The Structure of Efficient Liability Rules

Satish K. Jain*

Abstract

The purpose of this paper is to analyze the structure of efficient liability rules. The notion of a liability rule is defined here in a very general framework. The most important result of the paper shows that the subclass of the efficient liability rules is characterized by the conjunction of two conditions, namely, the condition of negligence liability and the requirement of non-reward for over-nonnegligence. Negligence liability requires that if one party is exactly nonnegligent and the other party is negligent then the negligent party must be fully liable. The requirement of non-reward for over-nonnegligence requires that if one party is exactly non-negligent and the other party is over-nonnegligent then the over-nonnegligent party's liability share must not be less than what it would be if both parties were exactly nonnegligent.

In tort law, as a general rule, no distinction is made as to whether a person takes the due care or more than the due care. An analysis of this feature shows that it cannot be explained solely in terms of efficiency. However, if one considers the subclass of efficient rules satisfying monotonicity, a condition which can be interpreted as formalization of an aspect of fairness, then it turns out that every liability rule in the subclass has the property of making no distinction between the due care and more than the due care. On the basis of this result it is argued that the tort law feature of making no distinction between the due care and more than the due care is partly grounded in fairness and partly in efficiency.

Keywords: Liability Rules, Efficient Liability Rules, Condition of Negligence Liability, Requirement of Non-Reward for Over-Nonnegligence, No-Distinction between the Due Care and More than the Due Care Requirement, Monotonicity, Nash Equilibria.

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The economic analysis of law in general and that of tort law in particular, both normative and positive, revolves around the core idea of economic efficiency. This, however, does not necessarily mean that non-efficiency values are altogether irrelevant in the context of economic analysis of law. It is of course true that if in a certain context it turns out that there is only one rule or procedure which is efficient then giving precedence to efficiency over all other values implies that any value which is not satisfied by the unique efficient rule or procedure cannot be incorporated. But in general there would be more than one rule which would be efficient in a given context; and consequently the choice of rule for adoption from among efficient rules could be made on the basis of values other than that of economic efficiency. From analogous considerations it follows that non-efficiency values have some relevance for positive analysis of law as well. Even if the observed choice of rule is efficient, efficiency can explain the observed choice only partly if the set of efficient rules in the given context contains more than one member. For a complete explanation it might be necessary to invoke values other than that of economic efficiency.

Thus in the context of positive analysis of law, even if it turns out that by and large laws are efficient, a two-stage analysis might be desirable in which in the first stage the totality of efficient rules or procedures are identified and in the second stage an explanation of the observed rule or procedure is attempted in terms of additional values. Similarly, even if efficiency is accorded primacy over all other values, a two-stage normative analysis of law seems appropriate in which first the efficient rules are identified and then efficient rules are analyzed from the perspective of other values which might be considered relevant in the given legal context.

The main purpose of this paper is to attempt such an exercise in the context of liability rules. In the paper we first analyze the structure of liability rules from the perspective of economic efficiency; and then the structure of efficient liability rules from the perspective of some non-efficiency values. Considerations relating to the efficiency of liability rules have occupied an important place in the law and economics literature right from its inception. The pioneering contribution by Calabresi (1961) analyzed the effect of liability rules on parties' behaviour. In his seminal contribution Coase (1960) looked at liability rules from the point of view of their implications for social costs. The rule of negligence was analyzed by Posner (1972) from the perspective of economic efficiency. The first formal analysis of liability rules was done by Brown (1973). His main results demonstrated the efficiency of both the rule of negligence and the rule of strict liability with the defense of contributory negligence. Formal treatment of some of the most important results of the extensive literature on liability rules is contained in Landes and Posner (1987), Shavell (1987), and Miceli (1997). A complete characterization of efficient liability rules is contained in Jain and Singh (2002).[1]

In the literature dealing with the question of efficiency of liability rules, the problem has generally been considered within the framework of accidents resulting from interaction of two risk-neutral parties, the victim and the injurer. Efficiency is taken to require minimization of total social costs, which are defined to be the sum of costs of care taken by the two parties and expected accident loss. The probability of accident and the amount of loss in case of occurrence of accident are assumed to depend on the levels of care taken by the two parties. A party is called nonnegligent if its care level is at least equal to the due care level; otherwise it is called negligent. A liability rule determines the proportions in which the two parties are to bear the loss in case of occurrence of accident as a function of whether and to what extents the parties involved in the interaction are negligent. A liability rule is efficient if it invariably induces both parties to behave in ways which result in socially optimal outcomes, i.e., outcomes under which total social costs are minimized. The central result regarding the efficiency question that has emerged is that a liability rule is efficient if and only if it satisfies the condition of negligence liability.[2] The condition of negligence liability requires that (i) if the victim is nonnegligent and the injurer is negligent then the entire loss, in case of occurrence of accident, must be borne by the injurer; and (ii) if the injurer is nonnegligent and the victim is negligent then the entire loss, in case of occurrence of accident, must be borne by the victim.

In tort law, as a general rule, no distinction is made as to whether a person's level of care is equal to the due care or is greater than the due care. In the literature on liability rules, this particular feature of tort law is invariably incorporated in the definition of liability rule itself. But this means that this particular feature of tort law is not being subjected

[1] The notion of a liability rule as defined in this paper is considerably more general than the corresponding notions considered in the law and economics literature. Standard results pertaining to efficiency of liability rules, including those of Jain and Singh (2002), consequently can be derived as simple corollaries from the results of this paper.

