‘Full’ Compensation Criteria in the Law of Torts

An Enquiry into the Doctrine of Causation

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INTRODUCTION

The principle of 'full' compensation is said to restore the victim of an accident to the position he was in before the tort. Different interpretations of the 'pre-tort' position of the victim have led to the emergence of two compensation criteria. In the conventional modelling of the rule of negligence, the 'pre-tort position' of the victim is taken to be the one in which he bears no accident losses at all. An implication of such an interpretation is that a negligent injurer is required to compensate his victim fully. That is, a negligent injurer bears all the losses and the victim none. Van Wijck and Winters (2001) have reinterpreted the 'pre-tort position' of the victim and proposed an 'alternative' specification of liability. They consider the victim's pre-tort position to be the one in which the expected loss suffered by him is just equal to the expected loss that will result when the injurer's care level is just equal to the due care level.

To make the things explicit, consider the following example. An injurer can decide whether or not to take care. Let the cost of care be 1. If the injurer takes care probability of an accident is 1/3, and probability is 2/3 if he does not take care. The actual loss in the event of an accident is 12. Thus, when the injurer takes care, the expected loss is $(1/3) \times 12 = 4$; while, if he doesn't take care, the expected loss is $(2/3) \times 12 = 8$. In such a scenario, economic efficiency requires the injurer to spend 1 on care. Under standard modeling of the rule of negligence, the court will find the injurer negligent if and only if he does not take care. Moreover, liability of the negligent injurer is the entire loss, i.e., 12. Compensation equal to 12 will restore the victim to his pre-tort ex ante position, i.e., to a position he will be in if there were no activity and hence no accident on the part of the injurer. Therefore, under the standard compensation criterion (SCC) based rule of negligence, for the purpose of compensation, the 'pretort' position of the victim is taken to be the one in which he bears no losses at all. As a result, the negligent injurer's expected liability is $(2/3) \times 12 = 8$. But, note that an accident with probability 1/3 can take place even when the injurer takes care. Thus, the injurer's negligence increases the expected loss only by 4, i.e., $12 \times (2/3-1/3)$, and not by 8, as the expected loss of 4 would be there even when the injurer was not negligent. Van Wijck and Winters (2001) consider the victim's pre-tort position to be the one in which he suffers the expected loss of 4, the expected loss when the injurer is just non-negligent. Therefore, under the 'alternative' compensation criterion (ACC) based rule of negligence, a negligent injurer's expected liability is equal to $8 - 4 = 4$, the expected loss caused by his negligence. Compensation of 4 will restore the victim to his pre-tort ex ante position, i.e., to a position he will be in if the injurer took due care. This alternative specification of liability is what we call '*causation*' liability, and forms the focus of the paper.

The alternative specification of liability has implications not only economic but also from the legal point of view. This liability assignment is interesting from economic point of view for at least the following two reasons. Very few analyses have formally dealt with such specification of liability. The seminal work by Kahan (1989), and Van Wijck and Winters (2001) examine the efficiency implications of such specification of liability. The central message of these analyses is as follows: The injurer takes efficient care under the rule of negligence when the liability assignment is causation-consistent. 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 may specify the due care for the both.[1] For such rules, the causation doctrine can be extended to the negligence of the victim.[2] On the second count, it should be noted that most of accidents involve bilateral-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 '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 bilateral.

The legal relevance of the ACC is borne out of the following fact. In standard modelling of liability rules the proportion of accident loss a party is required to bear, generally, does not depend upon the extent to which negligence on the part of the party contributed to the loss. For example, under the rule of negligence if the care level of an injurer was just below the due level of care, he is held liable for the *entire* loss in the event of an accident, even when the victim took no care at all. Similarly, under the rule of strict liability with the defense of contributory negligence, if the victim's care level fell just short of the due level, he is held liable for the entire loss irrespective of the level of care taken by the injurer. As a matter of legal doctrine, this specification of liability rules is said to be incorrect (see Grady, 1983, 88, 89; Kahan, 1989; Wright 1985, 87).[3]

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[1] 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.

[2] See Dari Mattiacci (2002).

[3] 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, 87).

Kahan (1989, p. 428), for example, writes: "Rather, in most models, liability turns solely upon an injurer's negli gence: 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...."

