharing irrespective of fault, as under fines, the regulator needs to know the distribution of the parties' types in order to set the shares optimally, but can ignore the actual costs of care of each party. Under the least-cost avoider approach, instead, the courts do not need to know the distribution of the parties' types. However, it is crucial that the parties' care costs be verifiable ex post, a task not strictly necessary under fines. Whether it is easier for regulators to acquire information about the parties' cost distributions ex ante or for courts about the parties' actual care costs ex post is difficult to say and it may depend on the accident context.

Precaution cost liability combines the informational requirements of the least-cost avoider approach (the parties' costs of care must be verifiable ex post) and a requirement similar but not identical to the regulatory approach; in fact, the distributions of the parties' costs of care must be known ex ante to the parties and not to the courts or to the regulator. However, this rule features a characteristic absent in any other. Under fines, parties' care choices are controlled at the moment when care decisions are taken, hence before the accident occurs and irrespective of it. Under liability, courts normally intervene only if an accident occurs and do nothing if either party takes care. Under precaution cost liability, when an accident occurs courts allocate the costs of the accident, but if no accident occurs courts also need to allocate the costs of care. This task may be feasible in certain industrial or environmental accidents, or in rescue cases—one example being Leebov[53]—but seems at first sight to be utterly difficult to implement in ordinary accident prevention. How can courts verify whether the fact that a motorist slowed down before a crossing point really avoided an accident that would have otherwise occurred? How can they possibly quantify the costs of care? For this reason, precaution cost liability, might not be always a practical solution.[54]

The doctrine of last clear chance seems to be sui generis in this respect, as it only requires courts to establish the order of the parties' sequential moves and whether or not the second mover could have done anything to prevent the

53. See the discussion in note 25 above.

54. On the applicability of marginal cost liability to contracts and property, see Wittman (1981).

accident, and it may be implemented irrespective of knowledge of the parties' ex ante costs distributions and of their actual ex post costs of care.

A second problem to be distinguished may concern the possibility to identify the parties as party 1 and party 2 ex ante. Our analysis has so far been confined to instances in which the parties can be so identified; for instance, they are a motorist and a pedestrian. Suppose instead that this is not possible, they are both motorists or both pedestrians. The third-best policy should then be to minimize expression (1) subject to $c_1 = c_2 = c_u$ since the standard cannot be conditioned on the party's characteristics.[55] When parties are not identifiable ex ante, the optimal standard is:

$$c_u^* = \left(1 - \frac{f_2(c_u^*)F_1(c_u^*) + f_1(c_u^*)F_2(c_u^*)}{f_1(c_u^*) + f_2(c_u^*)}\right)h. \tag{13}$$

The first remark should be that a corner solution can never be optimal. The second remark is that $c_u^* = h/2$ when $F_i(h/2) = 1/2$ for both $i = 1, 2$. As an illustration, take again the example of costs uniformly distributed. The social cost in expression (1) becomes $S(c_u) = \frac{c_u^2}{h} + \left(1 - \frac{c_u}{h}\right)^2 h$. The solution to the minimization problem is $c_u^* = h/2$. Due to the fact that parties cannot be identified ex ante and are alike, the threshold should be the same for both parties and equal to $h/2$.

In a regulatory setting, this solution would be easily achieved by a fine $\phi = c_u^*$ for both party 1 and party 2. As the model stands, all liability rules would be inefficient since none is able to replicate c_u^*. However, precaution cost liability, despite the difficulties in its implementation, could solve the problem and actually yield the second-best solution. In fact, under this rule parties need to be identified ex ante as under fines, but their different distributions must be known by the parties themselves rather than by the regulator. Therefore, the identification problem, although it has the same consequences, may occur under different conditions for the regulator (or the courts) and for the parties, leaving some room for the implementation of different rules.

It could be that obtaining information about the costs borne by the other party is socially optimal since at that point parties will have information concerning the least-cost avoider.[56] However, transforming least-cost avoidance into "least-cost acquisition of information" does not change the nature of the problem. It can be easily shown that under the least-cost avoider approach, the decision on whether or not to take care is essentially replaced by a decision on whether or not to acquire information. Let us allow each party to first decide

55. The ex ante identification of the parties is likely to be a less serious problem in sequential settings, as in these cases the order in which the parties move can be used as a way to distinguish them.

56. Shavell (1992) considers the incentives to obtain information about risk. He shows that, under strict liability, the injurer makes socially desirable decisions both with respect to information and care for the familiar reasons. Under negligence rules, the outcome depends on which of several possible rules apply. A complete negligence rule (a party is liable if he or she either failed to take due care or failed to acquire information) is socially optimal, negligence rules where liability only depends on the levels of care are generally inefficient.

whether or not to investigate the costs of the other party and then take care decisions. We have assumed in Section 2.1 that if party 1 takes care, he or she bears c_1, and if party 1 does not take care, he or she faces an expected cost $(1 - F_2(c_1))(1 - F_2(\hat{c}_2))h$. It has been defined in equation (3) that $\hat{c}_1$ is the critical threshold; party 1 takes care when c_1 is less than this threshold; party 1 does not take care otherwise.