[2] See Jain and Singh (2002).

to analysis. In particular, the question whether this feature of tort law has anything to do with efficiency is not being asked. The position taken in this paper, consistent with the approach of two-stage analysis, is that the identification of the totality of efficient liability rules should be done first; and the built-in features of law, like the tort law feature of making no distinction between the due care and more than the due care, should be incorporated in the second stage of analysis. We will refer to acts of taking less than the due care, taking exactly the due care, and taking more than the due care as negligence, exact nonnegligence and over-negligence respectively.

An analysis of the totality of all liability rules shows that the subclass of efficient liability rules is characterized by a conjunction of two conditions, namely the requirement of non-reward for over-nonnegligence and the condition of negligence liability. From a technical point of view this is the most general result on the efficiency of liability rules; the existing results on the efficiency of liability rules in the standard two-party setting can be derived from this general result. The requirement of non-reward for over-nonnegligence essentially requires that if one party is exactly nonnegligent then the other party must not benefit by moving from a position of exact nonnegligence to over-negligence. More precisely, what is required is that if one party is exactly nonnegligent then liability share of the other party when he or she is over-nonnegligent is greater than or equal to his or her liability share when he or she is exactly nonnegligent. The condition of negligence liability requires that if one party is exactly nonnegligent and the other party is negligent then the entire loss in case of accident must be borne by the negligent party.

An analysis of the class of efficient liability rules shows that the built-in feature of tort law which treats the due care and more than the due care identically cannot be explained in terms of economic efficiency alone. It is interesting to note that if one restricts attention only to the monotonic liability rules, i.e., the liability rules which never perversely punish for taking more care, then the rules belonging to the subclass of efficient monotonic rules all satisfy the no-distinction between the due care and more than the due care feature of tort law. This suggests that the no-distinction feature of tort law is partly grounded in fairness and partly in efficiency.

The paper is divided into three sections. Section 1 contains definitions, assumptions and the framework of analysis. In section 2 the structure of efficient liability rules is discussed in terms of the two characterizing conditions of the requirement of non-reward for over-nonnegligence and the negligence liability. Among other things, the section contains formal treatment of monotonicity condition and that of the tort law feature of treating the due care and more than the due care alike. The last section concludes with some remarks on viewing liability rules as embodiments of values. The formal proofs are relegated to the appendix.

1 Definitions and Assumptions

We consider accidents resulting from interaction of two parties, assumed to be strangers to each other, in which, to begin with, the entire loss falls on one party to be called the victim (plaintiff). The other party would be referred to as the injurer (defendant). We denote by $c \geq 0$ the cost of care taken by the victim; and by $d \geq 0$ the cost of care taken by the injurer. We assume that c and d are strictly increasing functions of levels of care of the two parties. This of course implies that c and d themselves can be taken as indices of levels of care of the victim and the injurer respectively.

Let

$C = \{c \mid \text{c is the cost of some feasible level of care which can be taken by the victim}\}$;

and

$D = \{d \mid \text{d is the cost of some feasible level of care which can be taken by the injurer}\}$.

We assume $0 \in C \wedge 0 \in D$. (A1)

Let π denote the probability of occurrence of accident and $H \geq 0$ the loss in case of occurrence of accident. Both π and H will be assumed to be functions of c and d; $\pi = \pi(c, d), H = H(c, d)$. Let $L = \pi H$. L is thus the expected loss due to accident. We assume:

$$(\forall c, c' \in C)(\forall d, d' \in D)[[c > c' \rightarrow L(c, d) \leq L(c', d)] \wedge [d > d' \rightarrow L(c, d) \leq L(c, d')]]. \quad \text{(A2)}$$

In other words, it is assumed that a larger expenditure on care by either party, given the expenditure on care by the other party, results in lesser or equal expected accident loss. Total social costs (TSC) are defined to be the sum of cost of care by the victim, cost of care by the injurer, and the expected loss due to accident; $TSC = c + d + L(c, d)$. Let $M = \{(c', d') \in C \times D \mid c' + d' + L(c', d') \text{ is minimum of } \{c + d + L(c, d) \mid c \in C \wedge d \in D\}\}$. Thus M is the set of all costs of care configurations (c', d') which are total social cost minimizing. It will be assumed that:

C, D, π and H are such that M is nonempty. (A3)

In order to characterize a party's level of care as negligent or otherwise a reference point (the due care level) for the party needs to be specified. Let c^* and d^*, where $(c^*, d^*) \in M$, denote the due care levels of the victim and the injurer respectively. We define nonnegligence functions p and q as follows:

$p : C \mapsto [0, \infty)$ such that[3] :

$$\begin{aligned} p(c) &= \tfrac{c}{c^*} \quad \text{if } c^* > 0; \\ &= 1 \quad \text{if } c^* = 0 \end{aligned}$$

$q : D \mapsto [0, \infty)$ such that:

$$\begin{aligned} q(d) &= \tfrac{d}{d^*} \quad \text{if } d^* > 0; \\ &= 1 \quad \text{if } d^* = 0. \end{aligned}$$

Remark 1 *Instead of defining* $p(c) = 1$ *for all* $c \in C$ *when* $c^* = 0$, *one could also define it in any other way subject to the following three restrictions without affecting any of the results of this paper:*
(i) $p(c^*) = 1$,
(ii) $p(c) \geq 1$ *for all* $c \in C$, *and*
(iii) p *is an increasing function of* c, *i.e.,* $(\forall c, c' \in C)[c > c' \ \rightarrow \ p(c) \geq p(c')]$.
Analogous remarks apply for function q *when* $d^* = 0$.