It has been claimed 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, and (ii) a negligent injurer is liable for *only* that loss which can be attributed to his negligence. That is, while determining the liability of a negligent injurer the reference point is his nonnegligent (rightful) act. The comparison is, as generally is the case with the standard modelling of the rule of negligence, not with the situation in which he does not act at all.[4] We show that ACC-based causation liability is consistent with the above-mentioned two requirements of the law of torts.

There is another literature to which this paper contributes. The economic analysis of liability rules has been undertaken by Brown (1973), Polinsky (1989), Landes and Posner (1987), Shavell (1987), Miceli (1997), Cooter and Ulen (1998), Jain and Singh (2002), and Singh (2003) among others. These works show that if negligent injurers are made liable for the entire loss suffered by the non-negligent 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) 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 difference to the outcome, but whether the fact that it was *wrongful* did so. (emphasis in the original)". Also Keeton et al (1984), Hart and Honore (1985), see Kahan (1989), and Schroeder (1997), etc.

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 the expected loss when both can be attributed to his act?' Calabresi (1970), Landes and Posner (1983, 87), Shavell (1987), Miceli (1996, 97), 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 (Cooter, 1987; Miceli 1997; pp. 22–24, Burrows 1999; Ben-Shahar, 2000; Schwartz, 2000, pp. 1031–33).[5] 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. 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 that a liability rule be as follows: When the victim is nonnegligent, if the injurer chooses to be negligent rather than nonnegligent, 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 2, shows the necessity of the condition for efficiency of any liability rule. Our analysis shows

[5] For criticism of the economic modelling of causation, see Marks (1994) and Burrows (1999).

that in at least one sense, rather than being contradictory, the above mentioned causationrequirements turn out to be a necessary element for the efficiency of liability rules.

Such an exercise, 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 the 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.

In reality many accidents involve bilateral-risk, that is, are such that both parties suffer losses in the event of an accident. Analysis in this paper covers bilateral-risk accidents as well. The existing results about the bilateral-risk accidents follow as a corollary to Theorem 3. 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 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.

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.

To start with, the entire loss falls on one party to be called the victim; the other party being the injurer. We denote by:

c the cost of care taken by the victim, $c \geq 0$,

d the cost of care taken by the injurer, $d \geq 0$,

$C = \{c \mid c$ is the cost of some feasible level of care for the victim$\}$,

$D = \{d \mid d$ 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, $H \geq 0$,

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 $L > 0$ 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; $TSC = c + d + L(c, d)$.

(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 at 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.[6] (A8) is a standard assumption.

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:

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

Where $x \geq 0$ $[y \geq 0]$ is the proportion of H that will be borne by the victim [injurer] under the rule, and $x + y = 1$.[7]

Remark 1

Note that the functional represention 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

[6] It should, however, be noted that technically speaking, a party can be negligent only if the rule specifies the due level of care for this 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.

[7] 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.

different application. Let the function f define a liability rule for the application specified by C_1, D_1, L_1, and $(c_1^\star, d_1^\star)$, and let function g define the *same* rule for the application specified by C_2, D_2, L_2, and $(c_2^\star, d_2^\star)$. 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 increases his care level beyond d^*, the proportion in which the injurer is required to bear the loss will exactly be the same as when he opted 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 increases his care beyond c^*, the proportion in which victim is required to bear the loss will exactly be the same as when he opted for c^*. As a matter of fact all the rules discussed in the literature satisfy properties (P1) and (P2). Moreover, we will show 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 $d \geq d^*$, $f(c, d) = (x_1, y_1)$.

For any c and d opted by the victim and the injurer, respectively, if 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). 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 $x_1 = 1 - y_1$.

Efficient Liability Rules

A liability rule is said to be efficient for a given application, i.e., for given C, D, L, and (c^*, d^*) if 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 $L(c, d') - L(c, d^*)$, the increase in the expected loss caused by his negligence.[8] 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 non-negligent, if the injurer re-duces his care from a level where he is non-negligent 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

[8] Suppose $c \geq c^*$, and initially the injurer was taking care $d'' > d^*$. 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 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).

by his negligence. Similarly for the victim. Based on this discussion we define the following condition.

