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‘Causation-consistent’ liability, economic efficiency and the law of torts

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Abstract

Some legal scholars have argued that the standard modeling of liability rules is inconsistent with the causation requirement of the law of torts. It has been claimed that under the doctrinal notion of causation liability, an injurer is liable only if he was negligent. Moreover, he is liable for only that loss which can be attributed to his negligence and *not* the entire loss, as is the case with the standard modeling of liability rules. Our analysis shows that the ‘causation-consistent’ liability provides interesting insights on several issues concerning efficiency as well as compensation. Paper shows that when care is bilateral, causation-consistent liability provides a basis for efficiency characterization of the *entire* class of liability rules. Moreover, it remains a basis for the efficiency classification of liability rules even for bilateral-risk accidents.

JEL classification: K13

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1. Introduction

In the standard modeling of liability rules, the proportion of accident loss a party is required to bear, generally, does not depend upon the extent to which the party contributed to the loss. For example, at the time of accident if the care level of an injurer was just below the due level of care, under the standard rule of negligence he is held liable for the *entire* loss. Moreover, a negligent injurer is held to be fully liable even when it can be established

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that at the time of accident the victim had taken no care at all. Similarly, under the rule of strict liability with the defense of contributory negligence, if the victim's care level falls just short of the due level, he would be liable for the entire accident loss irrespective of the level of care taken by the injurer. Some scholars have questioned this specification of liability rules (Grady, 1983, 1988, 1989; Kahan, 1989; Wright, 1985, 1987).

In several scholarly writings, it has been argued that as a matter of legal doctrine, the standard modeling of liability rules is incorrect.[1] Here, the argument is that under a liability rule, say the rule of negligence, the doctrinal notion of 'causation liability' has two requirements: (i) an injurer is liable only if he was negligent at the time of accident and (ii) a negligent injurer is liable for *only* the loss that can be attributed to his negligence. That is 'causation liability' restrict the liability of a negligent injurer to the part of accident loss that can be attributed only to the injurer's negligence.[2]

For the ease of illustration, consider the following example. While engaging in his activity, a (potential) injurer can decide whether or not to take care. Let the cost of care be 1. If the injurer takes care the actual loss in the event of an accident will be 6, and 9 if he does not. The probability of an accident also depends upon the care level of the injurer, and is 1/3 when he takes care and 2/3 when he does not. Thus, when the injurer takes care, the expected loss is $(1/3) \times 6 = 2$; while, if he does not take care, the expected loss is $(2/3) \times 9 = 6$. Assume that the court will find the injurer negligent if and only if he does not take care. Under the standard modeling of the rule of negligence, liability of the negligent injurer is the entire loss, i.e. 9. As a result, the negligent injurer's expected liability is $2/3 \times 9 = 6$. But, note that the expected loss goes up only by 4 (i.e. $2/3 \times 9 – 1/3 \times 6$) if the injurer does not take care. Therefore, under the standard rule of negligence, the *expected* liability of the negligent injurer is greater than the expected loss that can be attributed to his negligence. As an alternative, we can consider a liability assignment such that when the injurer is negligent his *expected* liability is only 4, i.e. equal to the increase in the expected loss caused by his negligence, not the entire expected loss.[3] This alternative specification of liability is what we call '*causation-consistent*' liability, and forms the focus of the paper.

Several noted legal scholars have advocated this alternative approach towards liability assignment. For instance, Honoré (1997) writes: "In a legal context, ... when the enquiry concerns the causal relevance of *wrongful* conduct, as is usual in tort claims, we must substitute for the wrongful conduct of the defendant *rightful* conduct on his part. That is, when liability is based on fault, the comparison is not with what would have happened had the defendant *done nothing*, but what would have happened had he *acted properly*. ... the aim of the legal enquiry is to discover not whether the defendant's *conduct* as such made a

[1] Kahan (1989, p. 428), e.g. writes: "Rather, in most models, liability turns solely upon an injurer's negligence: if the injurer was not negligent, he is not liable; but if he was negligent he is liable for any accident that arises – including, if only by implication, those accidents that would have happened even if he had employed due care – This characterization of liability is incorrect."

[2] One basic feature of the legal systems is that, the claim goes, a negligent party is held liable for the loss of which the party's negligence was a necessary and proximate cause—'the causation requirement' (among others, see Keeton (1963, sec. 14), Kahan (1989), Honoré (1983), Shavell (1987, ch. 5), and Wright (1985, 1987).

[3] Here, in case of an accident if the negligent injurer is required to pay 6 (instead of 9) his expected liability will be $2/3 \times 6 = 4$.

difference to the outcome, but whether the fact that it was *wrongful* did so." (emphasis in the original).[4]

In other words, under the standard modeling of the rule of negligence, when it comes to fixing the liability of a negligent injurer, the reference point is (the comparison is with) 'what would have happened had the injurer done nothing.' In contrast, under the causation-consistent liability, as our example illustrates, while determining the liability of a negligent injurer the reference point is his nonnegligent (rightful) act. The comparison is not with the situation in which he does not act at all. Note that in our example a compensation of 9 restores the victim to a position he would be in if there were no activity undertaken by the injurer and hence no accident. On the other hand, under the causation-consistent liability a victim will get compensation of only 6 (instead of 9).

Very few analyses have formally dealt with this alternative specification of liability. The seminal work by Kahan (1989), and a more recent contribution by Van Wijck and Winters (2001) examine the efficiency implications of such specification of liability. The central message of these analyses is as follows: injurers take efficient care under the rule of negligence when the liability assignment is causation-consistent.[5] These studies, however, have two drawbacks: (1) only the rule of negligence is considered, and (2) accidents are restricted to the unilateral-care case. On the first count, a liability rule may specify the due care only for the victim, or only for the injurer or may specify the due care levels for both the parties.[6] If so, then for the rules that specify the due care for the victim, the causation doctrine can be extended to the negligence of the victim.[7] On the second count, it should be noted that most accidents involve bilateral rather than unilateral care. This paper, in contrast to the above-mentioned works, studies the *entire* class of liability rules, and considers the bilateral-care accidents. We show that the 'causation-consistent' liability provides a basis for an efficiency characterization of the entire class of liability rules. Moreover, it remains a basis for an efficiency classification even when the risk is also bilateral.

There is another literature to which this paper contributes. The economic analysis of liability rules has been undertaken by Brown (1973), Diamond (1974), Polinsky (1989), Landes and Posner (1987), Shavell (1987), Barnes and Stout (1992), Posner (1992), Levmore (1994), Kaplow (1995), Biggar (1995), Miceli (1997), Cooter and Ulen (2000), and Jain and Singh (2002), among others.[8] These works show that if negligent injurers are made liable for the entire accident loss suffered by the nonnegligent victims, then injurers will be induced to take efficient care. We will show that liability for the entire loss is more than what is needed for efficiency; causation-consistent liability is sufficient.

[4] Honoré (1997, p. 372). Also see Keeton, Dobb, Keeton, and Owen (1984), Hart and Honoré (1985), Kahan (1989), and Schroeder (1997), etc.

[5] In Van Wijck and Winters (2001) liability assignment, though not attributed to the causation doctrine, is exactly along this line.

[6] The rule of strict liability with the defense of contributory negligence, for example, specifies the due care for only the victim. The rules of negligence with the defense of contributory negligence, comparative negligence, strict liability with the dual defense of contributory negligence specify the due care standards for both the parties.

[7] See Dari Mattiacci (2002).

[8] For a theory of tort doctrines see Hylton (2001).

As our example shows, other factors remaining the same, the choice of care level by a party is likely to have different implications for the *actual* loss (that will materialize in the event of an accident) and the *expected* loss. One important question that arises is, 'Should an injurer be considered as the 'cause' of the actual loss or of the expected loss when both can be attributed to his act?' Calabresi (1970), Landes and Posner (1983, 1987), Shavell (1985, 1987), Miceli (1996, 1997), among others, have addressed this question. The basic proposition emerging from this work is that a party's action can raise or reduce the risk of harm, and therefore is a cause of the expected harm (Ben-Shahar, 2000; Burrows, 1999; Cooter, 1987; Miceli, 1997, pp. 22–24, Schwartz, 2000, pp. 1031–1033).[9] Depending upon the context, that is, the nature of the expected loss function, the expected accident loss that can be attributed to an injurer's negligence can be grater than, equal to, or less than his contribution to the actual loss.[10] Without imposing any significant restriction on the expected loss function, we show that a necessary condition for any liability rule to be efficient is to make a solely negligent injurer bear at least that fraction of the expected accident loss which can be attributed to his negligence.

We introduce a condition called 'causation liability' that is consistent with the above-mentioned causation requirements. The condition of *causation liability* requires a liability rule to satisfy the following property: when the victim is nonnegligent, if the injurer chooses to be negligent rather than nonnegligent, then his expected liability will be more than his expected liability if he were just nonnegligent, by an amount that is at least the entire increase in the expected accident loss caused by his negligence. Similar rule applies for the victim. The first main result of the paper, Theorem 1, shows that if a liability rule satisfies this condition then it is efficient. Theorem 3, shows the necessity of the condition for efficiency of any liability rule. Our analysis shows that in at least one sense, rather than being contradictory, the above mentioned causation requirements turn out to be a necessary element for the efficiency of liability rules.

As it turns out, the study of causation liability in addition to delineating the efficient liability rules from inefficient ones, can serve some important purposes. For example, with the set of all possible efficient liability rules in hand one can look for an efficient rule that ensures the maximum possible compensation to victims. Our analysis provides important insights on such issues. We also show that the rules that are efficient in the standard framework will still be efficient even when under these rules liability of a negligent party is reduced, as long as it is compatible with the above-mentioned requirements of causation.

This paper captures yet another aspect of accidents. In reality many accidents involve bilateral-risk, that is, are such that both parties suffer losses in the event of an acci-

[9] For criticism of the economic modeling of causation, see Epstein (1979, 87), Marks (1994) and Burrows (1999).

[10] In our example, if we assume that the injurer's care affects only the loss and not the probability which remains fixed, say, at 2/3, then the expected loss caused by his negligence will be $2 = (2/3 \times 9 - 2/3 \times 6)$. But, his contribution to the actual loss will be 3 $(9 - 6)$, i.e. greater than his contribution towards the expected loss. On the other hand, if the injurer's care affects only the probability and not the loss which remains fixed, say, at 9 then his negligence caused expected loss will be 3. In both the cases, however, liability as is required by the causation requirement is less than the actual loss.

dent. Analysis in the paper covers bilateral-risk accidents as well. The existing results about the bilateral-risk accidents follow as a corollary to Theorem 4. Moreover, analogous to our results regarding unilateral-risk accidents, we show that for the purpose of economic efficiency it is not necessary that a solely negligent party bear all the losses suffered by both the parties, as is the case under the standard negligence-criterion based rules.

Section 2 introduces the framework of analysis that outlines the notations and the assumptions made in the paper. Section 3 provides an efficiency characterization of efficient liability rules when, to start with, only one party bears accident losses, that is when risk is unilateral. In Section 4, we extend our analysis to cover bilateral-risk accidents. We conclude in Section 5 with remarks on the nature of framework and analysis in the paper.