In case there is a legally binding due care level for the plaintiff, it would be taken to be identical with c^* figuring in the definition of function p; and in case there is a legally binding due care level for the defendant, it would be taken to be identical with d^* figuring in the definition of function q. Thus implicitly it is being assumed that the legally binding due care levels are always set appropriately from the point of view of minimizing total social costs.

p and q would be interpreted as proportions of nonnegligence of the victim and the injurer respectively. The victim would be called negligent if $p < 1$; exactly nonnegligent if $p = 1$; and over-nonnegligent if $p > 1$. Similarly, the injurer would be called negligent if $q < 1$; exactly nonnegligent if $q = 1$; and over-nonnegligent if $q > 1$.

We now proceed to define the notion of a liability rule in its most general form. From a technical point of view it is desirable to define the notion of a liability rule independently of its applications. The context in which a liability rule can be applied is completely specified if in addition to C, D, π and H we also specify the configuration of due care levels $(c^*, d^*) \in M$.

[3] We use the standard notation to denote:
$\{x \mid 0 \leq x \leq 1\}$ by $[0, 1]$, $\{x \mid 0 \leq x < 1\}$ by $[0, 1)$, $\{x \mid 0 < x \leq 1\}$ by $(0, 1]$, $\{x \mid 0 < x < 1\}$ by $(0, 1)$, $\{x \mid x \geq 0\}$ by $[0, \infty)$ and $\{x \mid x > 1\}$ by $(1, \infty)$.

Formally, a liability rule is a function f from $[0,\infty)^2$ to $[0,1]^2$, $f:[0,\infty)^2 \mapsto [0,1]^2$, such that: $f(p,q)=(x,y)$, where $x+y=1$.

Thus a liability rule is a rule which specifies the proportions in which the two parties are to bear the loss in case of occurrence of accident as a function of proportions of nonnegligence of the two parties.

A particular application of a liability rule consists of specifying C, D, π, H and $(c^*, d^*) \in M$; and in defining functions p and q along the lines discussed above. Consider a particular application of the rule given by C, D, π, H and $(c^*, d^*) \in M$. If accident takes place and loss of $H(c,d)$ materializes, then $xH(c,d)$ will be borne by the victim and $yH(c,d)$ by the injurer; where $(x,y) = f(p,q) = f[p(c), q(d)]$. As, to begin with, in case of occurrence of accident, the entire loss falls upon the victim, $yH(c,d)$ represents the liability payment by the injurer to the victim. The expected costs of the victim and the injurer, to be denoted by EC_1 and EC_2 respectively, therefore are $c + xL(c,d)$ and $d + yL(c,d)$ respectively. Both parties are assumed to prefer smaller expected costs to larger expected costs and be indifferent between alternatives with equal expected costs.

Let $f:[0,\infty)^2 \mapsto [0,1]^2$ be a liability rule. f is defined to be efficient for given C, D, π, H and $(c^*, d^*) \in M$ satisfying (A1) - (A3) iff $(\forall(\overline{c}, \overline{d}) \in C \times D)[(\overline{c}, \overline{d})$ is a Nash equilibrium $\rightarrow$ $(\overline{c}, \overline{d}) \in M]$ and $(\exists(\overline{c}, \overline{d}) \in C \times D)[(\overline{c}, \overline{d})$ is a Nash equilibrium].[4] f is efficient iff it is efficient for every possible choice of C, D, π, H and $(c^*, d^*) \in M$ satisfying (A1) - (A3). In other words, a liability rule is efficient for a particular application satisfying (A1) - (A3) iff (i) every Nash equilibrium is total social cost minimizing, and (ii) there exists at least one Nash equilibrium. A liability rule is efficient iff it is efficient for every application satisfying (A1) - (A3).

Remark 2 *It should be noted that if (A3) is not satisfied then no liability rule can be efficient.*

Throughout this paper we denote $f(1,1)$ by (x^*, y^*), i.e., we write $x(1,1)$ as x^* and $y(1,1)$ as y^*. We also denote $L(c^*, d^*)$ by L^*.

[4]Throughout this paper we consider only pure-strategy Nash equilibria.

2 The Structure of Efficient Liability Rules

Characterization of Efficient Liability Rules

First we define two conditions on liability rules.

Condition of Negligence Liability (NL): A liability rule f satisfies the condition of negligence liability iff $[[\forall p \in [0,1)][f(p,1)=(1,0)] \ \wedge \ [\forall q \in [0,1)][f(1,q)=(0,1)]]$.
In other words, a liability rule satisfies the condition of negligence liability iff its structure is such that (i) whenever the injurer is exactly nonnegligent and the victim is negligent, the entire loss in case of occurrence of accident is borne by the victim, and (ii) whenever the victim is exactly nonnegligent and the injurer is negligent, the entire loss in case of occurrence of accident is borne by the injurer.

Requirement of Non-Reward for Over-Nonnegligence (RNO): A liability rule f satisfies the requirement of non-reward for over-nonnegligence iff $[[\forall p \in (1,\infty)][x(p,1) \geq x(1,1)] \wedge [\forall q \in (1,\infty)][y(1,q) \geq y(1,1)]]$.
That is to say, a liability rule satisfies the requirement of non-reward for over-nonnegligence iff its structure is such that (i) given that the injurer is exactly nonnegligent, the liability share of the victim when he or she is over-nonnegligent is greater than or equal to his or her liability share when he or she is exactly nonnegligent, and (ii) given that the victim is exactly nonnegligent, the liability share of the injurer when he or she is over-nonnegligent is greater than or equal to his or her liability share when he or she is exactly nonnegligent.