Condition of Causation Liability (CL)

A liability rule is said to satisfy the condition of CL iff under such a rule; (*i*) when the victim is nonnegligent, if the injurer 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 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 non-negligent, by an amount that is at *least* the entire increase in the expected accident loss caused by his negligence.[9]

In Appendix A we have formally shown how, for various possible combinations of c & d, liability will be determined under a rule satisfying the condition CL. Suppose the victim is nonnegligent and the injurer is negligent, i.e., $c \geq c^*$ and the injurer chooses $d' < d^*$. Under a rule satisfying 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. Let at d^* the injurer's expected liability be $y_1 L(c, d^*)$. Therefore at d' his expected liability is at least $y_1 L(c, d^*) + [L(c, d') - L(c, d^*)]$, i.e., $L(c, d') - x_1 L(c, d^*)$, since $1 - y_1 = x_1$. Notice that here the injurer is solely negligent and if $y_1 < 1$, i.e., if $x_1 > 0$, $L(c, d') - x_1 L(c, d^*) < L(c, d')$, i.e., his liability is less than the full liability. Analogously, if $c < c^*$ and $d \geq d^*$ the victims liability will be at least $x_1 L(c^*, d) + L(c, d) - L(c^*, d)$, i.e., $L(c, d) - y_1 L(c^*, d)$.

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[9] 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.

Again, the victim is solely negligent, and 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*'.

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 negligence. On the contrary, from the definition of condition CL (and (i)–(iv) in Appendix A), 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. And, instead of (1), 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* loss. None of which is necessary under CL. Therefore, it follows that conditions CL and, in particular CL', impose less restriction on the structure of liability rules than is the case in their standard modelling.

EFFICIENT LIABILITY RULES WITH BILATERAL-CARE AND UNILATERALRISK

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 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 TAC 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, as is the case under condition CL, the injurer is made to bear this increased social costs 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.*

The claim can be proved arguing on the line of the proof of Claim 1. 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.[10] 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

[10] 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.

expected costs are just d. Clearly, the injurer can reduce his costs by opting d^* rather than $d > d^*$.

Now suppose $(\bar{c}, \bar{d})$ 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., $(\bar{c}, \bar{d} > d^*)$ 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. Finally, when $\bar{d} < d^*$, through a series of steps 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 claim follows immediately from Theorem 1 and the definition of condition CL'.

Claim 3 *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

In view of Theorem 1 and the definition of condition CL, 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 Claim 3, making a solely negligent party bear the entire loss is not necessary for economic efficiency.

For given C, D, L and (c^*, d^*), the standard negligence rule 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 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 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, under all these rules a solely negligent party is liable for the *entire* loss. In contrast, our analysis shows that all 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'. (Notice that none of the standard negligence-criterion based rules satisfies condition CL'). To make the argument explicit, consider the following examples.

Example 1

Specify any C, D, L and (c^*, d^*). *For this specification let a rule is 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 2

Specify any C, D, L and (c^*, d^*). *For this specification let 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.*

Liability rule in Example 1 makes the victim liable if and only if the victim is negligent and the injurer is not. Further, it makes a negligent victim liable for only the expected loss that can be attributed to his negligence. The rule in Example 2, likewise, makes a solely negligent injurer liable for only the expected loss that can be attributed to his negligence. Clearly both the rules satisfies conditions CL as well as CL', and in view of Theorem 1, 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 is also negligent. Moreover, he bears the entire loss. But, as the rule in Example 1 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 2 shows that the rule of negligence can be made less compensatory while preserving its efficiency.

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

For formal definitions of (C1) and (C2) see Appendix A. The condition CL is a necessary condition for efficiency in the sense described by Theorem 2.

Theorem 2 *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 cost of care will accrue to him. Therefore, the injurer will not fully internalize the consequences of his action and in some accident contexts, at least, he will be better-off opting inefficient care. 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 non-negligent, 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 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 increase by $\pi(c^*, d)\ [H(c^*, d) - H(c^*, d^*)]$. Whenever $\pi(c^*, d) > \pi(c^*, d^*)$ and $L(c^*, d^*) > 0$, $L(c^*, d) - L(c^*, d^*) > \pi(c^*, d)[H(c^*, d) - H(c^*, d^*)]$.[11] 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 2, in such a setting no liability rule can be efficient for all C, D, L and (c^*, d^*).