2. Formalizing liability rules: framework of analysis

We consider accidents resulting from the interaction of two parties who are strangers to each other. Parties are assumed to be risk-neutral. For this and Section 3, we assume that to start with, the entire loss falls on one party to be called the victim; the other party will be called the injurer. We denote by: c is the cost of care taken by the victim, $c \geq 0$; d the cost of care taken by the injurer, $d \geq 0$; $C = \{c | c$ is the cost of some feasible level of care for the victim$\}$, $D = \{d | d$ is the cost of some feasible level of care for the injurer$\}$; π the probability of occurrence of accident; H the loss in case accident actually materializes; $H \geq 0$ and L the expected loss due to accident. L is thus equal to πH.

We assume:

(A1) Costs of care to be strictly increasing functions of care levels. As a result, cost of care for a party will also represent the level of care for that party. Therefore, C is the care choice set for the victim, and D is the care choice set for the injurer. Also, $0 \in C$ and $0 \in D$.

(A2) π and H are functions of c and d; $\pi = \pi(c, d)$, $H = H(c, d)$.

(A3) L is thus a function of c and d; $L = L(c, d)$. Clearly, $L \geq 0$.

(A4) L is a non-increasing function of care level of each party. That is a larger care by either party, given the care level of the other party, results in lesser or equal expected accident loss. Decrease in L can take place due to decrease in π or H or both.

(A5) Activity levels of both the parties are given.

(A6) The social goal is to minimize the total social costs (TSC) of accident, which are the sum of costs of care taken by the two parties and the expected loss due to accident; $\mathrm{TSC} = c + d + L(c, d)$.

(A7) C, D, and L are such that TSC minimizing pair of care levels is unique and it is denoted by (c^*, d^*). As, TSC uniquely attain their minimum at (c^*, d^*), for all $(c, d) \neq (c^*, d^*)$, we have $c + d + L(c, d) > c^* + d^* + L(c^*, d^*)$.

(A8) The legal due care standard (level) for the injurer, wherever applicable (say under the rule of negligence), will be set at d^*. Similarly, the legal standard of care for the victim, wherever applicable (say under the rule of strict liability with defense), will be c^*. Also, $d \geq d^*$ would mean that the injurer is taking at least the due care and he will be called nonnegligent. $d < d^*$ would mean that he is taking less than the due care, i.e. he is negligent. Likewise, for the victim.[11]

Note that (A1)–(A8) are standard assumptions.

A liability rule can be considered as a rule or a mechanism that determines the proportions in which the victim and the injurer will bear the accident loss, as a function of their care levels. An application of a liability rule is characterized by the specification of C, D, L, and (c^*, d^*). Once C, D, L, and (c^*, d^*) have been specified, depending on the care levels of the victim and the injurer a liability rule uniquely determines the proportions in which they are to bear the loss H, in the event of an accident. Formally, for a given application specified by C, D, L, and (c^*, d^*), a liability rule can be defined by a unique function f:

$$f : C \times D \mapsto [0, 1]^2 \text{ such that; } f(c, d) = (x, y)$$

where $x \geq 0$ [$y \geq 0$] is the proportion of H that will be borne by the victim [the injurer] under the rule, and $x + y = 1$.[12]

Remark 1. Note that the functional representation of a liability is specific to the given application, i.e. given C, D, L, and (c^*, d^*). A different specification of C, D, L, and (c^*, d^*) would mean a different application; any change in C, or D, or L, or (c^*, d^*) would mean a different application. Let the function f define a liability rule for the application specified by C_1, D_1, L_1, and (c_1^*, d_1^*), and let function g define the *same* rule for the application specified by C_2, D_2, L_2, and (c_2^*, d_2^*). As the function defining the liability rule is application specific, f and g will be different, in general.

For any C, D, L, and (c^*, d^*) we assume that if the function f defines a liability rule, then f satisfies the following two properties:

(P1) For any c opted by the victim if $f(c, d^*) = (x', y')$, then for all $d \geq d^*$, $f(c, d) = (x', y')$.

(P2) For any d opted by the injurer if $f(c^*, d) = (x'', y'')$, then for all $c \geq c^*$, $f(c, d) = (x'', y'')$.

(P1) implies: Given any c opted by the victim, if the injurer chooses a care level that is greater than d^*, the proportion in which the injurer is required to bear the accident loss will exactly be the same as it would be when he just opts for d^*. That is under a liability rule, $d > d^*$ and $d = d^*$ are treated alike, the injurer is treated as nonnegligent. (P2), likewise, implies: Given any d opted by the injurer, if the victim opts for a care level beyond c^*, the proportion in which the victim is required to bear the loss will exactly be the same as it would be when he opts for c^*. In other words, liability rules do not discriminate among degrees of nonnegligence. As a matter of fact all the rules discussed in the literature satisfy properties (P1) and (P2). Moreover, we will show

[11] It should, however, be noted that technically speaking, a party can be negligent only if the rule specifies the due level of care for the party. In this paper, whenever the rule does not specify the due level of care for a party, negligence [nonnegligence] of the party would mean that care taken by this party is less than [greater than or equal to] the efficient level of care for it.

[12] Given C, D, L, and (c^*, d^*), since for every $c \in C$ and every $d \in D$ opted by the victim and the injurer, respectively, a liability rule uniquely determines the proportions in which the parties will bear the accident loss, the function f defining the liability rule for the *given* application is unique.

that (P1) and (P2) are important from efficiency point of view. As a direct consequence of (P1) and (P2) we get:

(P3) If $f(c^*, d^*) = (x_1, y_1)$, then for all $c \geq c^*$ and for all $d \geq d^*$, $f(c, d) = (x_1, y_1)$.

(P3) says that when both the parties are vigilant (nonnegligent), the shares in which they are required to bear the accident loss remain the same, regardless of the degrees of vigilance of the parties.

For any c and d opted by the victim and the injurer, respectively, if an accident actually materializes the realized loss will be $H(c, d)$, and the court will require the injurer to bear $y(c, d)H(c, d)$. Therefore, the injurer's expected liability will be $\pi(c, d) \times y(c, d)H(c, d)$, i.e. $y(c, d)L(c, d)$. As the entire loss is suffered by the victim initially, $y(c, d)L(c, d)$ represents the expected liability payment to be made by the injurer to the victim. The expected costs of a party are the sum of the cost of care taken by it plus its expected liability. Let, $f(c^*, d^*) = (x_1, y_1)$, then by (P3), for all $c \geq c^*$ and for all $d \geq d^*$, $f(c, d) = (x_1, y_1)$. Under the rule of negligence, e.g. $x_1 = 1$ and $y_1 = 0$. Therefore, when $c \geq c^*$ and $d \geq d^*$, the injurer's expected costs will be $d + y_1 L(c, d)$. And, the victim's expected costs will be $c + L(c, d) - y_1 L(c, d)$, i.e. $c + x_1 L(c, d)$, as $x_1 = 1 - y_1$.

Definition 2.1. *Efficient liability rules*

A liability rule is said to be efficient iff it motivates both the parties to take efficient care. Formally, a liability rule is efficient for given C, D, L, and (c^*, d^*), iff (c^*, d^*) is a unique Nash equilibrium (N.E.). A liability rule is defined to be *efficient* iff it is efficient for every possible application, i.e. iff for every possible choice of C, D, L, and (c^*, d^*) the rule is efficient.

Take any C, D, L, and (c^*, d^*). To start with let $c \geq c^*$ and $d = d^*$. Now, if the injurer reduces his care level to some $d' < d^*$, the increase in the expected loss that can be attributed *only* to the injurer's negligence is $L(c, d') - L(c, d^*)$. Suppose a liability rule has the following attribute: When the victim is nonnegligent, i.e. $c \geq c^*$, if the injurer reduces his level of care from $d \geq d^*$ to any $d' < d^*$ (where he is negligent), the *increase* in his expected liability is at least $L(c, d') - L(c, d^*)$; that is the increase in the injurer's expected liability is at least equal to the expected loss caused by his negligence.[13] Likewise, when the injurer is nonnegligent, i.e. $d \geq d^*$, if the victim reduces his level of care from $c \geq c^*$ to some $c' < c^*$, the increase in the victim's expected liability is at least $L(c', d) - L(c^*, d)$. Under such a rule, when the victim is nonnegligent, if the injurer reduces his care from a level where he is nonnegligent to a level where he is negligent, the *increase* in his expected liability is at least the entire increase in the expected accident loss that is caused by his negligence. Similarly for the victim. Based on this discussion we define the following condition.

Definition 2.2. *Condition of causation liability* (*CL*)

A liability rule is said to satisfy the condition CL iff under such a rule: (I) when the victim is nonnegligent, if the injurer chooses to be negligent then his expected liability

[13] Suppose $c \geq c^*$, and the injurer's care level is some $d'' > d^*$. Now, if the injurer reduces his care to some $d' < d^*$ then the increase in the expected loss that can be attributed to the injurer's negligence is only $L(c, d') - L(c, d^*)$ and not the entire increase of $L(c, d') - L(c, d'')$. This is so because of the fact that the injurer is negligent only when $d < d^*$ and not when $d < d''$ (when the injurer's care $d \in [d^*, d'')$ he is not negligent).

[at the corresponding level of care] is more than his expected liability when he were *just* nonnegligent, by an amount that is *at least* the entire increase in the expected accident loss that is caused by his negligence, and (II) when the injurer is nonnegligent, if the victim chooses to be negligent then his expected liability [at the corresponding level of care] is more than his expected liability when he were just nonnegligent, by an amount that is *at least* the entire increase in the expected accident loss caused by his negligence.[14]

To illustrate the requirements of the condition CL, consider an example.

Example 1. Suppose an accident context is characterized by the following specification:

$$C = \{0, 1, 2\}, \quad D = \{0, 1, 2, 3\}, \quad L(0,\ 0) = 10, \quad L(1, 0) = 7 = L(0, 1),$$

$$L(0, 2) = 5, \quad L(0, 3) = 4, \quad L(1, 1) = 4, \quad L(1, 2) = 2, \quad L(1, 3) = 1.5,$$

$$L(2, 0) = 5.5, \quad L(2, 1) = 3.5, \quad L(2, 2) = 1.5, \quad L(2, 3) = 1.$$

For this example it is clear that (1, 2) is the unique configuration of care levels which is TSC minimizing. Let $(c^*, d^*) = (1, 2)$. In the context of Example 1, condition CL requires that the liability rule be such that when the victim has opted for c^*, i.e. 1, if the injurer changes his care level from 2, where he is not negligent, to say 1, where he is negligent, then the increase in his expected liability is at least equal to $L(1, 1) - L(1, 2)$, i.e. 2, i.e. the increase in the expected accident loss that is caused by the injurer's negligence.[15] Likewise, condition CL demands that when the injurer has opted for d^*, i.e. 2, if the victim changes his care level from 1 to 0, then the increase in his expected liability is at least 3, i.e. equal to $L(0, 2) - L(1, 2)$, i.e. the increase in the expected accident loss that is caused by the victim's negligence. Note that under the standard rule of negligence, given that the victim has opted for 1, if the injurer changes his care level from 2 to 1, the increase in his expected liability is equal to 4. That is the increase in the expected liability of the injurer as necessitated by condition CL is strictly less than is required under the rule of negligence.