We move backward to consider the decision to obtain information concerning the costs borne by party 2. If party 1 investigates, there is a probability, $1 - F_2(c_1)$, that he or she is the least-cost avoider and his or her expected payoff will be $c_1(1 - F_2(c_1))$. If party 1 does not investigate, his or her expected payoff depends on whether he or she is below or above the threshold defined in equation (3). If below the threshold, investigation is always profitable since, in some cases, party 1 discovers that he or she is not the least-cost avoider. If above the threshold, acquiring information is not always efficient. Define $\bar{c}_1$ such that $\bar{c}_1 = (1 - F_2(\hat{c}_2))h$. If below the latter threshold, $c_1 \in [\hat{c}_1, \bar{c}_1]$, information is acquired because sometimes party 1 discovers that he or she is the least-cost avoider and can avoid liability by taking care. However, if above the threshold, no investigation and no care is chosen by party 1. Essentially, when party 1 expects party 2 to take care, there is no incentive to acquire information to the same extent that there is no incentive to take care. Therefore, the tragedy of common safety does not disappear when obtaining information about the costs borne by the other party is costless.[57]

5. Conclusions

The problem of providing incentives through tort liability to two parties who can alternatively prevent an accident is a commons problem. Each party will try to free ride on the other party's care. When both parties try to do so, accident prevention ends up being suboptimal. In this sense, accident prevention becomes a tragedy of common safety. Allocating responsibility on the party with the lower costs of care—the least-cost avoider approach—may not help, since, as we have stipulated, parties may not know each other's costs at the time when they decide whether or not to take care.

We have shown that there are two solutions to this problem, both of them helping to disentangle the commons problem. Fines target each party individually and ex ante, irrespective of whether or not an accident occurs. This way, both the costs of care and their benefits—the possibility to avoid the fine—are entirely private and hence no free riding arises. Contrary to fines, precaution cost liability makes the least-cost avoider liable either for the accident loss, if an accident occurs, or for the other party's costs of care, if the accident has been avoided by the other party. This way, parties again bear both the costs of

57. There are of course many situations where acquiring information about the costs borne by the other party is extremely expensive and therefore it is possible that parties might actually prefer to take care without acquiring prior information.

care and its benefit, and they are prevented from free riding on each other's care. A modified version of this rule applies to sequential moves contexts.

We have also shown that both fines and precaution cost liability achieve the desirable outcome, where all other liability approaches fail. However, they differ with respect to their actual feasibility. Whereas fines are a centralized incentive device, which requires informed regulators, precaution cost liability appears to be a more decentralized system, which requires informed parties. Moreover, precaution cost liability requires courts to adjudicate a case even when an accident did not occur, in order to allocate the costs of care. This task may be not so difficult to carry out in some cases, such as rescue, but it seems utterly complex and, in fact, severely curbs the applicability range of this rule in ordinary torts.

Our model analyzes a situation in which two injurers may prevent a loss incurred by passive victims and when there is an injurer and a passive victim. In the version with two injurers, resorting to regulation implies that injurers face a fine, whereas the accident loss is borne by the passive victim. In contrast, when both injurers and victims' incentives are considered, a rule of no liability simply means liability of the victims,[58] which may distort the incentive effects of fines. Thus, in order to clear the victims from the effects of liability and enable the functioning of fines, it may not be sufficient to remove liability in a *legal* sense, by denying any liability claim, but it is necessary to remove liability in an *economic* sense, by actually removing the accident loss from all parties involved in the accident. This result may be attained through public or private insurance or any other means to prevent all parties from bearing the accident loss. For this reason, when the problem is to provide incentives to victims and injurers, rather than to injurers only, fines need to be complemented by an insurance coverage.[59]

We also analyzed several other liability rules and concluded that any liability rule other than precaution cost liability fails to solve the tragedy of common safety. This is because liability is normally exclusively triggered by the occurrence of the accident. Thus, each individual party's liability costs are inescapably dependent on the other party's care decision. Since one party's care, by concurring to avoid the accident, also reduces the prospect of liability for the other party, accident prevention is undersupplied under any standard liability rule.

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58. See on this point Landes and Posner (1987:62) noting that no liability is a liability rule in an economic sense, since it only differs from strict liability in that it allocates the accident loss to the victim instead of to the injurer.

59. This point and the function of insurance as a way to remove tort liability was originally developed by De Geest and Dari-Mattiacci (2003).

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