Remark 4 shows that if care by a party affects the probability of 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

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

of its negligence in the form of increased probability of accident. Therefore, as is argued in the discussion following Theorem 2, the party will be induced to take less than the efficient care.

Example 3

Consider the following C, D, and L:

$C = \{0, c_0, c_1\}$, *where* $c_0 > 0$ *and* $c_1 > c_0$; $D = \{0, d_0, d_1\}$, *where* $d_0 > 0$ *and* $d_1 > d_0$; $L(0, 0) = c_0 + d_0 + \delta_1 + \delta_2 + 2\Delta$, *where* $\delta_1, \delta_2 > 0$, $c_1 - c_0 > \Delta$, *and* $2\Delta > d_1 - d_0 > \Delta$; $L(c_0, 0) = d_0 + \delta_2 + 2\Delta$; $L(0, d_0) = c_0 + \delta_1 + 2\Delta$; $L(c_1, 0) = d_0 + \delta_2 + \Delta$; $L(0, d_1) = c_0 + \delta_1 + \Delta$; $L(c_0, d_0) = 2\Delta$; $L(c_0, d_1) = \Delta = L(c_1, d_0)$; *and* $L(c_1, d_1) = 0$.

In example 3, (c_0, d_0) is uniquely TAC 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 3. Where f is such that: $(\forall c \geq c_0)(\forall d \leq d_0)[f(c, d) = (0, 1)]$, $(\forall d \geq d_0)[f(0, d) = (1, 0)]$, $f(0, 0) = (1/2, 1/2)$, $f(c_0, d_1) = (1, 0)$, $(\forall \mathrm{d} \geq d_0)[f(c_1, d) = (0, 1)]$. 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.

EFFICIENT LIABILITY RULES WITH BILATERAL-CARE AND BILATERALRISK

In the previous section we considered unilateral-risk accidents where, to start with, only one party suffered all the losses from an accident. In this section we extended our model to bilateral-risk accidents, i.e., to the cases wherein both the parties suffer losses in the event of an accident. As is the case with the actual functioning of the law of torts we assume that each individual may sue the other for compensation. That is, depending on their care levels and the rule in force, each party to an accident can get compensated for its losses by the other.[12] In such settings, each party is both a potential injurer and potential victim simultaneously. But, only for the expositional ease 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 $L(c, d) = \pi(c, d)[H_v(c, d) + H_i(c, d)] = L_v + L_i$.

The total social costs (TSC) of accident are $c + d + L(c, d) = c + d + L_v(c, d) + L_i(c, d)$. 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 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 it is denoted by (c^{**}, d^{**}). Again $(c, d) \neq (c^{**}, d^{**})$ implies $c + d + L_v(c, d) + L_i(c, d) > c^{**} + d^{**} + L_v(c^{**}, d^{**}) + L_i(c^{**}, d^{**})$.

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

Bi-liability Rule

As is mentioned above, depending upon their care levels and the legal position, parties to an accident can get compensated by the other.

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

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 will define 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, Li and (c^{**}, d^{**}), a bi-liability rule can be defined by a unique function f:

$f : C \times D \rightarrow [0, 1]^2 \times [0, 1]^2$ 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 (loss suffered by the victim) that will be borne by the victim [injurer] under the rule, $x_v + y_v = 1$. Similarly, $x_i \geq 0$ $[y_i \geq 0]$ is the proportion of H_i (loss suffered by the injurer) that will be borne by the victim [injurer], $x_i + y_i = 1$.

For example, if activity of the injurer is governed by standard rule of negligence, and of the victim by the rule of strict liability with defense of contributory negligence (SLWD),[13] then $f(c, d) = ((1, 0), (1, 0))$ when $c \geq c^{**}$ & $d \geq d^{**}$,[14] and $f(c, d) = ((0, 1), (0, 1))$ when $c \geq c^{**}$ & $d < d^{**}$.

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

[13] 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.

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

a biliability 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 4. Proof of the claim is provided in Appendix B.