More generally, consider any C, D, L, and (c^*, d^*). Take any liability rule that satisfies condition CL and let the function f define the rule for the given C, D, L, and (c^*, d^*). Let, $f(c^*, d^*) = (x_1, y_1)$. Then, under f for different care levels liability assignment will be as follows:

(i) when $c \geq c^*$ and $d \geq d^*$, $f(c, d) = (x_1, y_1)$ where $x_1, y_1 \in [0, 1]$;
(ii) when $c \geq c^*$ and $d < d^*$, $f(c, d) = (x, y)$, where $y \geq 1 - [x_1 L(c, d^*)/L(c, d)]$, i.e. $yL(c, d) \geq y_1 L(c, d^*) + L(c, d) - L(c, d^*)$;
(iii) when $c < c^*$ and $d \geq d^*$, $f(c, d) = (x, y)$, where $x \geq 1 - [y_1 L(c^*, d)/L(c, d)]$, i.e. $xL(c, d) \geq x_1 L(c^*, d) + L(c, d) - L(c^*, d)$;
(iv) when $c < c^*$ and $d < d^*$, $f(c, d) = (x, y)$ where $x, y \in [0, 1]$.

[14] It should be noted that the 'increase' in expected liability of a party refers to the increase in its expected liability over and above this party's liability, if any, when it were just nonnegligent.

[15] The increase in the injurer's liability should be at least $L(1, 0) - L(1, 2)$, i.e. 5, if he reduces his care from 2 to 0.

(iv) Follows directly from the definition of a liability rule and the fact that when both the parties are negligent the condition CL does not impose any restriction on the structure of a liability rule. (i) Follows from property (P3) and the fact that when both the parties are nonnegligent the condition CL does not impose any restriction on liability assignment. To see (ii), note that when $c \geq c^*$ and $d < d^*$ the victim is nonnegligent and the injurer is negligent. Since, the rule satisfies condition CL, at d the injurer's expected liability is more than his expected liability at d^* by an amount that is greater than or equal to $L(c, d) - L(c, d^*)$, the increase in the expected loss caused solely by his negligence. In view of (i), at d^* the injurer's expected liability is $y_1 L(c, d^*)$, where $y_1 \in [0, 1]$. Therefore, at d his expected liability is at least $y_1 L(c, d^*) + [L(c, d) - L(c, d^*)]$. That is when $c \geq c^*$ and $d < d^*$, $y(c, d)$ is such that $y(c, d)L(c, d) \geq y_1 L(c, d^*) + L(c, d) - L(c, d^*)$, i.e. $y(c, d)L(c, d) = y_1 L(c, d^*) + L(c, d) - L(c, d^*) + \beta$, where $\beta \geq 0$. That is $y(c, d) \geq 1 - [x_1 L(c, d^*)/L(c, d)]$, since $1 - y_1 = x_1$.[16] Notice that here the injurer is solely negligent and if $y_1 < 1$ and $\beta = 0$, $y_1 L(c, d^*) + L(c, d) - L(c, d^*) < L(c, d)$, i.e. his liability is less than the full liability. Explanation for (iii) is analogous. When $c < c^*$ and $d \geq d^*$ the victim is solely negligent, and it can easily be checked that his liability as necessitated by condition CL is less than the full liability.

Condition CL′: Condition CL′ is the same as the condition CL with '*at least*' replaced by '*just equal to*'. Liability assignment under condition CL′ will be as under the condition CL with '*semiequalities*' both in (ii) and (iii) above replaced with '*strict equalities*'.

Remark 2. The following defining conditions completely characterize any rule of comparative negligence: (1) when one party is negligent and the other is not then the solely negligent party bears the *entire* loss; (2) when both the parties are nonnegligent then only one party namely the victim bears the entire loss; and (3) when both the parties are negligent then both of them bear the loss, and their shares (in some sense) are proportional to their respective degree of negligence.[17] On the contrary, from the definition of condition CL (and (i)–(iv) above), it should be clear that *none* of these three conditions is necessary for CL to hold. In particular, when both the parties are nonnegligent or both of them are negligent, in contrast to conditions (2) and (3), CL does not impose any restriction on a liability rule—liability could be imposed only on one party or, alternatively, could be shared between them in any proportion, without violating the condition. And, unlike (1) above, making the solely negligent party bear the entire loss is not necessary under CL. Moreover, all other standard negligence-criterion based rules satisfy condition (1) above, and are such that when both the parties are nonnegligent or both are negligent then only one party bears the *entire* accident loss. None of these restrictions is necessary under CL. Therefore, it

[16] Note that (assuming $L(c, d) > 0$), if $\beta = 0$, i.e. the increase in the injurer's liability on account of his negligence is just equal to the negligence-caused expected loss, $L(c, d) - L(c, d^*)$, then for all $c \geq c^*$ and $d < d^*$, $y(c, d) = 1 - [x_1 L(c, d^*)/L(c, d)]$. That is CL-consistent $y(c, d)$ is uniquely determined.

[17] For important analyses of the rule of comparative negligence see Schwartz (1978), Landes and Posner (1983), Cooter and Ulen (1986), Haddock and Curran (1985), Shavell (1985), Rubinfeld (1987), Rea (1987), Chung (1993), and Edlin (1994). Haddock and Curran (1985), Shavell (1985), and Young, Faure, and Fenn (2004), among others, have argued that in the presence of uncertainties, the rule of comparative negligence is better than the other rules of negligence. For a critical review of some of these works see Liao and White (2002), and Bar-Gill and Ben-Shahar (2003). However, it should be noted that in this paper we are assuming away all the uncertainties.

follows that conditions CL and, in particular CL′, impose less restriction on the structure of liability rules than is the case in their standard modeling.

The contrast of the liability assignment under the rule of comparative negligence with the assignment as is required by the condition CL can be highlighted by resorting back to Example 1. Given that $(c^*, d^*) = (1, 2)$, under the rule of comparative negligence the liability assignment will be as follows: If $c = 1$ and $d = 2$, then $y = 0$, i.e. the expected liability of the injurer is 0; If $c = 0$ and $d = 2$, then $y = 0$, i.e. the expected liability of the injurer is 0, and, therefore, the expected liability of the victim is 5, i.e. $L(0, 2)$; If $c = 1$ and $d = 1$, then $y = 1$, i.e. the expected liability of the injurer is 4, i.e. $L(1, 1)$; If $c = 0$ and $d = 1$, then $y = (2 - 1)/(1 - 0)+(2 - 1) = 1/2$, i.e. the expected liability of the injurer is 3.5, i.e. $1/2\,L(0, 1)$.

On the other hand, the following assignment of liability is ‘consistent’ with the requirement of the condition CL: If $c = 1$ and $d = 2$, then $y = y_1$, where $0 \leq y_1 \leq 1$, i.e. the expected liability of the injurer is $y_1\ 2$, i.e. $y_1 L(1, 2)$ (i.e. his expected liability can be any number between 0 and 2); If $c = 0$ and $d = 2$, then the expected liability of the victim is $(1 - y_1)L(1, 2) + [L(0, 2) - L(1, 2)]$, i.e. $(1 - y_1)L(1, 2) + 3$ and, therefore, the expected liability of the injurer is $y_1 L(1, 2)$; If $c = 1$ and $d = 1$, then the expected liability of the injurer is $y_1\ 2 + 2$, i.e. $y_1 L(1, 2) + L(1, 1) - L(1, 2)$[18]; If $c = 0$ and $d = 1$, then $0 \leq y \leq 1$, i.e. the expected liability of the injurer can be any number between 0 and 7, i.e. any proportion of $L(0, 1)$.

3. Efficient liability rules with bilateral-care and unilateral-risk

Claim 1. *If a liability rule satisfies condition CL then for every possible choice of C, D, L, and (c^*, d^*); (c^*, d^*) is a Nash equilibrium.*

For a complete proof, see Appendix B. Intuitively speaking, suppose the victim has opted for c^*. If the injurer decides to reduce his care from d^* to some other level, say $d' < d^*$, then (c^*, d^*) being uniquely TSC minimizing pair implies that the resulting increase in the expected loss, $L(c^*, d') - L(c^*, d^*)$, will be more than the reduction in the cost of care. Now, if the injurer is made to bear this increased social costs, as is the case under condition CL, he will not find such an act to be advantageous. And, if the injurer decides to increase his care level to some $d' > d^*$, the consequent reduction in the expected loss and hence the reduction in the expected loss borne by him will be less than the cost of the increased care level. Again, he will be worse-off choosing d' rather than d^*. In fact, as the proof shows, given c^* opted by the victim, d^* is a unique best response for the injurer, and *vice versa*.

Claim 2. *If a liability rule satisfies condition CL then for every possible choice of C, D, L and (c^*, d^*); (c^*, d^*) is a unique Nash equilibrium.*

18 Note that if we take $y_1 < 1$, then injurer’s liability is strictly less than 4.

For a complete proof, see Appendix B. Informally the argument can be put as follows. Suppose a liability rule satisfies condition CL. For expositional simplicity assume that under the rule when both the parties are nonnegligent, only the injurer or only the victim will bear the entire loss.[19] Let the victim be this party. Take any C, D, L and (c^*, d^*). When the injurer is nonnegligent, i.e. when $d \geq d^*$, under such a rule the victim will bear the entire loss irrespective of his care level. When $c \geq c^*$, this follows from the assumption that when both the parties are nonnegligent the victim bears the entire loss. And when $c < c^*$, the victim is negligent and in view of CL he will also bear the additional loss caused by his negligence. Thus, whenever $d \geq d^*$, irrespective of c, expected liability of the injurer is zero and his expected costs are just d. Clearly, the injurer can reduce his costs by opting d^* rather than $d > d^*$.

Now suppose that $(\bar{c}, \bar{d})$ is a N.E. That is given $\bar{c}$ opted by the victim, $\bar{d}$ is a best response for the injurer, and *vice versa*. In view of the above, under the rule irrespective of $\bar{c}$, $\bar{d} > d^*$ cannot be a best response for the injurer, i.e. when $\bar{d} > d^*$, $(\bar{c}, \bar{d})$ cannot be a N.E. Thus, $(\bar{c}, \bar{d})$ is a N.E. implies $\bar{d} \leq d^*$. When $\bar{d} = d^*$, from the proof of Claim 1 we know that c^* is a unique best response for the victim. Therefore, $\bar{c} \neq c^*$, cannot be a best response for the victim, i.e. when $\bar{d} = d^*$, if $(\bar{c}, \bar{d}) \neq (c^*, d^*)$ then $(\bar{c}, \bar{d})$ cannot be a N.E. Moreover, when $\bar{d} < d^*$, through a series of steps (as is shown in the proof) it can be shown that regardless of $\bar{c}$, $(\bar{c}, \bar{d})$ cannot be a N.E. Thus, whenever $(\bar{c}, \bar{d}) \neq (c^*, d^*)$, $(\bar{c}, \bar{d})$ cannot be a N.E. Finally, in view of Claim 1, (c^*, d^*) is a unique N.E. Analogously, if the injurer bears the entire loss when both the parties are nonnegligent, (c^*, d^*) is a unique N.E.

Theorem 1. *If a liability rule satisfies the condition of causation liability then it is efficient for every possible choice of* C, D, L *and* (c^*, d^*).

Proof. Claims 1 and 2, in conjunction, establish the result. □

The following result follows immediately from Theorem 1 and the definition of condition CL′.

Theorem 2. *If a liability rule satisfies the condition CL′ then it is efficient for every possible choice of* C, D, L *and* (c^*, d^*).

Remark 3. From Theorem 1 and the definition of the condition CL, it follows that how a liability rule assigns liability when both the parties are negligent or when both are nonnegligent, has no implications for the efficiency of the rule. Moreover, in view of Remark 2 and Theorem 2, making a solely negligent party bear the *entire* accident loss is not necessary for economic efficiency.

