ON THE CHOICE OF LIABILITY RULES

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Abstract. Rules for the assignment of liabilities for losses arising out of interactions involving negative externalities usually depend on which of the interacting parties are negligent and which are not. It has been established in the literature that if negligence is defined as failure to take some cost justified taken precaution then there is no rule which can always lead to an efficient outcome. The objective of this paper is to try and understand if *it is still possible to make pairwise comparisons between liability rules on the basis of efficiency and to use such a method to explain/evaluate choices from a given set of rules.* We focus on the of five of the most widely used rules and show that pairwise comparisons between rules in this set fail. The paper, thus, demonstrates that an efficiency based explanation for any choice from these five rules is not consistent with the notion of negligence defined as failure to take some cost justified precaution.

Keywords: Liability rule, Negligence, Cost-justified untaken precaution, Maximal elements, Best element, Efficiency.

JEL Classification: K13, K40, C72, D60, D62

1. Introduction

Courts from across the world are routinely required to decide on matters relating to apportionment of losses resulting from accidents. A variety of rules are used by courts for the assignment of liabilities for such losses. Which of these rules, by providing appropriate incentives to parties involved, always results in efficient outcomes is a key question addressed in economic analysis of law.[1] The attempt here is to provide an efficiency based explanation of why some rules are (ought to be) chosen over the others.

In the standard framework,[2] the question is analysed in the context of interactions between two risk-neutral parties who are strangers to one another. It is assumed that the loss, in case of accident, falls on one of the parties called the victim. The other party is referred to as the injurer. The probability of accident and the actual loss in case of accident are assumed to depend on the care levels of the two parties. It is also assumed that the social objective is to minimize the total social costs which are defined as the sum of costs of care of the parties involved and the expected accident loss. The assignment of liabilities for accidental losses by courts is usually based on the levels of nonnegligence of the victim and the injurer where the level of nonnegligence of a party is either 0 (indicating that the party is negligent) or 1 (indicating that the party is nonnegligent). A rule for the assignment of liabilities specifies the proportions

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[1]There is a large literature on the efficiency of rules for the assignment of liabilities for accidental losses starting with pioneering contributions from Calabresi ([2], [3], [4]) and Coase[5] followed by Brown[1], Diamond[6], Posner ([14], [15]), Shavell [16], Jain and Singh[11] among others. Brown was the first to present a formal analysis of many of the important rules for assignment of liabilities. The subsequent literature is built upon Brown's formal model which was later on generalized by Jain and Singh[11]. A systematic treatment of the economic analysis of rules for the assignment of liabilities is contained in Jain[12].

[2]The framework is based on the general model presented by Jain and Singh[11].

of the loss, in case of occurrence of accident, that the victim and the injurer have to bear for every possible combination of their levels of nonnegligence. It is assumed that parties have common knowledge about their interaction (the rule, the possible care levels for both with their corresponding costs and the expected accident losses) and choose their respective care levels simultaneously to minimize their expected costs where the expected cost of a party is the sum of cost of her (his) chosen care level and the expected value of her (his) share of the loss. Thus, an interaction between the parties is modeled as a static game of complete information. A rule for assignment of liabilities is said to be efficient if and only if it always induces both parties to choose care levels that minimize total social costs.

Since the apportionment of accidental losses by courts is usually based on who is negligent and who is not, the determination of negligence of a party involved in an accident is a very crucial element of the process of liability assignment and can have important implications. In the standard literature on the efficiency of rules for the assignment of liabilities for accidental losses, negligence is usually defined as the shortfall from a court-specified total social cost minimizing due care level.[3] Thus an injurer (victim) is considered negligent iff she (he) is found to have taken less than the care due from her (him). Negligence has, alternatively, been defined as the failure to take a cost-justified untaken precaution.[4] Given the care levels of the two parties, any other care level of a party (which is higher than her actual care) is cost-justified if and only if it involves an additional cost which is less than the reduction in expected loss it would have brought about. Thus, according to this notion, injurer (victim) is considered negligent iff the other party can demonstrate a failure on her part to take some cost justified precaution. It has been established in the literature that, if negligence is defined as shortfall from legally specified total social cost minimizing due care then there are liability rules which provide appropriate incentives for taking efficient levels of care to involved parties.[5] It has also been established that no rule is efficient when negligence is defined as failure to take some cost justified precaution.[6] Thus, while the notion of negligence as shortfall from due care is consistent with the objective of efficiency the notion of negligence as failure to take some cost justified precaution is not.