Claim 4 *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 3 *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 4, (c^{**}, d^{**}) is a N.E. Also, arguing on the lines of proof provided for Claim 2 it can be shown that (c^{**}, d^{**}) is a unique N.E. •

It will be interesting to compare the claim ofTheorem 3 with the relevant results in the existing literature.Arlen (1900), and Dhammika and Hoffmann (2002) have shown that in the contexts of bilateralrisk accidents if activities of both parties are governed by any *but the same* standard negligence-criterion based rule (e.g. the rule of negligence governing activities of both the parties) then the outcome will be efficient.[15] Note that when $c \geq c^{**}$& $d \geq d^{**}$, or when $c < c^{**}$& $d < d^{**}$ condition CL does not impose any restriction on a bi-liability rule. Also, any combination of the standard negligencecriterion based rules (one for the first party and one for the second) will give us $f(c, d) = ((x_v, y_v), (x_i, y_i)) = ((0, 1), (0, 1))$ when $c \geq c^{**}$& $d < d^{**}$, and $f(c, d) = ((x_v, y_v), (x_i, y_i)) = ((1, 0), (1, 0))$ when $c < c^{**}$& $d \geq d^{**}$. That is, a solely negligent party is made to bear the losses suffered by both the parties. But, (though not necessarily required) that is consistent with

[15] Dhammika and Hoffmann (2002) have shown that this claim holds even when costs of care are interdependent.

condition CL. Hence, any combination of standard negligence based rules will result in an efficient outcome. This, in particular, implies that if the same standard negligence based rules governs activities of both parties, the outcome will be efficient. Therefore, we get the relevant results in Arlen (1900), and Dhammika and Hoffmann (2002) as a corollary to Theorem 3. Im portance of the theorem, however, is shown by Remark 5.

Remark 5

Any *arbitrary* combination of the standard negligencecriterion based rules that cover activities of the parties satisfies condition CL, and therefore ensures efficiency. More importantly, 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 based rules (see $(i)'$–$(iv)'$ in Appendix A).

CONCLUDING REMARKS

It is a well-established fact that in bilateral-care settings, negligence or due care criterion-based liability rules are efficient. In the standard compensation criterion (SCC) based liability rules, liability assignment has a common attribute: In the event of an accident, if one party is negligent and the other is not, the negligent party bears the *entire* loss. This attribute causes a sudden jump in the liability of at least one party. Criticizing such modelling, some (legal) scholars have argued that this drastic change in liability is not a part of the law of torts. Our analysis (Theorem 1 and Claim 3) shows that this drastic change in liability is not necessary for economic efficiency. Theorem 2, shows that in at least one sense, alternative compensation criterion (ACC) based or causation-based liability is a necessary condition for any liability rule to be efficient. Analogous to our results regarding unilateral-risk accidents, for accidents involving bilateral-risk we have shown 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.

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 will take efficient care, (2) 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 negligence-criterion based liability rules. Whether the second claim holds in bilateral-care settings, and for other liability rules are the questions future research studies might answer.

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 U.S. 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 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 entire set of efficient liability rules, including those actually applied by courts and also other possible rules.

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 strongly argued that the discrete and sometimes even dichotomous care is the reality of many accident settings. It should be noted that our modelling does not impose any condition and is more general in this regard; it is equally applicable to both continuous and discrete variables. Finally, 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 3, (P1) and (P2) have important efficiency implications.

APPENDIX A

Liability assignment under conditions CL and CL': Consider any C, D, L, and (c^*, d^*). Take any liability rule satisfying 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 $x, y \in [0, 1]$.

(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 (P2) and the fact that when both the parties are nonnegligent the condition CL does not impose any restriction on liability assignment. To see (ii), 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. That is, when $c \geq c^*$, at $d' < d^*$ the injurer expected liability $y(c, d')L(c, d') = y_1 L(c, d^*) + L(c, d') - L(c, d^*) + \beta$, where $\beta \geq 0$, i.e., $y(c, d')L(c, d') \geq y_1 L(c, d^*) + L(c, d') - L(c, d^*)$. Formally, under f: $(\forall c \geq c^*)$ $(\forall d' < d^*)$ $[f(c, d') = x(c, d'), y(c, d'))]$, where $y(c, d')$ is such that $y(c, d')\ L(c, d') \geq y_1 L(c, d^*) + L(c, d') - L(c, d^*)$, i.e., $y(c, d') \geq 1 - [x_1 L(c, d^*)/L(c, d')]$.[16] Explanation for (iii) is analogous.