For given C, D, L and (c^*, d^*), the standard rule of negligence can be defined as: $d \geq d^* \Rightarrow x = 1 (y = 0)$, and $d < d^* \Rightarrow x = 0 (y = 1)$. In particular, under this rule a solely negligent party is liable for the *entire* loss. Note that the rule satisfies condition CL and therefore

[19] This property is satisfied by all the rules discussed in the literature. But, as the proof shows this assumption is not necessary for the claim to hold.

is efficient. But, it must be stressed, the condition CL requires that when the injurer is negligent and the victim is not, the injurer's liability is *at least* the loss caused by his negligence (and not necessarily the entire loss). Similarly, it can be checked that all of the standard negligence-criterion based rules satisfy condition CL and, as a corollary to Theorem 1, are efficient for every possible C, D, L and (c^*, d^*). As was mentioned earlier on, under all of these rules a solely negligent party is liable for the *entire* accident loss. In contrast, our analysis shows that all of these rules will still be efficient even if the liability of the solely negligent party is restricted, as long as its consistent with the condition CL′. (Note that none of the standard negligence-criterion based rules satisfies the condition CL′). To make the argument explicit, consider the following examples.

Example 2. Specify any C, D, L and (c^*, d^*). For this specification let a rule be defined by function f: $f(c, d) = (x, y)$ such that: $x = 1 - [L(c^*, d)/L(c, d)]$, i.e. $xL(c, d) = L(c, d) - L(c^*, d)$, when $c < c^*$ and $d \geq d^*$; and $x = 0$, otherwise.

Example 3. Specify any C, D, L and (c^*, d^*). For this specification suppose a rule is defined by function f: $f(c, d) = (x, y)$ such that: $y = 1 - [L(c, d^*)/L(c, d)]$, i.e. $yL(c, d) = L(c, d) - L(c, d^*)$, when $c \geq c^*$ and $d < d^*$; and $y = 0$, otherwise.

The liability rule in Example 2 makes the victim liable if and only if the victim is negligent and the injurer is not. Furthermore, it makes a negligent victim liable for only the expected loss that can be attributed to his negligence. The rule in Example 3, likewise, makes a solely negligent injurer liable for only the expected loss that can be attributed to his negligence. Clearly both the rules satisfy conditions CL as well as CL′, and in view of Theorems 1 and 2, are efficient. Now, consider the standard rule of strict liability with the defense of contributory negligence. Under this rule a negligent victim bears the loss even when the injurer also happens to be negligent. Moreover, he bears the entire loss. But, as the rule in Example 2 shows, none of these requirements is necessary for efficiency. The rule of strict liability with defense will still be efficient even if it is redefined to make a negligent victim liable only when he is solely negligent, and only for the loss that can be attributed to his negligence. Similarly, Example 3 shows that the rule of negligence can be made less compensatory while preserving its efficiency.

Theorem 1 establishes the sufficiency of the condition CL for the efficiency of any liability rule. Now, consider the following violations of the condition CL:

(C1) When the victim is nonnegligent, if the injurer opts to be negligent then the difference between his expected liability at the corresponding level of care and his expected liability when he were just nonnegligent is *less* than the increase in the expected accident loss due to his negligence.

(C2) Likewise for a negligent victim, when the injurer is nonnegligent.

Formally, for given C, D, L and (c^*, d^*), let $f(c^*, d^*) = (x_1, y_1)$. Now, (C1) says:

- If $c \geq c^*$ and $d < d^*$, $y < 1 - [x_1 L(c, d^*)/L(c, d)]$, i.e. $yL(c, d) - y_1 L(c, d^*) < L(c, d) - L(c, d^*)$.

And, (C2) says:

- If $c < c^*$ and $d \geq d^*$, $x < 1 - [y_1 L(c^*, d)/L(c, d)]$, i.e. $xL(c, d) - x_1 L(c^*, d) < L(c, d) - L(c^*, d)$.

The condition CL is a necessary condition for efficiency in the sense described by Theorem 3.

Theorem 3. *Under a liability rule if* (*C1*) *or* (*C2*) *holds then the rule cannot be efficient for every possible choice of* C, D, L *and* (c^*, d^*).

For a formal and complete proof, see Appendix B. Suppose (C1) holds. This means that under the rule whenever the injurer reduces his care from where he is not negligent to where he is, he will bear only a fraction of the resulting increase in the expected accident loss. But, the entire benefit of the reduction in the cost of care will accrue to him. Therefore, the injurer will not fully internalize the consequences of his action and, at least, in some accident contexts he will be better-off opting an inefficient care level. Similarly, when (C2) holds, at least in some accident contexts, the victim will find it advantageous to take less than the efficient care.

Remark 4. When the victim is nonnegligent, i.e. $c = c^*$, if the injurer reduces his care from d^* to any $d < d^*$, the consequent increase in the expected loss is $L(c^*, d) - L(c^*, d^*)$. But, the increase in the actual loss is $H(c^*, d) - H(c^*, d^*)$. If the liability is based on the causal contribution to the actual loss caused by the injurer's negligence, a court might require him to bear $H(c^*, d) - H(c^*, d^*)$. In that case his expected liability will be $\pi(c^*, d)[H(c^*, d) - H(c^*, d^*)]$. Whenever $\pi(c^*, d) > \pi(c^*, d^*)$ and $L(c^*, d^*) > 0$, $L(c^*, d) - L(c^*, d^*) > \pi(c^*, d)[H(c^*, d) - H(c^*, d^*)]$.[20] Thus, the increase in the injurer's liability will be *less* than $L(c^*, d) - L(c^*, d^*)$, i.e. (C1) will hold. Therefore, in view of Theorem 3, in such a setting the liability rule cannot be efficient for all C, D, L and (c^*, d^*).

Remark 4 shows that if care by a party affects the probability of accident as well as the harm that will occur in the event of an accident, which generally is the case, then a liability assignment that is based solely on a negligent party's contribution to the actual (rather than the expected) loss will not induce efficient care. When liability assignment makes a negligent party bear its contribution only to the actual loss the party will internalize only a part of the social costs caused by its negligence; it will not internalize the effects of its negligence in the form of increased probability of accident. Therefore, as is argued in the discussion following Theorem 3, the party will be induced to take less than the efficient care.

Example 4. Consider the following C, D, and L:

$$C = \{0, c_0, c_1\}, \text{ where } c_0 > 0 \text{ and } c_1 > c_0; \quad D = \{0, d_0, d_1\}, \text{ where } d_0 > 0 \text{ and } d_1 > d_0;$$

[20] $L(c, d) - L(c^*, d^*) = \pi(c, d)H(c, d) - \pi(c^*, d^*)H(c^*, d^*)$. It is obvious that if $c = c^*$ and $d < d^*$, $L(c, d) - L(c^*, d^*) > \pi(c, d)[H(c, d) - H(c^*, d^*)]$, whenever $\pi(c, d) > \pi(c^*, d^*)$ and $L(c^*, d^*) > 0$.

$L(0,0) = c_0+d_0+\delta_1+\delta_2 + 2\Delta,$ where $\delta_1, \delta_2 > 0,\ c_1 - c_0 > \Delta,$ and $2\Delta > d_1 - d_0 > \Delta;$

$L(c_0, 0) = d_0 + \delta_2 + 2\Delta;\ L(0, d_0) = c_0 + \delta_1 + 2\Delta; \quad L(c_1, 0) = d_0 + \delta_2 + \Delta;$

$L(0, d_1) = c_0 + \delta_1 + \Delta; \quad L(c_0, d_0) = 2\Delta; \quad L(c_0, d_1) = \Delta = L(c_1, d_0);$

$L(c_1, d_1) = 0.$

In Example 4, (c_0, d_0) is uniquely TSC minimizing, i.e. $(c_0, d_0) = (c^*, d^*)$. Consider a liability rule defined by the function *f* for the *C*, *D*, and *L* in Example 4. Where *f* is such that:

$$(\forall c \geq c_0)(\forall d \leq d_0)[f(c,d) = (0,1)], \quad (\forall d \geq d_0)[f(0,d) = (1,0)],$$

$$f(0,0) = (1/2, 1/2), \quad f(c_0, d_1) = (1,0), \quad (\forall d \geq d_0)[f(c_1, d) = (0,1)]$$

Obliviously this rule satisfies condition CL but is not compatible with (P1) and (P2), the properties imposed by us on the structure of liability rules. It is easy to see that the rule is not efficient in the above accident context, since under the rule the unique TSC minimizing pair (c_0, d_0) is not a N.E.

4. Efficient liability rules with bilateral-care and bilateral-risk

In the previous sections, we considered unilateral-risk accidents wherein, to start with, only one party suffers all the losses from an accident. In this section, we extend our model to what are called the bilateral-risk accidents, i.e. to the cases wherein both the parties suffer losses in the event of an accident. This extension is useful. Since, most of the road accidents involving two vehicles, e.g. two cars are of this type.

For the bilateral-risk accidents, as is the case with the actual functioning of the law of torts, we assume that each party to an accident is allowed to sue the other party for compensation. That is depending on the care levels opted by the parties at the time of the accident and the rule in force, a party may get compensated by the other party for the accident loss.[21] In such settings, each party is both a potential injurer and a potential victim simultaneously. However, for the ease of exposition we will stick to our characterization of the parties; the first party will be called the victim and the second one the injurer. In addition to our notations in Section 2, we denote by:

- H_v the loss suffered by the victim in the event of an accident;
- H_i the loss suffered by the injurer;
- L_v the expected loss faced by the victim, L_v is thus equal to πH_v, $L_v \geq 0$;
- L_i the expected loss faced by the injurer, L_i is thus equal to πH_i, $L_i \geq 0$;
- L the *total* expected accident loss, thus $L(c, d) = \pi(c, d)[H_v(c, d) + H_i(c, d)] = L_v + L_i$.

[21] For details and references corroborating this claim see Arlen (1990, 1992), and Cooter and Ulen (2000, p. 311).

The total social costs (TSC) of accident are $c + d + L(c, d)$, i.e. $c + d + L_v(c, d) + L_i(c, d)$. In addition to (A1)–(A3) and (A5)–(A6) [in (A2), replace H with H_v, H_i] we assume:

(A4)′ Both L_v and L_i are non-increasing functions of the care level of each party. Decrease in L_v can take place due to decrease in π or H_v or both. Likewise for L_i.

(A7)′ C, D, L_v and L_i are such that TSC minimizing pair of care levels is unique, and is denoted by (c^{**}, d^{**}). Again $(c, d) \neq (c^{**}, d^{**})$ implies that:

$$c + d + L_v(c, d) + L_i(c, d) > c^{**} + d^{**} + L_v(c^{**}, d^{**}) + L_i(c^{**}, d^{**}).$$

(A8)′ The due care level for the injurer [the victim], wherever applicable, is set at d^{**} [c^{**}].