The cost justified precaution approach to determination of negligence, though inconsistent with the objective of efficiency, has several advantages to its credit. The determination of negligence according to the shortfall from due care approach requires the court to play an active role in collecting and processing information on costs of care of parties and expected accident losses. In the other approach while the injurer (victim) has to demonstrate the existence of some cost justified precaution of the victim (injurer) to establish her (his) negligence, the court plays the role of a neutral referee. Thus, in comparison to the shortfall from due care approach, this approach is more in harmony with the adversarial system of law. It has been argued that the cost of determining efficient level of care by courts can be significantly more than the costs that parties might have to incur in establishing negligence of each other. It has also been argued that, in determining negligence, courts actually do not try to fix due care levels but look for evidence of failure to take a cost justified precaution[7]. It is therefore important to explore the

[3]For a formal definition of the notion of negligence as shortfall from due care see [11].

[4]The notion of negligence as failure to take some cost-justified precaution was first put forward by Grady ([7], [8] and [9]) and was later on formalized by Jain[10].

[5]Jain and Singh[11] provides a complete characterization of efficient liability rules when negligence is defined as shortfall from legally specified due care.

[6]See Jain[10] for a formal statement and proof of this impossibility result.

[7]The empirical evidence is not conclusive enough. See Pal[13] for an in-depth analysis of judgments from 3 common law jurisdictions (United States, Britain and India) trying to figure out how negligence is determined in these jurisdictions

possibility of retaining efficiency consideration in the standard model while using the notion of negligence as failure to take some precaution which is cost-justified.

In this paper we pose the following question: if negligence is defined as the existence of some cost justified precaution then is it possible to choose a rule from a given set on the basis of efficiency considerations? To answer the above question we define a binary relation on a set of rules as follows: A rule is at least as efficient as another if and only if the set of applications for which it is inefficient is a subset of the set of applications for which the other one is inefficient. A rule in the set is best if and only if it is at least as efficient as every other rule in the set. A rule in the set is maximal if and only if there in no other rule in the set which is more efficient. If there exist a best element of the set with respect to the above relation then such an element is an obvious choice. If a best element does not exist but a maximal element of the set exists then such an element is socially desirable. In this paper, we focus on the set of the following 5 rules which are among the most widely used and also the ones most analysed in the literature: no liability, strict liability, negligence, negligence with the defense of contributory negligence and strict liability with the defense of contributory negligence.[8] It turns out that none of these rules is comparable to any of the others and therefore none is best but every rule is maximal with respect to the above relation. Thus it follows that, when negligence is defined as the existence of some cost justified precaution, it is not possible to make a meaningful choice from these five rules on the basis of efficiency considerations as embedded in the relation discussed above.

The paper is organized as follows: The model is presented in Section 2. All definitions and assumptions are stated here and are illustrated with appropriate examples. Section 3 states an impossibility result. Section 4 presents the main results of the paper in the form of Theorems 1 and 2 and also contains the intermediate results (Lemmas 1 - 5) which are used to prove the two theorems. Section 5 concludes the paper with a discussion on the implications of the results.

2. Model

We consider interactions between two parties (generically called party i where $i \in \{1, 2\}$), assumed to be strangers to each other, which can result in an accidental harm falling on party 1. We'll refer to party 1 as the victim and party 2 as the injurer. It is assumed that the probability of accident and the magnitude of harm in case of an accident depend on the levels of non-negative care that the parties might choose to take. Let $a_i \geq 0$ be the index of the level of care taken by party i and let $A_i = \{a_i \mid a_i \geq 0$ be the index of some feasible level of care which can be taken by party $i\}$. We assume that

$0 \in A_i$. (A1)

We denote by $c_i(a_i)$ the cost to party i of care level a_i. Let $C_i = \{c_i(a_i) \mid a_i \in A_i\}$. We assume

$c_i(0) = 0$. (A2)

We also assume that

c_i is a strictly increasing function of a_i. (A3)

In view of (A2) and (A3) it follows that $(\forall c_i \in C_i)(c_i \geq 0)$.

A consequence of (A3) is that c_i itself can be taken to be an index of the level of care taken by party i.

Let $\pi : C_1 \times C_2 \mapsto [0, 1]$ denote the probability of occurrence of accident and $H : C_1 \times C_2 \mapsto \Re_+$ the loss in case of occurrence of accident. Let $L : C_1 \times C_2 \mapsto \Re_+$ be defined as: $L(c_1, c_2) = \pi(c_1, c_2)H(c_1, c_2)$ for all $(c_1, c_2) \in C_1 \times C_2$. L is, thus, the expected loss due to accident.