Liability assignment under condition CL' will be as under the condition CL with '*semi-equalities*' both in (ii) and (iii) above replaced with '*strict equalities*'.

Conditions (C1) and (C2): Let, $f(c^*, d^*) = (x_1, y_1)$.
Now, (C1) says: Whenever $c \geq c^*$ andd $< d^*$,$y < 1 - [x_1 L(c, d^*)/L(c, d)]$, i.e., $yL(c, d) - y_1 L(c, d^*) < L(c, d) - L(c, d^*)$.

And, (C2) says: Whenever $c < c^*$ and $d \geq d^*$, $x < 1 - [y_1 L(c^*, d)/L(c, d)]$, i.e., $xL(c, d) - x_1 L(c^*, d) < L(c, d) - L(c^*, d)$.

Liability assignment under a bi-liability rule satisfying condition CL

We assume that f satisfies both (P1) and (P2) mentioned in Section 2. (P3), e.g., 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 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.

When $c \geq c^{**}$ if the injurer reduces his care from d^{**} to some $d < d^{**}$ he causes an increase in total expected loss that is equal to $L(c, d) - L(c, d^{**}) = [L_v(c, d) - Lv(c, d^{**}) + L_i(c, d) - L_i(c, d^{**})]$. As before,

[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 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.

under a rule that satisfies condition CL, when $c \geq c^{**}$ and $d < d^{**}$ expected liability of the injurer will be the sum of his liability when he is just nonnegligent, $y_v^1 L_v(c, d^{**}) + y_i^1 L_i(c, d^{**})$ and $[L_v(c, d) - L_v(c, d^{**}) + L_i(c, d) - L_i(c, d^{**})] + \delta(\geq 0)$ on account of his negligence, i.e., his expected liability will be greater than or equal to $y_v^1 L_v(c, d^{**}) + y_i^1 L_i(c, d^{**}) + [L_v(c, d) - L_v(c.d^{**}) + L_i(c, d) - L_i(c, d^{**})$.

Consider any C, D, L_v, L_i and (c^{**}, d^{**}). Take any bi-liability rule satisfying condition CL and let the function f define the rule for the given C, D, L_v, L_i and (c^{**}, d^{**}). Let, $f(c^{**}, d^{**}) = ((x_v^1, y_v^1), (x_i^1, y_i^1))$. Then, under f for different care levels liability assignment will be as follows:

(*i*)′ When $c \geq c^{**}$ and $d \geq d^{**}$, $f(c, d) = ((x_v^1, y_v^1), (x_i^1, y_i^1))$ where $x_v^1, y_v^1, x_i^1, y_i^1 \in [0,]$;

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

Explanation for (i)′ – (iv)′ is very similar to the one provided for (i)–(iv) in the above.[17]

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), $(\forall c \geq c^*)(\forall d \geq$

[17] Notice that when $c \geq c^{**}$ & $d < d^{**}$ 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 $c < c^{**}$ & $d \geq d^{**}$.

$d^*)[f(c, d) = (x_1, y_1)]$. 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, his expected costs are $d^* + y_1 L(c^*, d^*)$ at d^*. First, consider a choice of $d' > d^*$ by the injurer. Note that

$$d' + y_1 L(c^*, d') + (1 - y_1)L(c^*, d') = d' + L(c^*, d') \tag{1}$$
$$> d^* + L(c^*, d^*) \tag{2}$$
$$= d^* + y_1 L(c^*, d^*) + (1 - y_1)L(c^*, d^*) \tag{3}$$

(1) and (3) hold by simple algebra. Inequality (2) holds since (c^*, d^*) uniquely minimizes social cost $c + d + L(c, d)$, so d^*, in particular, will uniquely minimize $d + L(c^*, d)$. From (1) and (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 $c = c^*$ & $d' < d^*$, the injurer is negligent and the victim is not. So, by condition CL, at d' the injurer's 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,

$$d' + L(c^*, d') - x_1 L(c^*, d^*) + \beta > d^* + L(c^*, d^*) - x_1 L(c^*, d^*) + \beta \geq d^* + y_1 L(c^*, d^*) \tag{4}$$

(4) holds since d^* uniquely minimizes $d + L(c^*, d)$, therefore $d' + L(c^*, d') > d^* + L(c^*, d^*)$. And (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 his costs 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.•