Definition 4.1. *Bi-liability rule*

As is mentioned above, depending upon their care levels and the legal position, a party to an accident may get compensated by the other party for the accident loss. A legal position that allows the parties to sue each other, is like an application of two liability rules at the same time; one deciding on the losses suffered by the first party, and the other deciding on the losses suffered by the second party. We shall call such rules or legal positions as ‘bi-liability’ rules. A bi-liability rule will determine the proportion in which the victim will bear the losses suffered by the injurer, and the proportion in which the injurer will bear the losses suffered by the victim. Formally, for given C, D, L_v, L_i and (c^{**}, d^{**}), a bi-liability rule can be defined by a unique function $f: C \times D \to [0, 1]^2 \times [0, 1]^2$ such that:

$$f(c, d) = ((x_v, y_v), (x_i, y_i))$$

where $x_v \geq 0$ [$y_v \geq 0$] is the proportion of H_v (the accident loss suffered by the victim) that will be borne by the victim [the injurer] under the rule. x_v and y_v are such that $x_v + y_v = 1$. Similarly, $x_i \geq 0$ [$y_i \geq 0$] is the proportion of H_i (the accident loss suffered by the injurer) that will be borne by the victim [the injurer]. Again, $x_i + y_i = 1$.

As a matter of legal practice, there can be circumstances wherein activity of the first party is governed by one liability rule and that of the second party by some other rule. For example, assume that the activity of the injurer is governed by standard rule of negligence, and that of the victim is governed by the rule of strict liability with the defense of contributory negligence (SLWD).[22] In such a case,[23]

$$f(c, d) = ((1, 0), (1, 0)) \text{ when } c \geq c^{**} \text{ and } d \geq d^{**},$$

$$f(c, d) = ((0, 1), (0, 1)) \text{ when } c \geq c^{**} \text{ and } d < d^{**}$$

We assume that f satisfies both (P1) and (P2) as mentioned in Section 2. (P3), for instance, would mean that if $f(c^{**}, d^{**}) = ((x_v^1, y_v^1), (x_i^1, y_i^1))$ then for all $c \geq c^{**}$ and all $d \geq d^{**}$, $f(c, d) = ((x_v^1, y_v^1), (x_i^1, y_i^1))$. Therefore, when $c \geq c^{**}$ and $d \geq d^{**}$ expected costs of the

[22] As is argued in Arlen (1990, 1992), and Cooter and Ulen (2000, p. 311) there can be circumstances wherein activity of the first party is governed by one liability rule and that of the other by some other rule.

[23] Since the activity of the injurer is governed by the rule of negligence and when $c \geq c^{**}$ and $d \geq d^{**}$ he is not negligent, he will not bear any part of H_v. Therefore, $(x_v, y_v) = (1, 0)$. Similarly, as the activity of the victim is governed by SLWD, and when $c \geq c^{**}$ and $d \geq d^{**}$ the injurer is not negligent. Therefore, the victim will bear the entire H_i, i.e. $(x_i, y_i) = (1, 0)$. Therefore, when $c \geq c^{**}$ and $d \geq d^{**}$, $f(c, d) = ((1, 0), (1, 0))$.

victim and the injurer will be $c + x_v^1 L_v(c, d) + x_i^1 L_i(c, d)$ and $d + y_v^1 L_v(c, d) + y_i^1 L_i(c, d)$, respectively.

The *condition of causation liability* will be as it is in the last section but the term 'the expected loss' would refer to the *total* expected loss, i.e. $L = L_v + L_i$. To see how liability will be determined under a bi-liability rule satisfying condition CL, see Appendix A. However, notice that like in the case of unilateral-risk, when the risk is bilateral, the condition CL makes a solely negligent party bear the social loss that can be attributed only to its negligence, and not the entire loss. For arguments similar to the ones provided for Claim 1 we have Claim 3. A proof of the claim is provided in Appendix B.

Claim 3. *If a bi-liability rule satisfies condition CL then for every possible choice of* C, D, L_v, L_i *and* (c^{**}, d^{**}); (c^{**}, d^{**}) *is a Nash equilibrium.*

Theorem 4. *If a bi-liability rule satisfies condition CL then for every possible choice of* C, D, L_v, L_i *and* (c^{**}, d^{**}); *it is efficient.*

Proof. Take any C, D, L_v, L_i and (c^{**}, d^{**}). From Claim 3, (c^{**}, d^{**}) is a N.E. Also, arguing along the lines of the proof provided for Claim 2, it can be shown that (c^{**}, d^{**}) is a unique N.E. □

It is interesting to compare the claim of Theorem 4 with the relevant results in the existing literature. Arlen (1900), and Dhammika and Hoffmann (2005) have shown that in the contexts of bilateral-risk accidents if activities of both parties are governed by *the same* standard negligence-criterion based rule (e.g. the rule of negligence may govern the activities of both the parties) then the outcome will be efficient.[24] Note that when $c \geq c^{**}$ and $d \geq d^{**}$, or when $c < c^{**}$ and $d < d^{**}$ condition CL does not impose any restriction on a bi-liability rule. Also, *any* combination of the standard negligence-criterion based rules (one rule for the first party and the other for the second party) produces the following assignment:

$$f(c, d) = ((x_v, y_v), (x_i, y_i)) = ((0, 1), (0, 1)), \text{ whenever } c \geq c^{**} \text{ and } d < d^{**};$$

$$f(c, d) = ((x_v, y_v), (x_i, y_i)) = ((1, 0), (1, 0)), \text{ whenever } c < c^{**} \text{ and } d \geq d^{**}$$

In other words, under *an arbitrary* combination of the standard negligence-criterion based rules, a solely negligent party is made to bear the losses suffered by both the parties. But, this (though not necessarily required) is consistent with the condition CL. Hence, any combination of standard negligence based rules will result in an efficient outcome. This general claim, in particular, implies that if any one of the standard negligence criterion based rules governs the activities of both the parties, the outcome will be efficient. Therefore, we get the relevant results in Arlen (1990), and Dhammika and Hoffmann (2005) as a corollary to Theorem 4. Importance of the theorem, however, is illustrated by Remark 5.

24 Dhammika and Hoffmann (2005) have shown that this claim holds even when costs of care are interdependent.

Remark 5. Any *arbitrary* combination of the standard negligence-criterion based rules satisfies the condition CL, and therefore ensures efficiency. More importantly, for the purpose of the economic efficiency it is not necessary to require a solely negligent party to bear all the losses suffered by both the parties (see (i)′–(iv)′ in Appendix A).

5. Concluding remarks

In the literature on the law of torts, it is a well-established fact that when care is bilateral, the negligence or the due care criterion-based liability rules are efficient. These rules, as they are modeled in the economic analysis, have a common attribute: in the event of an accident, if one party is negligent and the other is not, then the negligent party is liable for the *entire* accident loss. This common feature of the negligence criterion-based liability rules causes a sudden jump in the liability of at least one party—for at least one party it is true that when the party reduces its care level from where it is not negligent to where it is negligent its liability jumps from no-liability to full-liability. Criticizing the standard modeling of liability rules, some (legal) scholars have argued that the above-mentioned drastic change in liability is not consistent with the causation doctrine of the law of torts.[25] From an efficiency point of view, our analysis (Theorems 1 and 2) shows that a drastic change in liability is not necessary for economic efficiency; causation-consistent liability is sufficient to ensure efficiency. Theorem 3, shows that in at least one sense, causation-based liability is a necessary condition for any liability rule to be efficient. We have established similar results for the accident contexts that involve bilateral-risk. In particular, we have shown that for the purpose of economic efficiency, it is not necessary that a solely negligent party bear all the accident losses suffered by both the parties. This claim holds irrespective of whether the risk is unilateral or bilateral.

Our enquiry into the efficiency implications of what we have called the causation-consistent liability throws up interesting research questions. These questions are relevant for the studies that have adopted an approach that is similar to ours. For example, when the liability assignment is ‘causation-consistent’ and care is unilateral, for the rule of negligence, Kahan (1989) and Van Wijck and Winters (2001) have proved two important results: (1) injurers opt for the efficient care level, and (2) the causation-consistent liability is superior to the conventional specification of liability in that the injurers’ care will still be efficient even when the legal standard of care is set at a higher (inefficient) level. Our analysis shows that the first claim can be extended to the bilateral-care accidents, and holds for all the negligence-criterion based liability rules. Whether the second claim holds in bilateral-care settings, and for other liability rules are the questions that need to be investigated. Future research studies might answer some of these questions.

Earlier analyses of causation particularly by Grady and Kahan have argued that courts in fact apply the causation limit; but in the later analyses, it is argued that under the US tort law a negligent injurer is liable for the entire loss suffered by the victim. If so, causation-consistent liability is not a description of how the law of torts is practiced in courts. (But, note

[25] See Grady (1983, 1988, 1989), Kahan (1989), Honoré (1997).

that though the condition CL does not insist on liability for the entire loss, full liability is not inconsistent with it.) We have shown that for economic efficiency, full liability is not necessary even when an injurer is solely negligent. Importance of the condition CL is underlined by the fact that it completely distinguishes the set of efficient liability rules, including those actually applied by courts and also other possible rules, from the rules that are not efficient.

Finally a remark on the nature of the framework of analysis adopted in the paper. In the standard analyses it is generally taken that the cost of care is a continuous variable and the expected loss function is differentiable. But, Feldman and Frost (1998) have argued that the discrete and sometimes even dichotomous care is the reality of many accident settings. It should be noted that our modeling does not impose any condition and is more general than the standard modeling in this regard; it is equally applicable to both the continuous as well as the discrete variables. In addition, the liability rules considered in the paper are such that they satisfy the properties (P1) and (P2). Here, it is important to note that not only all the rules discussed in the literature satisfy these properties, as is shown in the discussion on Example 4, (P1) and (P2) have important efficiency implications.

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Appendix A

A.1. Liability assignment under a bi-liability rule that satisfies the condition CL

Consider any C, D, L_{v}, L_{i} and (c^{**}, d^{**}). Take any bi-liability rule that satisfies the condition CL. When $c \geq c^{**}$, if the injurer reduces his care from d^{**} to some $d < d^{**}$ he causes an increase in the total expected loss that is equal to $L(c, d) - L(c, d^{**}) = [L_{\mathrm{v}}(c, d) - L_{\mathrm{v}}(c, d^{**}) + L_{\mathrm{i}}(c, d) - L_{\mathrm{i}}(c, d^{**})]$. As before, under the rule, when $c \geq c^{**}$ and $d < d^{**}$ expected liability of the injurer will be the sum of his expected liability when he is just nonnegligent, i.e. $y_{\mathrm{v}}^1 L_{\mathrm{v}}(c, d^{**}) + y_{\mathrm{i}}^1 L_{\mathrm{i}}(c, d^{**})$, and $[L_{\mathrm{v}}(c, d) - L_{\mathrm{v}}(c, d^{**}) + L_{\mathrm{i}}(c, d) - L_{\mathrm{i}}(c, d^{**})] + \delta$ on account of his negligence (where $\delta \geq 0$), i.e. his expected liability will be greater than or equal to $y_{\mathrm{v}}^1 L_{\mathrm{v}}(c, d^{**}) + y_{\mathrm{i}}^1 L_{\mathrm{i}}(c, d^{**}) + [L_{\mathrm{v}}(c, d) - L_{\mathrm{v}}(c, d^{**}) + L_{\mathrm{i}}(c, d) - L_{\mathrm{i}}(c, d^{**})]$.