The most important result of this paper, stated in Theorem 1, says that efficient liability rules are characterized by the conjunction of the two conditions defined above. The following is the formal statement of the the characterization theorem:

Theorem 1 *A liability rule $f : [0,\infty)^2 \mapsto [0,1]^2$ is efficient for every possible choice of C, D, π, H and $(c^*, d^*) \in M$ satisfying (A1) - (A3) iff it satisfies the requirement of non-reward for over-nonnegligence and the condition of negligence liability.*

The Theorem is proved via four propositions whose statements and proofs are given in the Appendix. Proposition 1 establishes that if a liability rule satisfies both RNO and NL then regardless of which permissible application, i.e., application satisfying (A1) - (A3), of the liability rule is considered $(c^*, d^*) \in M$ constitutes a Nash equilibrium. Proposition 2 establishes that regardless of which permissible application of a liability rule satisfying RNO and NL is considered all Nash equilibria are total social cost minimizing. Propositions 1 and 2 together thus show that a liability rule satisfying RNO and NL is efficient for every permissible application; and therefore establish the sufficiency of RNO and NL for efficiency. Propositions 1 and 2 together, in fact, establish more than the sufficiency part. To establish sufficiency part we need only (i) all Nash equilibria to be total social cost minimizing and (ii) the existence of a Nash equilibrium for every application. Rather than merely showing the existence of a Nash equilibrium, Proposition 1 establishes a much stronger result; namely that the configuration of due care levels is always a Nash equilibrium.

Proposition 3 establishes that RNO is a necessary condition for efficiency of any liability rule; and Proposition 4 establishes that NL is a necessary condition for efficiency of any liability rule. Propositions 3 and 4 together therefore establish the necessity of conjunction of RNO and NL for efficiency. As a liability rule is efficient iff it is efficient for every permissible application, it follows that in order to show that a particular condition is necessary for efficiency one has to show that regardless of which liability rule violating the condition one considers one can always find a permissible application for which the liability rule in question would be inefficient.

Both RNO and NL put restrictions on the assignment of liability shares when one party is exactly negligent and the other party is not. Neither of the two conditions constrains in any way if neither party is exactly negligent or if both parties are exactly negligent. In particular if one part is negligent and the other party is over-nonnegligent then neither condition constrains liability assignments in any way whatsoever. Consequently it follows that it is possible for a liability rule to be efficient and at the same time exhibit rather perverse features. Consider the following example:

Example 1 *Let the liability rule $f : [0,\infty)^2 \mapsto [0,1]^2$ be defined by:*

$$
\begin{aligned}
f(p,q) &= (\tfrac{1}{2},\tfrac{1}{2}) && \textit{if } p < 1 \wedge q < 1;\\
&= (1,0) && \textit{if } p < 1 \wedge q = 1;\\
&= (0,1) && \textit{if } p < 1 \wedge q > 1;\\
&= (0,1) && \textit{if } p = 1 \wedge q < 1;\\
&= (\tfrac{1}{2},\tfrac{1}{2}) && \textit{if } p = 1 \wedge q = 1;\\
&= (\tfrac{1}{2},\tfrac{1}{2}) && \textit{if } p = 1 \wedge q > 1;\\
&= (1,0) && \textit{if } p > 1 \wedge q < 1;\\
&= (\tfrac{1}{2},\tfrac{1}{2}) && \textit{if } p > 1 \wedge q = 1;\\
&= (\tfrac{1}{2},\tfrac{1}{2}) && \textit{if } p > 1 \wedge q > 1.
\end{aligned}
$$

This liability rule is efficient as it satisfies both RNO and NL. The perverse feature of the rule lies in the fact that when one party is negligent and the other is over-nonnegligent the entire liability falls on the over-nonnegligent party.

The No-Distinction between the Due Care and More than the Due Care Requirement

One of the basic features of tort law is that for the purpose of assigning liability shares, as a general rule, it does not distinguish between the due care and more than the due care. There are two different ways in which this characteristic feature of tort law can be incorporated in the analysis of liability rules. One can either treat the no-distinction feature as a condition on liability rules or the feature can be incorporated in the definition of a liability rule itself. The no-distinction feature of tort law as a condition on liability rules can be stated as follows:

The No-Distinction between the Due Care and More than the Due Care Requirement (NDMR): A liability rule f satisfies the no-distinction between the due care and more than the due care requirement iff $[\forall p, q \in [0, \infty)][[p \geq 1 \rightarrow f(p, q) = f(1, q)] \wedge [q \geq 1 \rightarrow f(p, q) = f(p, 1)]]$.

It is immediate that any liability rule which satisfies NDMR would also satisfy RNO. Therefore, it follows, from Theorem 1, that for the subclass of liability rules satisfying NDMR a necessary and sufficient condition for efficiency is that NL holds. We formally state the result as a theorem.