We assume:

π and H are non-increasing in c_1 and c_2. (A4)

(A4) implies that L is non-increasing in c_1 and c_2.

[8]Formal definitions of these rules are given in the next section.

We define the total social cost of the interaction between the two parties, $T : C_1 \times C_2 \mapsto \Re_+$, as: $T(c_1, c_2) = c_1 + c_2 + L(c_1, c_2)$ for all $(c_1, c_2) \in C_1 \times C_2$. Let $M = \{(c_1', c_2') \in C_1 \times C_2 \mid (\forall (c_1, c_2) \in C_1 \times C_2)[T(c_1', c_2') \leq T(c_1, c_2)]\}$. Thus, M is the set of all costs of care profiles (c_1', c_2') which are total social cost minimizing. It will be assumed that:

C_1, C_2, π and H are such that M is nonempty. (A5)

Let $p_i : C_1 \times C_2 \mapsto \{0, 1\}$ denote the level of nonnegligence of party i with $p_i(c_1, c_2) = 0$ indicating that party i is negligent and $p_i(c_1, c_2) = 1$ indicating that party i is nonnegligent.[9] The exact form of the function would depend on the definition of negligence.

2.1. **Negligence as failure to take some cost justified precaution.** Consider any $(c_1, c_2) \in C_1 \times C_2$. $c_1^u \in C_1$ is cost justified for the victim iff $c_1^u > c_1$ and $c_1^u - c_1 < L(c_1, c_2) - L(c_1^u, c_2)$. Similarly, $c_2^u \in C_2$ is cost justified for the injurer iff $c_2^u > c_2$ and $c_2^u - c_2 < L(c_1, c_2) - L(c_1, c_2^u)$. In other words, given the care levels of the two parties, care level of a party (which is higher than her actual care) is cost justified if and only if it involves an additional cost which is less than the reduction in expected loss it would have brought about.

Let Λ_i denote the set of all subsets of C_i. We define functions $C_1^u : C_1 \times C_2 \mapsto \Lambda^1$ and $C_2^u : C_1 \times C_2 \mapsto \Lambda^2$ as follows:

$$C_1^u(c_1, c_2) = \{c_1^u \in C_1 \mid c_1^u > c_1 \text{ and } c_1^u - c_1 < L(c_1, c_2) - L(c_1^u, c_2)\} \text{ and}$$
$$C_2^u(c_1, c_2) = \{c_2^u \in C_2 \mid c_2^u > c_2 \text{ and } c_2^u - c_2 < L(c_1, c_2) - L(c_1, c_2^u)\}.$$

Thus, $C_i^u(c_1, c_2)$ specifies the set of all care levels of i which are cost justified at (c_1, c_2). We define functions $p_i : C_1 \times C_2 \mapsto \{0, 1\}$ as follows:

$$\begin{aligned} p_i(c_1, c_2) &= 0 \quad \text{if } C_i^u(c_1, c_2) \neq \phi \\ &= 1 \quad \text{otherwise.} \end{aligned}$$

At (c_1, c_2), if there does not exist a cost justified untaken precaution then $p_i(c_i)$ takes the value 1 otherwise it takes the value 0. [10]

2.2. **Simple Liability Rule.** A simple liability rule is a function $g : \{0, 1\}^2 \mapsto [0, 1]^2$, such that: $g(p_1, p_2) = (x_1, x_2)$; $x_1 + x_2 = 1$ where x_1 is the proportion of loss to be borne by the victim and x_2 is the proportion of the loss to be borne by the injurer. In other words, a simple liability rule is a rule which specifies, for every possible configuration of the levels of nonnegligence of the two parties, the proportions of the loss, in case of accident, to be borne by each of the two parties.

Example 1. *Consider the following simple liability rules:*

(i) *Rule of no liability (g_1): the victim always bears the entire loss.*
$$g_1(p_1, p_2) = (1,\ 0) \quad \textit{for all } (p_1, p_2).$$

(ii) *Rule of strict liability (g_2): the injurer always bears the entire loss.*

[9] The level of nonnegligence can be more generally formalized as $p_i : C_1 \times C_2 \mapsto [0, 1]$ with $p_i(c_1, c_2) < 1$ indicating that party i is negligent and $p_i(c_1, c_2) = 1$ indicating that party i is nonnegligent. In this paper we will restrict ourselves to the less general formulation given in the text above.