Let the function f define the rule for the given $C, D, L_{\mathrm{v}}, L_{\mathrm{i}}$ and (c^{**}, d^{**}). Let, $f(c^{**}, d^{**}) = ((x_{\mathrm{v}}^1, y_{\mathrm{v}}^1), (x_{\mathrm{i}}^1, y_{\mathrm{i}}^1))$. Then, under f, for different care levels liability assignment will be as follows:

(i)′ When $c \geq c^{**}$ and $d \geq d^{**}$, $f(c, d) = ((x_{\mathrm{v}}^1, y_{\mathrm{v}}^1), (x_{\mathrm{i}}^1, y_{\mathrm{i}}^1))$ where $x_{\mathrm{v}}^1, y_{\mathrm{v}}^1, x_{\mathrm{i}}^1, y_{\mathrm{i}}^1 \in [0, 1]$;
(ii)′ When $c \geq c^{**}$ and $d < d^{**}$, $f(c, d) = ((x_{\mathrm{v}}, y_{\mathrm{v}}), (x_{\mathrm{i}}, y_{\mathrm{i}}))$, where $y_{\mathrm{v}} \geq 1 - [x_{\mathrm{v}}^1 L_{\mathrm{v}}(c, d^{**})/L_{\mathrm{v}}(c, d)]$, and $y_i \geq 1 - [x_i^1 L_i(c, d^{**})/L_i(c, d)]$;

(iii)′ When $c < c^{**}$ and $d \geq d^{**}$, $f(c, d) = ((x_v, y_v), (x_i, y_i))$, where $x_v \geq 1 - [y_v^1 L_v(c^{**}, d)/L_v(c, d)]$, and $x_i \geq 1 - [y_i^1 L_i(c^{**}, d)/L_i(c, d)]$;
(iv)′ When $c < c^{**}$ and $d < d^{**}$, $f(c, d) = ((x_v, y_v), (x_i, y_i))$ where $x_v, y_v, x_i, y_i \in [0, 1]$.

Explanations for (i)′–(iv)′ are very similar to those provided for (i)–(iv) in the definition of CL, respectively.[26]

Appendix B

Proof of Claim 1. Let a liability rule satisfy the condition CL. Take any arbitrary C, D, L, and (c^*, d^*). Suppose for this specification of C, D, L, and (c^*, d^*) the rule is defined by the function f. Let, $f(c^*, d^*) = (x_1, y_1)$, where $x_1 + y_1 = 1$. By property (P3), $(\forall c \geq c^*)(\forall d \geq d^*)[f(c, d) = (x_1, y_1)]$. Now, suppose the victim's care level is c^*. If the injurer chooses $d \geq d^*$, his expected costs are $d + y_1 L(c^*, d)$, where $y_1 \in [0, 1]$. That is at d^* his expected costs are $d^* + y_1 L(c^*, d^*)$. First, consider a choice of $d' > d^*$ by the injurer. Note that:

$$d' + y_1 L(c^*, d') + (1 - y_1) L(c^*, d') = d' + L(c^*, d') \tag{B.1}$$

$$> d^* + L(c^*, d^*) \tag{B.2}$$

$$= d^* + y_1 L(c^*, d^*) + (1 - y_1) L(c^*, d^*) \tag{B.3}$$

Eqs. (B.1) and (B.3) hold by simple algebra. Inequality (B.2) holds since the pair (c^*, d^*) uniquely minimizes the total social cost $c + d + L(c, d)$, so d^*, in particular, uniquely minimizes $d + L(c^*, d)$. From (B.1) and (B.3) we have $d' + y_1 L(c^*, d') + (1 - y_1) L(c^*, d') > d^* + y_1 L(c^*, d^*) + (1 - y_1) L(c^*, d^*)$. By rearranging we have $d' + y_1 L(c^*, d') > d^* + y_1 L(c^*, d^*) + (1 - y_1)[L(c^*, d^*) - L(c^*, d')]$. This implies $d' + y_1 L(c^*, d') > d^* + y_1 L(c^*, d^*)$, because $1 - y_1 \geq 0$, and $d' > d^*$ implies $L(c^*, d^*) \geq L(c^*, d')$. That is the injurer's expected costs are strictly greater at d' than at d^*, hence he will not choose any $d > d^*$ over d^*.

Next, consider a choice of $d' < d^*$ by the injurer. When $c = c^*$ and $d' < d^*$, the injurer is negligent and the victim is not. So, by condition CL, at d' the injurer's expected liability is more than his expected liability at d^* by at least $L(c^*, d') - L(c^*, d^*)$, i.e. by $L(c^*, d') - L(c^*, d^*) + \beta$, where $\beta \geq 0$. As, the injurer's liability is $y_1 L(c^*, d^*)$ when $d = d^*$, at d' his expected liability is $y_1 L(c^*, d^*) + L(c^*, d') - L(c^*, d^*) + \beta$, i.e. $L(c^*, d') - x_1 L(c^*, d^*) + \beta$. Thus, at $d' < d^*$ the injurer's expected costs are $d' + L(c^*, d') - x_1 L(c^*, d^*) + \beta$. But,

$$d' + L(c^*, d') - x_1 L(c^*, d^*) + \beta > d^* + L(c^*, d^*) - x_1 L(c^*, d^*) + \beta \tag{B.4}$$

$$\geq d^* + y_1 L(c^*, d^*) \tag{B.5}$$

[26] Notice that when $c \geq c^{**}$ and $d < d^{**}$ any y_v, y_i such that $y_v \in [1 - \{x_v^1 L_v(c, d^{**})/L_v(c, d)\}, 1]$, and $y_i \in [1 - \{x_i^1 L_i(c, d^{**})/L_i(c, d)\}, 1]$ are consistent with CL. Likewise when $c < c^{**}$ and $d \geq d^{**}$.

Eq. (B.4) holds since d^* uniquely minimizes $d + L(c^*, d)$, therefore $d' + L(c^*, d') > d^* + L(c^*, d^*)$. And (B.5) follows from the fact that $y_1 = 1 - x_1$ and that $\beta \geq 0$. Again, the injurer's expected costs are strictly greater at d' than at d^*.

Therefore, given c^* opted by the victim, d^* is a unique best response for the injurer. An analogous argument shows that given d^* opted by the injurer, c^* is a unique best response for the victim. Hence, (c^*, d^*) is a N.E. □

Proof of Claim 2. Take any liability rule that satisfies condition CL. Take any C, D, L, and (c^*, d^*). Let the function f define the rule for this specification of C, D, L, and (c^*, d^*). Assume $f(c^*, d^*) = (x_1, y_1)$. To prove the uniqueness, suppose $(\bar{c}, \bar{d})$ is a N.E. The following cases arise.

Case 1: $\bar{c} \geq c^*$ & $\bar{d} \geq d^*$: When $\bar{c} \geq c^*$ and $\bar{d} \geq d^*$, from (P3), $f(c^*, d^*) = (x_1, y_1) \Rightarrow (\forall \bar{c} \geq c^*)(\forall \bar{d} \geq d^*)[f(\bar{c}, \bar{d}) = (x_1, y_1)]$. That is, in this case the injurer's liability is $y_1 L(\bar{c}, \bar{d})$ and that of the victim's is $x_1 L(\bar{c}, \bar{d})$. $(\bar{c}, \bar{d})$ is a N.E., in particular, implies that given $\bar{d}$ opted by the injurer, the victim's expected costs at $\bar{c}$ are less than or equal to his costs at c^*, i.e.:

$$\bar{c} + x_1 L(\bar{c}, \bar{d}) \leq c^* + x_1 L(c^*, \bar{d}) \tag{B.6}$$

Again, $(\bar{c}, \bar{d})$ is a N.E., in particular, implies that given $\bar{c}$ opted by the victim, the injurer's expected costs at $\bar{d}$ are less than or equal to his costs at d^*, i.e.:

$$\bar{d} + y_1 L(\bar{c}, \bar{d}) \leq d^* + y_1 L(\bar{c}, d^*) \tag{B.7}$$

Adding (B.6) and (B.7), $(\bar{c}, \bar{d})$ is a N.E $\rightarrow \bar{c} + \bar{d} + L(\bar{c}, \bar{d}) \leq c^* + d^* + x_1 L(c^*, \bar{d}) + y_1 L(\bar{c}, d^*)$, since $x_1 + y_1 = 1$. But, $\bar{c} \geq c^*$ implies $L(\bar{c}, d^*) \leq L(c^*, d^*)$ and $\bar{d} \geq d^*$ implies $L(c^*, \bar{d}) \leq L(c^*, d^*)$. As $x_1 \geq 0$ and $y_1 \geq 0$, so $x_1 L(c^*, \bar{d}) \leq x_1 L(c^*, d^*)$ and $y_1 L(\bar{c}, d^*) \leq y_1 L(c^*, d^*)$. Therefore, $(\bar{c}, \bar{d})$ is a N.E. $\rightarrow \bar{c} + \bar{d} + L(\bar{c}, \bar{d}) \leq c^* + d^* + [x_1 + y_1]L(c^*, d^*)$, i.e. $\bar{c} + \bar{d} + L(\bar{c}, \bar{d}) \leq c^* + d^* + L(c^*, d^*)$. But, $(\bar{c}, \bar{d}) \neq (c^*, d^*) \Rightarrow \bar{c} + \bar{d} + L(\bar{c}, \bar{d}) > c^* + d^* + L(c^*, d^*)$, since (c^*, d^*) is uniquely TSC minimizing. Therefore, the semi-equality $\bar{c} + \bar{d} + L(\bar{c}, \bar{d}) \leq c^* + d^* + L(c^*, d^*)$ can hold only when $(\bar{c}, \bar{d}) = (c^*, d^*)$; when $(\bar{c}, \bar{d}) \neq (c^*, d^*)$ it will not hold. Formally,

$$\bar{c} \geq c^* \& \bar{d} \geq d^* \& (\bar{c}, \bar{d}) \text{ is a N.E.} \Rightarrow (\bar{c}, \bar{d}) = (c^*, d^*) \tag{B.8}$$

Case 2: $\bar{c} \geq c^*$ & $\bar{d} < d^*$: Subcase 1: $\bar{c} = c^*$: From Claim 1 we know that, given $\bar{c} = c^*$ opted by the victim, d^* is a unique best response for the injurer, so ($\bar{c} = c^*$ & $\bar{d} < d^*$) cannot be a N.E. Subcase 2: $\bar{c} > c^*$: At $(\bar{c}, \bar{d})$ total expected loss is $L(\bar{c}, \bar{d})$. When $\bar{c} > c^*$ & $\bar{d} < d^*$ the injurer is negligent and the victim is not. So, by condition CL at $\bar{d} < d^*$ the injurer's liability is more than his expected liability at d^* at least by $L(\bar{c}, \bar{d}) - L(\bar{c}, d^*)$. But, from (P3), $f(c^*, d^*) = (x_1, y_1)$ implies that at $(\bar{c} > c^*, d^*)$ the injurer's expected liability is $y_1 L(\bar{c}, d^*)$. Thus, when $\bar{c} > c^*$, at $\bar{d} < d^*$ the injurer's expected liability is $y_1 L(\bar{c}, d^*) + L(\bar{c}, \bar{d}) - L(\bar{c}, d^*) + \beta$, i.e. $L(\bar{c}, \bar{d}) - x_1 L(\bar{c}, d^*) + \beta$, where $\beta \geq 0$. And the victim will bear the remaining loss of $L(\bar{c}, \bar{d}) - [L(\bar{c}, \bar{d}) - x_1 L(\bar{c}, d^*) + \beta]$, i.e. $x_1 L(\bar{c}, d^*) - \beta$. Therefore, at $(\bar{c}, \bar{d})$, the expected costs of the injurer and the victim are $\bar{d} + L(\bar{c}, \bar{d}) - x_1 L(\bar{c}, d^*) + \beta$, and $\bar{c} + x_1 L(\bar{c}, d^*) - \beta$, respectively.