Theorem 2 *Let liability rule $f : [0, \infty)^2 \mapsto [0, 1]^2$ belong to the subclass of liability rules satisfying the no-distinction between the due care and more than the due care requirement. Then, a necessary and sufficient condition for f to be efficient for every possible choice of C, D, π, H and $(c^*, d^*) \in M$ satisfying (A1) - (A3) is that it satisfy the condition of negligence liability.*

If the no-distinction between the due care and more than the due care requirement is to be incorporated in the definition of a liability rule itself then the most appropriate way to do so seems to be to define a liability rule as a function from $[0, 1]^2$ to $[0, 1]^2$, rather than from $[0, \infty)^2$ to $[0, 1]^2$; along with the required changes in the definitions of functions p and q. Under this procedure for incorporating the no-distinction between the due care and more than the due care requirement, a liability rule f would be defined by:

$f : [0, 1]^2 \mapsto [0, 1]^2$, where $f(p, q) = (x, y)$, $x + y = 1$.

An application of f would consist of specification of $C, D, \pi, H, (c^*, d^*) \in M$ satisfying (A1) - (A3); along with functions p and q defined as follows:

$p : C \mapsto [0,1]$ such that:

$$\begin{aligned} p(c) &= \tfrac{c}{c^*} \quad \text{if } c < c^*; \\ &= 1 \quad \text{if } c \geq c^* \end{aligned}$$

$q : D \mapsto [0,1]$ such that:

$$\begin{aligned} q(d) &= \tfrac{d}{d^*} \quad \text{if } d < d^*; \\ &= 1 \quad \text{if } d \geq d^*. \end{aligned}$$

RNO, of course, is inapplicable in this framework. Within this framework, the efficient liability rules are characterized by condition NL.[5]

The no-distinction between the due care and more than the due care requirement is logically completely independent of efficiency. There are both efficient and inefficient liability rules satisfying NDMR as well as violating it. Therefore, it follows that this very important feature of tort law cannot possibly have an explanation solely rooted in the normative criterion of economic efficiency. In what follows we argue that this feature of tort law is based partly on fairness considerations and partly on efficiency considerations. In order to establish this we first introduce the property of monotonicity.

Monotonic Liability Rules

As taking greater care never results in greater expected accident losses, fairness would seem to require that greater levels of care should not be associated with greater liability shares. In other words, the use of liability rules which perversely associate larger liability shares for larger proportions of nonnegligence might be thought inappropriate on grounds of fairness. A liability rule which does not perversely associate larger liability shares with larger proportions of nonnegligence would be called a monotonic liability rule. Intuitively, the monotonicity requirement seems to be quite compelling on considerations of fairness and justice. It is therefore not surprising that all liability rules used in practice satisfy the monotonicity requirement. Formally, the monotonicity condition is defined as follows:

Monotonicity (M): A liability rule f satisfies the condition of monotonicity iff $[\forall p, p', q, q' \in [0,\infty)][[p \geq p' \rightarrow x(p,q) \leq x(p',q)] \ \wedge \ [q \geq q' \rightarrow y(p,q) \leq y(p,q']]$.

If one considers only the class of monotonic liability rules, then in view of Theorem 1 it follows that all efficient monotonic liability rules satisfy the no-distinction requirement of tort law. We state this important result as a theorem. The proof is given in the Appendix.

[5] For the result that efficient liability rules in this framework are characterized by condition NL, see Jain and Singh (2002).

Theorem 3 *Let liability rule $f : [0, \infty)^2 \mapsto [0, 1]^2$ belong to the subclass of liability rules satisfying the condition of monotonicity. Then, if f is efficient for every possible choice of C, D, π, H and $(c^*, d^*) \in M$ satisfying (A1) - (A3) then it satisfies the no-distinction between the due care and more than the due care requirement.*

The monotonicity condition, by itself, seems to be unrelated to efficiency. From Theorem 1 it follows that the class of efficient liability rules includes both monotonic and non-monotonic rules; and so does the class of inefficient rules. The no-distinction between the due care and more than the due care requirement, however, seems to be, in view of Theorem 3, partly grounded in fairness and partly in efficiency.

The Requirement of No-Distinction among Levels of Care Which are less than the Due Care

Most liability rules used in practice do not distinguish among levels of care which are less than the due care. A notable exception is the rule of comparative negligence. The requirement that no distinction be made among different levels of care as long as they are all less than the due care can be formalized as follows:

The Requirement of No-Distinction among Levels of Care Which are less than the Due Care (RNDL): A liability rule f satisfies the requirement of no-distinction among levels of care which are less than the due care iff $[\forall p, q \in [0, \infty)][[p < 1 \rightarrow f(p, q) = f(0, q)] \wedge [q < 1 \rightarrow f(p, q) = f(p, 0)]]$.

It is easy to see that this condition is not only unrelated to efficiency and monotonicity (which is being interpreted as a formalization of an aspect of fairness) taken singly but also when they are considered jointly. Thus, this requirement, although analogous to NDMR, does not seem to based on any value of a compelling nature.

The structure of liability rules which satisfy both NDMR and RNDL is extremely simple as the liability assignments depend only on whether and which parties are negligent. If both the conditions are incorporated in the definition of a liability rule itself, then a liability rule f becomes a function from $\{0, 1\}^2$ to $[0, 1]^2$; $f : \{0, 1\}^2 \mapsto [0, 1]^2$, where $f(p, q) = (x, y)$, $x + y = 1$.