Proof of Theorem 2: Take any liability rule. Without any loss of generality suppose under the rule (C1) holds. Take any $t > 0$. Choose $r > 0$ such that $r < t$. Now consider the following C, D, and L:

$C = \{0, c_0\}$, where $c_0 > 0$, $D = \{0, d', d_0\}$, where $d_0 - d' = r$,
$L(0, 0) = t + d' + c_0 + \delta + \Delta$, where $\delta > 0$, and $\Delta \geq 0$,
$L(c_0, 0) = t + d' + \Delta$, $L(0, d') = t + c_0 + \delta + \Delta$,
$L(0, d_0) = c_0 + \delta + \Delta$, $L(c_0, d') = t + \Delta$, $L(c_0, d_0) = \Delta$.

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, $f(c^*, d^*) = (x_1, y_1)$. 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.[18] 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

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

$d \leq d^*$ expected liability of the injurer is $\alpha[L(c^*, d) - L(c^*, d^*)]$, i.e., at $d \leq d^*$ his expected costs are $d + y_1 L(c^*, d^*) + \alpha[L(c^*, d) - L(c^*, d^*)]$ and he will choose $\bar{d}$ satisfying $1 = -\alpha Ld(c^*, d)$. 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 4: 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, $(\forall c \geq c^{**})(\forall d \geq d^{**})[f(c, d) = ((x_v^1, y_v^1), (x_i^1, y_i^1))]$. 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

$$d' + (x_v^1 + y_v^1)L_v(c^{**}, d') + (x_i^1 + y_i^1)L_i(c^{**}, d')$$

$$= d' + L_v(c^{**}, d') + L_i(c^{**}, d') \quad (1)$$

$$> d^{**} + L_v(c^{**}, d^{**}) + L_i(c^{**}, d^{**}) \quad (2)$$

$$= d^{**} + (x_v^1 + y_v^1)L_v(c^{**}, d^{**}) + (x_i^1 + y_i^1)L_i(c^{**}, d^{**}) \quad (3)$$

(1) and (3) hold by simple algebra. Inequality (2) holds since (c^{**}, d^{**}) uniquely minimizes $c + d + Lv(c, d) + Li(c, d)$, so d^{**}, in particular, will uniquely minimize $d + L_v(c^{**}, d) + L_i(c^{**}, d)$. From (1) and (3) 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 $d' + y_v^1 L_v (c^{**}, d') + y_i^1 L_i(c^{**}, d') > d^{**} + y_v^1 L_v(c^{**}, d^{**}) + y_v^1 L_i(c^{**}, d^{**})$, because $x_v^1 \geq 0, x_i^1 \geq 0$ and $d' > d^{**} \rightarrow [L_v(c^{**}, d^{**}) \geq L_v(c^{**}, d')$ & $L_i(c^{**}, d^{**})$ $L_i(c^{**}, d')]$. 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 $d' + y_v^1 L_v(c^{**}, d^{**}) +$

$$\gamma_i^1 L_i(c^{**},d^{**}) + L_v(c^{**},d') - L_v(c^{**},d^{**}) + L_i(c^{**},d') - L_i(c^{**},d^{**}) + \delta$$

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,

$$\begin{aligned} & d' + L_v(c^{**},d') + L_i(c^{**},d') - x_v^1 L_v(c^{**},d^{**}) - x_i^1 L_i(c^{**},d^{**}) + \delta > \\ & \quad L_v(c^{**},d^{**}) + L_i(c^{**},d^{**}) - x_v^1 L_v(c^{**},d^{**}) - x_i^1 L_i(c^{**},d^{**}) + \delta \quad (4) \\ & \quad \geq d^{**} + \gamma_v^1 L_v(c^{**},d^{**}) + \gamma_i^1 L_i(c^{**},d^{**}) \end{aligned}$$

(4) holds since since d^{**} uniquely minimizes $d + Lv(c^{**}, d) + L_i(c^{**}, d)$, therefore, $d' + Lv(c^{**}, d') + Li(c^{**}, d') > d^{**} + L_v(c^{**}, d^{**}) + L_i(c^{**}, d^{**})$. And (5) follows from the fact that $\gamma^1 = 1 - x^1$ 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.•

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