But, given that $\bar{c} > c^*$, if the injurer instead opts for d^* his expected liability will be $y_1 L(\bar{c}, d^*)$ and, therefore, his expected costs will be $d^* + y_1 L(\bar{c}, d^*)$.

Clearly, $\bar{d} + L(\bar{c}, \bar{d}) - x_1 L(\bar{c}, d^*) + \beta >$ or $\leq d^* + y_1 L(\bar{c}, d^*)$. If $\bar{d} + L(\bar{c}, \bar{d}) - x_1 L(\bar{c}, d^*) + \beta > d^* + y_1 L(\bar{c}, d^*)$ holds, the injurer will be better of choosing d^* rather than $\bar{d}$, given $\bar{c}$ opted by the victim. In that case $(\bar{c}, \bar{d})$ cannot be a N.E. Therefore, let:

$$\bar{d} + L(\bar{c}, \bar{d}) - x_1 L(\bar{c}, d^*) + \beta \leq d^* + y_1 L(\bar{c}, d^*) \tag{B.9}$$

Since $(\bar{c}, \bar{d}) \neq (c^*, d^*)$, $c^* + d^* + L(c^*, d^*) < \bar{c} + \bar{d} + L(\bar{c}, \bar{d})$. Since $x_1 + y_1 = 1$, we get $c^* + d^* + x_1 L(c^*, d^*) + y_1 L(c^*, d^*) < \bar{c} + \bar{d} + L(\bar{c}, \bar{d})$. But, $\bar{c} > c^*$ means $L(\bar{c}, d^*) \leq L(c^*, d^*)$, then $y_1 L(\bar{c}, d^*) \leq y_1 L(c^*, d^*)$ since $y_1 \geq 0$. Thus:

$$c^* + d^* + x_1 L(c^*, d^*) + y_1 L(\bar{c}, d^*) < \bar{c} + \bar{d} + L(\bar{c}, \bar{d}) \tag{B.10}$$

Now, by subtracting the right hand [left hand] side of (B.9) from the left hand [right hand] of (B.10):

$$c^* + x_1 L(c^*, d^*) < \bar{c} + x_1 L(\bar{c}, d^*) - \beta \tag{B.11}$$

Now, given $\bar{d}$ opted by the injurer, if the victim instead opts for c^* his expected liability will be $x_1 L(c^*, d^*) - \beta'$, where $\beta' \geq 0$.[27] Therefore, at c^* the victim's expected costs will be $c^* + x_1 L(c^*, d^*) - \beta'$. But, as shown above, given $\bar{d}$ opted by the injurer, if he stays at $\bar{c}$ his expected costs are $\bar{c} + x_1 L(\bar{c}, d^*) - \beta$. In view of (B.11), this means that, given $\bar{d}$ opted by the injurer, c^* rather than $\bar{c}$ is a better choice for the victim. Hence, whether $\bar{d} + L(\bar{c}, \bar{d}) - x_1 L(\bar{c}, d^*) + \beta >$ or $\leq d^* + y_1 L(\bar{c}, d^*)$:

$$\bar{c} \geq c^* \,\&\, \bar{d} < d^* \Rightarrow (\bar{c}, \bar{d}) \text{ cannot be a N.E.} \tag{B.12}$$

Case 3: $\bar{c} < c^*$ & $\bar{d} \geq d^*$: An argument analogous to the one in the Case 2 shows that:

$$\bar{c} < c^* \,\&\, \bar{d} \geq d^* \Rightarrow (\bar{c}, \bar{d}) \text{ cannot be a N.E.} \tag{B.13}$$

Case 4: $\bar{c} < c^*$ & $\bar{d} < d^*$: In this case it should be noted that the condition CL does not impose any restriction on liability assignment. Suppose $f(\bar{c}, \bar{d}) = (x', y')$. Then, at $(\bar{c}, \bar{d})$ expected costs of the injurer and the victim are $\bar{d} + y' L(\bar{c}, \bar{d})$ and $\bar{c} + x' L(\bar{c}, \bar{d})$, respectively. On the other hand, given $\bar{d} < d^*$, if the victim instead opts for c^* then he will be nonnegligent and the injurer remains negligent. An argument very similar to the one provided in Case 2 shows that at $(c^*, \bar{d} < d^*)$ the victim's expected costs are $c^* + x_1 L(c^*, d^*) - \alpha$, $\alpha \geq 0$. Similarly, given $\bar{c} < c^*$ opted by the victim, if the injurer opts for d^* his expected costs are $d^* + y_1 L(c^*, d^*) - \alpha'$, where $\alpha' \geq 0$. Now, if $\bar{c} + x' L(\bar{c}, \bar{d}) > c^* + x_1 L(c^*, d^*) - \alpha$ the victim's expected costs are strictly less at c^* than at $\bar{c}$, i.e. $(\bar{c}, \bar{d})$ cannot be a N.E. So, let $\bar{c} + x' L(\bar{c}, \bar{d}) \leq c^* + x_1 L(c^*, d^*) - \alpha$, i.e.:

$$\bar{c} + x' L(\bar{c}, \bar{d}) \leq c^* + x_1 L(c^*, d^*) \tag{B.14}$$

But, as $(\bar{c}, \bar{d}) \neq (c^*, d^*)$, $c^* + d^* + L(c^*, d^*) < \bar{c} + \bar{d} + L(\bar{c}, \bar{d})$, i.e.:

$$c^* + d^* + (x_1 + y_1) L(c^*, d^*) < \bar{c} + \bar{d} + (x' + y') L(\bar{c}, \bar{d}) \tag{B.15}$$

[27] As CL and $\bar{d} < d^*$ imply that out of the total expected loss of $L(c^*, \bar{d})$, $L(c^*, \bar{d}) - x_1 L(c^*, d^*) + \beta'$, will be borne by the injurer.

Eq. (B.15), in view of (B.14), $\Rightarrow \bar{d} + y'L(\bar{c}, \bar{d}) > d^* + y_1L(c^*, d^*)$, i.e. $\bar{d} + y'L(\bar{c}, \bar{d}) > d^* + y_1L(c^*, d^*) - \alpha'$, i.e. given $\bar{c}$ opted by the victim, the injurer's expected costs are less at d^* than at $\bar{d}$. Therefore, whether $\bar{c} + x'L(\bar{c}, \bar{d}) > c^* + x_1L(c^*, d^*) - \alpha$, or $\bar{c} + x'L(\bar{c}, \bar{d}) \leq c^* + x_1L(c^*, d^*) - \alpha$,

$$\bar{c} < c^* \,\&\, \bar{c} < c^* \Rightarrow (\bar{c}, \bar{d}) \text{ cannot be N.E.} \tag{B.16}$$

Finally, (B.8), (B.12), (B.13) & (B.16) $\Rightarrow [(\bar{c}, \bar{d})$ is a N.E. $\rightarrow (\bar{c}, \bar{d}) = (c^*, d^*)]$. This, in view of Claim 1, implies that (c^*, d^*) is a unique N.E. □

Proof of Theorem 3. Take any liability rule. Without any loss of generality suppose that under the rule (C1) holds. Take any $t > 0$. Choose $r > 0$ such that $r < t$. Now consider the following C, D, and L:

$$C = \{0, c_0\}, \text{ where } c_0 > 0, \quad D = \{0, d', d_0\}, \text{ where } d_0 - d' = r,$$

$$L(0, 0) = t + d' + c_0 + \delta + \Delta, \text{ where } \delta > 0, \text{ and } \Delta \geq 0, \quad L(c_0, 0) = t + d' + \Delta,$$

$$L(0, d') = t + c_0 + \delta + \Delta, \quad L(0, d_0) = c_0 + \delta + \Delta, \quad L(c_0, d') = t + \Delta,$$

$$L(c_0, d_0) = \Delta$$

Clearly, (c_0, d_0) is uniquely TSC minimizing pair. Take $(c^*, d^*) = (c_0, d_0)$. Let the function f define the rule for the above C, D, and L. Suppose, $f(c^*, d^*) = (x_1, y_1)$, where $x_1, y_1 \in [0, 1]$. Assume that the victim opts for c_0. If the injurer opts for d_0 his expected liability is $y_1\Delta$ and his expected costs are $d_0 + y_1\Delta$. In view of (C1), suppose, if the injurer reduces his care from d_0 to d', the increase in his expected liability is α times the resulting increase in the expected loss, where $\alpha < 1$. Thus, if he reduces his care to d', the consequent increase in his liability is $\alpha[L(c_0, d') - L(c_0, d_0)] = \alpha t$. Then, at d' his expected costs are $d' + \alpha t + y_1\Delta$. Clearly, $\alpha t < t$. Let r be such that $\alpha t < r < t$. Then $d' + \alpha t + y_1\Delta < d_0 + y_1\Delta$, since $\alpha t < r = d_0 - d'$, i.e. $d_0 > d' + \alpha t$. Therefore, the injurer is better-off choosing d' rather than d_0. Thus, uniquely TSC minimizing pair (c^*, d^*) is not a N.E. That is there exist C, D, L and (c^*, d^*) such that the rule is not efficient.[28] Therefore, when (C1) or (C2) holds no rule can be efficient for every possible C, D, L and (c^*, d^*).

If we assume that c, d are continuous variables and L is differentiable twice with $L_d < 0$, $L_c < 0$, $L_{dd} > 0$, $L_{cc} > 0$, $L_{cd} > 0$, as is the standard practice, then the claim follows immediately. When (C1) holds, given c^* opted by the victim, suppose (for simplicity) at $d \leq d^*$ increase in expected liability of the injurer is $\alpha[L(c^*, d) - L(c^*, d^*)]$, i.e. at $d \leq d^*$ his expected costs are $d + y_1L(c^*, d^*) + \alpha[L(c^*, d) - L(c^*, d^*)]$. In that case the injurer will choose $\bar{d}$ satisfying $1 = -\alpha L_d(c^*, d)$. When $\alpha = 1$, $\bar{d} = d^*$. But, when $\alpha < 1$, $L_{dd} > 0$ means that $\bar{d} < d^*$, i.e. (c^*, d^*) in not a N.E. □

Proof of the Claim 3. Let a bi-liability rule satisfy the condition CL. Take any C, D, L_v, L_i and (c^{**}, d^{**}). Suppose for the given C, D, L_v, L_i and (c^{**}, d^{**}) the rule is defined by the function f. Let, $f(c^{**}, d^{**}) = ((x_v^1, y_v^1), (x_i^1, y_i^1))$. Again, $(\forall c \geq c^{**})(\forall d \geq d^{**})[f(c, d) =$

[28] It should be noted that we have not assumed any thing about the magnitude of α part from assuming that $\alpha < 1$. Irrespective of the magnitude as long as $\alpha < 1$ such contexts can be specified.