An application of f consists of specification of $C, D, \pi, H, (c^*, d^*) \in M$ satisfying (A1) - (A3); along with functions p and q defined as follows:

$p : C \mapsto \{0, 1\}$ such that:

$$
\begin{aligned}
p(c) &= 0 \quad \text{if } c < c^*; \\
&= 1 \quad \text{if } c \geq c^*
\end{aligned}
$$

$q : D \mapsto \{0, 1\}$ such that:

$$
\begin{aligned}
q(d) &= 0 \quad \text{if } d < d^*; \\
&= 1 \quad \text{if } d \geq d^*.
\end{aligned}
$$

3 Concluding Remarks

The analysis of liability rules can be done in two different, although related, ways. Given any property defined for liability rules one can ask the question as to which liability rules satisfy the property and which liability rules do not. Alternatively, one can consider a given liability rule and find out which properties are or are not satisfied by the given rule. In a given context if the purpose is to explain the choice of a particular liability rule it would be ideal if one could obtain a complete characterization of the liability rule in question in terms of the embodied values. The characterizing set of values would then constitute a complete explanation of the observed choice.

From a normative point of view, exercises of both kinds are important. Given a set of values one could find out the set of liability rules satisfying the given values. If the set contains more than one liability rule, it would be possible to satisfy some additional values. If the set contains only one liability rule then the given values completely determine the choice of liability rule. If the set of liability rules is empty, it would mean that all given values cannot be satisfied simultaneously; some values in the set would have to be discarded. Thus the analysis of embodied values is of great significance from both normative and positive perspectives.

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Appendix

Proposition 1 *If a liability rule* $f : [0,\infty)^2 \mapsto [0,1]^2$ *satisfies conditions NL and RNO then for any arbitrary choice of* C, D, π, H *and* $(c^*, d^*) \in M$ *satisfying (A1) - (A3),* (c^*, d^*) *is a Nash equilibrium.*

Proof: Let liability rule f satisfy conditions NL and RNO. Take any C, D, π, H and $(c^*, d^*) \in M$ satisfying (A1) - (A3).
Suppose (c^*, d^*) is not a Nash equilibrium. This implies:
$(\exists c' \in C)[c' + x[p(c'), q(d^*)]L(c', d^*) < c^* + x^*L^*] \vee (\exists d' \in D)[d' + y[p(c^*), q(d')]L(c^*, d') < d^* + y^*L^*]$. (1.1)
Suppose $(\exists c' \in C)[c' + x[p(c'), q(d^*)]L(c', d^*) < c^* + x^*L^*]$ holds. (1.2)
$c' < c^* \wedge (1.2) \rightarrow c' + L(c', d^*) < c^* + x^*L^*$, as $x[p(c'), q(d^*)] = 1$ by condition NL
$\rightarrow c' + L(c', d^*) < c^* + L^*$, as $x^* \in [0,1]$ and $L^* \geq 0$
$\rightarrow c' + d^* + L(c', d^*) < c^* + d^* + L^*$
$\rightarrow TSC(c', d^*) < TSC(c^*, d^*)$.
This is a contradiction as total social costs are minimum at (c^*, d^*). Therefore we conclude:
$c' < c^* \rightarrow$ (1.2) cannot hold. (1.3)
For $c' > c^*$, we have:
If $c^* = 0$ then $x[p(c'), q(d^*)] = x(1,1) = x^*$;
If $c^* > 0$ then $x[p(c'), q(d^*)] \geq x^*$, by condition RNO.
Therefore,
$c' > c^* \rightarrow x[p(c'), q(d^*)] \geq x^*$.
Consequently,
$c' > c^* \wedge (1.2) \rightarrow c' + x^*L(c', d^*) < c^* + x^*L^*$
$\rightarrow (1 - x^*)c' + x^*[c' + d^* + L(c', d^*)] < (1 - x^*)c^* + x^*[c^* + d^* + L^*]$
$\rightarrow (1 - x^*)c' < (1 - x^*)c^*$, as $TSC(c', d^*) \geq TSC(c^*, d^*)$. (1.4)
$(1 - x^*) > 0 \wedge (1.4) \rightarrow c' < c^*$, which contradicts the hypothesis that $c' > c^*$. (1.5)
$(1 - x^*) = 0 \wedge (1.4) \rightarrow 0 < 0$, a contradiction. (1.6)
(1.5) and (1.6) establish that (1.4) cannot hold. Therefore it follows that:
$c' > c^* \rightarrow$ (1.2) cannot hold. (1.7)
(1.3) and (1.7) establish that (1.2) cannot hold. By an analogous argument one can show that $(\exists d' \in D)[d' + y[p(c^*), q(d')]L(c^*, d') < d^* + y^*L^*]$ cannot hold.
This establishes that (c^*, d^*) is a Nash equilibrium.

Proposition 2 *If a liability rule* $f : [0,\infty)^2 \mapsto [0,1]^2$ *satisfies conditions NL and RNO then for every possible choice of* C, D, π, H *and* $(c^*, d^*) \in M$ *satisfying (A1) - (A3):*
$(\forall(\overline{c}, \overline{d}) \in C \times D)[(\overline{c}, \overline{d})$ *is a Nash equilibrium* $\rightarrow (\overline{c}, \overline{d}) \in M]$.

Proof: Let liability rule f satisfy conditions NL and RNO. Take any C, D, π, H and $(c^*, d^*) \in M$ satisfying (A1) - (A3).

Let $(\overline{c}, \overline{d})$ be a Nash equilibrium. $(\overline{c}, \overline{d})$ being a Nash equilibrium implies:

$$(\forall c \in C)[\overline{c} + x[p(\overline{c}), q(\overline{d})]L(\overline{c}, \overline{d}) \leq c + x[p(c), q(\overline{d})]L(c, \overline{d})] \tag{2.1}$$

and

$$(\forall d \in D)[\overline{d} + y[p(\overline{c}), q(\overline{d})]L(\overline{c}, \overline{d}) \leq d + y[p(\overline{c}), q(d)]L(\overline{c}, d)] \tag{2.2}$$

(2.1) and (2.2) imply respectively:

$$\overline{c} + x[p(\overline{c}), q(\overline{d})]L(\overline{c}, \overline{d}) \leq c^* + x[p(c^*), q(\overline{d})]L(c^*, \overline{d}) \tag{2.3}$$

$$\overline{d} + y[p(\overline{c}), q(\overline{d})]L(\overline{c}, \overline{d}) \leq d^* + y[p(\overline{c}), q(d^*)]L(\overline{c}, d^*) \tag{2.4}$$

Adding inequalities (2.3) and (2.4) we obtain:

$$\overline{c} + \overline{d} + L(\overline{c}, \overline{d}) \leq c^* + d^* + x[p(c^*), q(\overline{d})]L(c^*, \overline{d}) + y[p(\overline{c}), q(d^*)]L(\overline{c}, d^*). \tag{2.5}$$

By the definitions of functions p and q; and condition RNO:

if $\overline{c} \geq c^*$ then $y[p(\overline{c}), q(d^*)] \leq y^*$; and

if $\overline{d} \geq d^*$ then $x[p(c^*), q(\overline{d})] \leq x^*$.

By condition NL:

if $\overline{c} < c^*$ then $y[p(\overline{c}), q(d^*)] = 0$; and

if $\overline{d} < d^*$ then $x[p(c^*), q(\overline{d})] = 0$.

Also, by (A2),

if $\overline{c} \geq c^*$ then $L(\overline{c}, d^*) \leq L^*$; and

if $\overline{d} \geq d^*$ then $L(c^*, \overline{d}) \leq L^*$.

In view of the above,

$$\overline{c} \geq c^* \wedge \overline{d} \geq d^* \wedge (2.5) \rightarrow \overline{c} + \overline{d} + L(\overline{c}, \overline{d}) \leq c^* + d^* + x^* L(c^*, \overline{d}) + y^* L(\overline{c}, d^*)$$
$$\rightarrow \overline{c} + \overline{d} + L(\overline{c}, \overline{d}) \leq c^* + d^* + x^* L^* + y^* L^* = c^* + d^* + L^*; \tag{2.6}$$
$$\overline{c} < c^* \wedge \overline{d} \geq d^* \wedge (2.5) \rightarrow \overline{c} + \overline{d} + L(\overline{c}, \overline{d}) \leq c^* + d^* + x[p(c^*), q(\overline{d})]L(c^*, \overline{d})$$
$$\rightarrow \overline{c} + \overline{d} + L(\overline{c}, \overline{d}) \leq c^* + d^* + L(c^*, \overline{d})$$
$$\rightarrow \overline{c} + \overline{d} + L(\overline{c}, \overline{d}) \leq c^* + d^* + L^*; \tag{2.7}$$
$$\overline{c} \geq c^* \wedge \overline{d} < d^* \wedge (2.5) \rightarrow \overline{c} + \overline{d} + L(\overline{c}, \overline{d}) \leq c^* + d^* + y[p(\overline{c}), q(d^*)]L(\overline{c}, d^*)$$
$$\rightarrow \overline{c} + \overline{d} + L(\overline{c}, \overline{d}) \leq c^* + d^* + L(\overline{c}, d^*)$$
$$\rightarrow \overline{c} + \overline{d} + L(\overline{c}, \overline{d}) \leq c^* + d^* + L^*; \tag{2.8}$$
$$\overline{c} < c^* \wedge \overline{d} < d^* \wedge (2.5) \rightarrow \overline{c} + \overline{d} + L(\overline{c}, \overline{d}) \leq c^* + d^*$$
$$\rightarrow \overline{c} + \overline{d} + L(\overline{c}, \overline{d}) \leq c^* + d^* + L^*. \tag{2.9}$$

(2.6)-(2.9) establish that:

$(2.5) \rightarrow TSC(\overline{c}, \overline{d}) \leq TSC(c^*, d^*)$.

As $TSC(c^*, d^*)$ is minimum, it follows that we must have $TSC(\overline{c}, \overline{d}) = TSC(c^*, d^*)$.

This establishes that $(\overline{c}, \overline{d}) \in M$.

Proposition 3 *If a liability rule $f : [0, \infty)^2 \mapsto [0, 1]^2$ is efficient for every possible choice of C, D, π, H and $(c^*, d^*) \in M$ satisfying (A1) - (A3), then it satisfies condition RNO.*