$((x_v^1, y_v^1), (x_i^1, y_i^1))$]. Suppose the victim's care level is c^{**}. If the injurer chooses $d \geq d^{**}$, his expected costs are $d + y_v^1 L_v(c^{**}, d) + y_i^1 L_i(c^{**}, d)$, where $y_v^1, y_i^1 \in [0, 1]$. At d^{**} his expected costs are $d^{**} + y_v^1 L_v(c^{**}, d^{**}) + y_i^1 L_i(c^{**}, d^{**})$. Now, consider a choice of $d' > d^{**}$ by the injurer. Note that:

$$d' + (x_v^1 + y_v^1)L_v(c^{**}, d') + (x_i^1 + y_i^1)L_i(c^{**}, d') = d' + L_v(c^{**}, d') + L_i(c^{**}, d') \tag{B.17}$$

$$> d^{**} + L_v(c^{**}, d^{**}) + L_i(c^{**}, d^{**}) \tag{B.18}$$

$$= d^{**} + (x_v^1 + y_v^1)L_v(c^{**}, d^{**}) + (x_i^1 + y_i^1)L_i(c^{**}, d^{**}) \tag{B.19}$$

Eqs. (B.17) and (B.19) hold by simple algebra. Inequality (B.18) holds since (c^{**}, d^{**}) uniquely minimizes $c + d + L_v(c, d) + L_i(c, d)$, so d^{**}, in particular, will uniquely minimize $d + L_v(c^{**}, d) + L_i(c^{**}, d)$. From (B.17) and (B.19) by rearranging we have $d' + y_v^1 L_v(c^{**}, d') + y_i^1 L_i(c^{**}, d') > d^{**} + y_v^1 L_v(c^{**}, d^{**}) + y_i^1 L_i(c^{**}, d^{**}) + x_v^1[L_v(c^{**}, d^{**}) - L_v(c^{**}, d')] + x_i^1[(L_i(c^{**}, d^{**}) - L_i(c^{**}, d')]$. That is when $d' > d^{**}$ we get $d' + y_v^1 L_v(c^{**}, d') + y_i^1 L_i(c^{**}, d') > d^{**} + y_v^1 L_v(c^{**}, d^{**}) + y_i^1 L_i(c^{**}, d^{**})$, because $x_v^1 \geq 0, x_i^1 \geq 0$ and $d' > d^{**} \Rightarrow [L_v(c^{**}, d^{**}) \geq L_v(c^{**}, d')\ \&\ L_i(c^{**}, d^{**}) \geq L_i(c^{**}, d')]$. That is the injurer's expected costs are strictly greater at d' than at d^{**}, hence he will not choose a $d > d^{**}$ over d^{**}.

Next, consider a choice of $d' < d^{**}$ by the injurer. When $c = c^{**}$ & $d' < d^{**}$, the injurer is negligent and the victim is not. So, by condition CL, at d' the injurer's expected costs are $d' + y_v^1 L_v(c^{**}, d^{**}) + y_i^1 L_i(c^{**}, d^{**}) + L_v(c^{**}, d') - L_v(c^{**}, d^{**}) + L_i(c^{**}, d') - L_i(c^{**}, d^{**}) + \delta$, i.e. $d' + L_v(c^{**}, d') + L_i(c^{**}, d') - x_v^1 L_v(c^{**}, d^{**}) - x_i^1 L_i(c^{**}, d^{**}) + \delta$, where $\delta > 0$. But,

$$\begin{aligned} d' + L_v(c^{**}, d') + L_i(c^{**}, d') - x_v^1 L_v(c^{**}, d^{**}) - x_i^1 L_i(c^{**}, d^{**}) + \delta > d^{**} \\ + L_v(c^{**}, d^{**}) + L_i(c^{**}, d^{**}) - x_v^1 L_v(c^{**}, d^{**}) - x_i^1 L_i(c^{**}, d^{**}) + \delta \end{aligned} \tag{B.20}$$

$$\geq d^{**} + y_v^1 L_v(c^{**}, d^{**}) + y_i^1 L_i(c^{**}, d^{**}) \tag{B.21}$$

Eq. (B.20) holds since d^{**} uniquely minimizes $d + L_v(c^{**}, d) + L_i(c^{**}, d)$, therefore, $d' + L_v(c^{**}, d') + L_i(c^{**}, d') > d^{**} + L_v(c^{**}, d^{**}) + L_i(c^{**}, d^{**})$. And (B.21) follows from the fact that $y^1 = 1 - x^1$ and that $\delta \geq 0$. Again, the injurer's expected costs are strictly greater at d' than his costs at d^{**}.

Therefore, given c^{**} opted by the victim, d^{**} is a unique best response for the injurer. Analogous argument shows that given d^{**} opted by the injurer, c^{**} is a unique best response for the victim. Hence, (c^{**}, d^{**}) is a N.E. □

References

Arlen, J. (1990). Re-examining liability rules when injurers as well as victims suffer losses. *International Review of Law and Economics*, *10*, 233–239.

Arlen, J. (1992). Liability for physical injury when injurers as well as victims suffer losses. *Journal of Law, Economics and Organization*, *8*, 411–426.

Bar-Gill, O., & Ben-Shahar, O. (2003). The uneasy case for comparative negligence. *American Law and Economic Review*, *5*, 433–469.

Barnes, D. W., & Stout, L. A. (1992). *The economic analysis of tort law*. St. Paul: West Publishing Company.

Ben-Shahar, O. (2000). Causation and foreseeability. In B. Bouckaert & G. De Geest (Eds.), *Encyclopedia of law and economics*. Cheltenham: Edward Elgar.

Biggar, D. (1995). A model of punitive damages in torts. *International Review of Law and Economics*, *15*, 1–24.

Brown, J. P. (1973). Toward an economic theory of liability. *Journal of Legal Studies*, *2*, 323–350.

Burrows, P. (1999). A deferential role for efficiency theory in analysing causation-based Tort law. *European Journal of Law and Economics*, *8*, 29–49.

Calabresi, G. (1970). *The costs of accidents*. New Haven: Yale University Press.

Chung, T.-Y. (1993). Efficiency of comparative negligence: A game theoretic analysis. *Journal of Legal Studies*, *22*, 395–404.

Cooter, R. D. (1987). Torts as the union of liberty and efficiency: An essay on causation. *Chicago-Kent Law Review*, *63*, 522–551.

Cooter, R. D., & Ulen, T. S. (1986). An economic case for comparative negligence. *New York University Law Review*, *81*, 1067–1110.

Cooter, R. D., & Ulen, T. S. (2000). *Law and economics* (2nd ed.). New York: Addison-Wesley.

Dari Mattiacci, G. (2002). Tort law and economics. In A. Hatzis (Ed.), *Economics analysis of law: A European perspective*. Edward Elgar.

Dhammika, D., & Hoffmann, S. A. (2005). Bilateral accidents with intrinsically interdependent costs of precaution. *Journal of Legal Studies*, *34*, 239–272.

Diamond, P. A. (1974). Single activity accidents. *Journal of Legal Studies*, *3*, 107–164.

Edlin, A. S. (1994). Efficient standards of due care: Should courts find more parties negligent under comparative negligence? *International Review of Law and Economics*, *14*, 21–34.

Epstein, R. A. (1979). Causation and corrective justice: A reply to two critics. *Journal of Legal Studies*, *8*, 477–504.

Epstein, R. A. (1987). Causation—in context: An afterword. *Chicago-Kent Law Review*, *63*, 653–680.

Feldman, A. M., & Frost, J. M. (1998). A simple model of efficient tort liability rules. *International Review of Law and Economics*, *18*, 201–215.

Grady, M. F. (1983). A new positive theory of negligence. *Yale Law Journal*, *92*, 799–829.

Grady, M. F. (1988). Discontinuities and information burdens: Review of the economic structure or tort law by William M. Landes and Richard A. Posner. *George Washington Law Review*, *56*, 658–678.

Grady, M. F. (1989). Untaken precautions. *Journal of Legal Studies*, *18*, 139–156.

Haddock, D., & Curran, C. (1985). An economic theory of comparative negligence. *Journal of Legal Studies*, *14*, 49–72.

Hart, H. L. A., & Honoré, T. (1985). *Causation in the law* (2nd ed.). Oxford: Oxford University Press.

Honoré, T. (1983). Causation and remoteness of damages. *International Encyclopedia of Comparative Law*, *XI*(1).

Honoré, T. (1997). Necessary and sufficient condition in tort law. In D. G. Owen (Ed.), *Philosophical foundations of tort law*. Oxford: Clarendon Press.

Hylton, K. N. (2001). The theory of tort doctrine and the restatement of torts. *Vanderbilt Law Review*, *54*, 1413.

Jain, S. K., & Singh, R. (2002). Efficient liability rules: Complete characterization. *Journal of Economics*, *75*(2), 105–124.

Kahan, M. (1989). Causation and incentives to take care under the negligence rule. *Journal of Legal Studies*, *18*, 427–447.

Kaplow, L. (1995). A model of the optimal complexity of legal rules. *Journal of Law, Economics, and Organization*, *11*, 150–163.

Keeton, R. (1963). *Legal cause in law of torts*. Columbus: Ohio State University Press.

Keeton, W. P., Dobb, D., Keeton, R., & Owen, D. (1984). *Prosser and keeton on torts* (5th ed.). St Paul, MN: West Publishers.

Landes, W. M., & Posner, R. A. (1983). Causation in tort law: An economic approach. *Journal of Legal Studies*, *12*, 109–134.

Landes, W. M., & Posner, R. A. (1987). *The economic structure of tort law*. Cambridge, MA: Harvard University Press.

Levmore, S. (1994). *Foundations of tort law*. Oxford: Oxford University Press.

Liao, Y.-P., & White, M. J. (2002). No-fault for motor vehicles: An economic analysis. *American Law and Economics Review*, 258–294.

Marks, S. V. (1994). Discontinuities, causation, and Grady's uncertainty theorem. *Journal of Legal Studies*, *23*, 287–301.

Miceli, T. J. (1996). Cause in fact, proximate cause, and the hand rule: Extending Grady's positive economic theory of negligence. *International Review of Law and Economics*, *16*, 473–482.

Miceli, T. J. (1997). *Economics of the law: Torts, contracts, property, litigation*. Oxford: Oxford University Press.

Polinsky, A. M. (1989). *An introduction to law and economics* (2nd ed.). Boston: Little, Brown and Co.

Posner, R. A. (1992). *Economic analysis of law* (4th ed.). Boston: Little, Brown and Co.

Rea, S. A., Jr. (1987). The economics of comparative negligence. *International Review of Law and Economics*, *7*, 149–162.

Rubinfeld, D. L. (1987). The efficiency of comparative negligence. *Journal of Legal Studies*, *16*, 375–394.

Schroeder, C. H. (1997). Causation, compensation, and moral responsibility. In D. G. Owen (Ed.), *Philosophical foundations of tort law*. Oxford: Clarendon Press.

Schwartz, G. T. (1978). Contributory and comparative negligence: A reappraisal. *Yale Law Journal*, *87*, 697–727.

Schwartz, W. F. (2000). Legal error. In B. Bouckaert & G. De Geest (Eds.), *Encyclopedia of law and economics* (pp. 682–734). Cheltenham: Edward Elgar.

Shavell, S. (1985). Uncertainty over causation and the determination of civil liability. *Journal of Legal Studies*, 597–609.

Shavell, S. (1987). *Economic analysis of accident law*. Cambridge, MA: Harvard University Press.

Van Wijck, P. V., & Winters, J. K. (2001). The principle of full compensation in tort law. *European Journal of Law and Economics*, *11*(3), 319–332.

Wright, R. W. (1985). Causation in tort law. *California Law Review*, *73*, 1737–1826.

Wright, R. W. (1987). The efficiency theory of causation and responsibility: Unscientific formalism and false semantics. *Chicago-Kent Law Review*, *63*, 553–578.

Young, R., Faure, M., & Fenn, P. (2004). Causality and causation in tort law. *International Review of Law and Economics*, *24*, 507–523.