Proof: Let liability rule f violate condition RNO. Then:
$[\exists p \in (1,\infty)][x(p,1) < x(1,1)] \ \vee \ [\exists q \in (1,\infty)][y(1,q) < y(1,1)]$.
Suppose $[\exists q \in (1,\infty)][y(1,q) < y(1,1)]$ holds.
Let t be a positive number. Choose u such that:
$u > \frac{(q-1)t}{y(1,1)-y(1,q)}$.
It should be noted that $u > 0$.
Choose a positive number μ such that $\mu < (q-1)t$.
Let s, ϵ and δ be any positive numbers. Let C, D and L be specified as follows:
$C = \{0, s\}, D = \{0, t, qt\}$,
$L(0,0) = s + \epsilon + t + \delta + u, L(s,0) = t + \delta + u$
$L(0,t) = s + \epsilon + u, L(s,t) = u$
$L(0,qt) = s + \epsilon + u - (q-1)t + \mu, L(s,qt) = u - (q-1)t + \mu$.
$\epsilon > 0, \delta > 0$ and $0 < \mu < (q-1)t$ imply that (s,t) is the unique total social cost minimizing configuration, i.e., $M = \{(s,t)\}$.
Let $(c^*, d^*) = (s,t)$.
Now,
$EC_2(s,t)$
$= t + y(1,1)L(s,t)$
$= t + y(1,1)u$
$EC_2(s,qt)$
$= qt + y(1,q)L(s,qt)$
$= qt + y(1,q)[u - (q-1)t + \mu]$
$EC_2(s,t) - EC_2(s,qt)$
$= t + y(1,1)u - qt - y(1,q)[u - (q-1)t + \mu]$
$= -(q-1)t + [y(1,1) - y(1,q)]u + y(1,q)[(q-1)t - \mu]$
As $y(1,q)[(q-1)t - \mu] \geq 0$, we conclude:
$EC_2(s,t) - EC_2(s,qt) \geq -(q-1)t + [y(1,1) - y(1,q)]u$.
As $u > \frac{(q-1)t}{y(1,1)-y(1,q)}$, it follows that:
$EC_2(s,t) - EC_2(s,qt) > 0$.
This implies that the unique total social cost minimizing configuration (s,t) is not a Nash equilibrium. Consequently f is not efficient.
If $[\exists p \in (1,\infty)][x(p,1) < x(1,1)]$ holds, then by an analogous argument one can show that f is not efficient.
This establishes the proposition.

Proposition 4 *If a liability rule $f : [0,\infty)^2 \mapsto [0,1]^2$ is efficient for every possible choice of C, D, π, H and $(c^*, d^*) \in M$ satisfying (A1) - (A3), then it satisfies condition NL.*

Proof: Let liability rule f violate condition NL. Then:

$[\exists p \in [0,1)][f(p,1) \neq (1,0) \;\vee\; [\exists q \in [0,1)][f(1,q) \neq (0,1)]$.
Suppose $[\exists q \in [0,1)][f(1,q) \neq (0,1)]$ holds.
Let $t > 0$. Choose r such that $0 \leq y(1,q)t < r < t$. Let $v = \frac{r}{1-q}$. Let $u > 0$ and $\epsilon > 0$.
Let C, D and L be specified as follows:
$C = \{0, u\}, D = \{0, qv, v\}$,
$L(0,0) = u + \epsilon + t + qv, L(u,0) = t + qv$
$L(0,qv) = u + \epsilon + t, L(u,qv) = t$
$L(0,v) = u + \epsilon, L(u,v) = 0$.
$\epsilon > 0$ and $t > r = (1-q)v$ imply that $M = \{(u,v)\}$.
Let $(c^*, d^*) = (u,v)$.
Now,
$EC_2(u,v) = v$
$EC_2(u,qv)$
$= qv + y(1,q)L(u,qv)$
$= qv + y(1,q)t$
$EC_2(u,v) - EC_2(u,qv)$
$= v - qv - y(1,q)t$
$= (1-q)v - y(1,q)t$
$= r - y(1,q)t$
> 0.
This implies that the unique total social cost minimizing configuration (u,v) is not a Nash equilibrium. f is therefore not efficient.
If $[\exists p \in [0,1)][f(p,1) \neq (1,0)]$ holds, then by an analogous argument it can be shown that f is not efficient.
This establishes the proposition.

Proof of Theorem 1: Let liability rule f satisfy the requirement of non-reward for over-nonnegligence and the condition of negligence liability. Then by Propositions 1 and 2 f is efficient for every possible choice of C, D, π, H and $(c^*, d^*) \in M$ satisfying (A1) - (A3). Proposition 3 and 4 establish that if f is efficient for every possible choice of C, D, π, H and $(c^*, d^*) \in M$ satisfying (A1) - (A3), then it satisfies the requirement of non-reward for over-nonnegligence and the condition of negligence liability.

Proof of Theorem 3: Let f be an efficient monotonic liability rule. Therefore, f satisfies RNO and NL by Theorem 1.
$p \geq 1 \rightarrow x(p,q) \leq x(1,q)$, by condition M (1)
$q \geq 1 \rightarrow x(1,q) \leq x(1,1)$, by RNO (2)
$q \geq 1 \rightarrow x(p,q) \geq x(p,1)$, by M (3)

$p \geq 1 \rightarrow x(p,1) \geq x(1,1)$, by RNO (4)

From (1) and (2) we conclude:

$$p \geq 1 \wedge q \geq 1 \rightarrow x(p,q) \leq x(1,1) \tag{5}$$

From (3) and (4) we conclude:

$$p \geq 1 \wedge q \geq 1 \rightarrow x(p,q) \geq x(1,1) \tag{6}$$

(5) and (6) imply:

$$p \geq 1 \wedge q \geq 1 \rightarrow x(p,q) = x(1,1) \tag{7}$$

In view of (1), (2) and (7) it follows that:

$$p \geq 1 \wedge q \geq 1 \rightarrow x(p,q) = x(1,q) \tag{8}$$

Now,

$q < 1 \rightarrow x(1,q) = 0$, by NL (9)

(1) and (9) imply:

$$p \geq 1 \wedge q < 1 \rightarrow x(p,q) = x(1,q) \tag{10}$$

(8) and (10) imply:

$$p \geq 1 \rightarrow x(p,q) = x(1,q) \tag{11}$$

By an analogous argument it follows that:

$$q \geq 1 \rightarrow x(p,q) = x(p,1) \tag{12}$$

(11) and (12) establish the theorem.