[10] For a more general definition of negligence as failure to take some cost justified precaution, which makes a distinction between varying degrees of negligence of a negligent party see Jain[10]. In this paper we will stick to the less general formulation given in the text above.

$$g_2(p_1, p_2) = \textit{(0, 1)} \quad \textit{for all } (p_1, p_2).$$

(iii) *The negligence rule (g_3): If the injurer is negligent then she has to bear the entire loss and victim bears nothing; if the injurer is not negligent then she bears nothing and the entire loss is borne by the victim.*

$$\begin{aligned} g_3(p_1, p_2) &= \textit{(0, 1)} \quad \textit{if } p_2 = 0 \\ &= \textit{(1, 0)} \quad \textit{otherwise.} \end{aligned}$$

(iv) *Negligence rule with the defense of contributory negligence (g_4): If the injurer is negligent and the victim is not then she has to bear the entire loss and victim bears nothing; otherwise she bears nothing and the entire loss is borne by the victim.*

$$\begin{aligned} g_4(p_1, p_2) &= \textit{(0, 1)} \quad \textit{if } p_1 = 1 \textit{ and } p_2 = 0 \\ &= \textit{(1, 0)} \quad \textit{otherwise.} \end{aligned}$$

(v) *Rule of strict liability with the defense of contributory negligence (g_5): If the victim is negligent then he has to bear the entire loss and injurer bears nothing; if the victim is not negligent then he bears nothing and the entire loss is borne by the injurer.*

$$\begin{aligned} g_5(p_1, p_2) &= \textit{(1, 0)} \quad \textit{if } p_1 = 0 \\ &= \textit{(0, 1)} \quad \textit{otherwise.} \end{aligned}$$

A rule for the assignment of liabilities can be more generally formalized as a liability rule. A liability rule is a function $f : [0,1]^2 \mapsto [0,1]^2$, such that: $f(p_1, p_2) = (x_1, x_2)$; $x_1 + x_2 = 1$ where x_1 is the proportion of loss to be borne by the victim and x_2 is the proportion of the loss to be borne by the injurer. Thus, in general, a liability rule distinguishes between varying degrees of negligence of a negligent party and this distinction can matter in the assignment of liabilities. A simple liability rule, however, makes no distinction between varying degrees of negligence of a negligent party.

Remark 1. *Corresponding to every simple liability rule g there is a class of liability rules $F(g) = \{f \mid f = g \text{ for all } (p_1, p_2) \in \{0,1\}^2\}$. Any two rules in this class can differ in their assignment of liabilities only if $p_1 \in (0,1)$ or $p_2 \in (0,1)$. If $f \in F(g)$ is such that $(\forall p_1, p_2 \in [0,1])[p_1 < 1 \rightarrow f(p_1, p_2) = f(0, p_2) \text{ and } p_2 < 1 \rightarrow f(p_1, p_2) = f(p_1, 0)]$ then the assignment of liabilities under f is identical to that under g.*

Example 2. *Consider the following liability rule:*

(i) *Rule of comparative negligence (g_6): If the injurer is nonnegligent then the injurer bears none of loss, otherwise the injurer's share of the loss is given by his negligence as a proportion to the negligence of the two parties taken together and the remaining loss falls on the victim.*

$$\begin{aligned} f_1(p_1, p_2) &= \textit{(1, 0)} \quad \textit{if } p_2 = 1 \\ &= \left(\frac{1-p_1}{2-p_1-p_2}, \frac{1-p_2}{2-p_1-p_2}\right) \quad \textit{otherwise.} \end{aligned}$$

Note that f_1 belongs to $F(g_6)$ where g_6 is defined as follows:

$$\begin{aligned} g_6(p_1, p_2) &= \textit{(1, 0)} \quad \textit{if } p_2 = 1 \\ &= \textit{(0, 1)} \quad \textit{if } p_1 = 1, p_2 = 0. \\ &= \left(\tfrac{1}{2}, \tfrac{1}{2}\right) \quad \textit{if } p_1 = p_2 = 0. \end{aligned}$$

However, the assignment of liabilities under f_1 is not identical to that under g_6.

2.3. **Application of a rule.** An application, ω, is a specification of C_1, C_2, π and H. Let Ω denote the set of all applications which satisfy assumptions (A1) - (A5).
Let g be any simple liability rule and $\omega \in \Omega$ be any application of g. If the victim chooses c_1, the injurer chooses c_2 and the accident occurs then the actual loss will be $H(c_1, c_2)$. According to g party i will be made to bear $x_i(p_1(c_1), p_2(c_2))H(c_1, c_2)$. $E_i : C_1 \times C_2 \mapsto \Re_+$ defined as: $E_i(c_1, c_2) = c_i + x_i(p_1, p_2)L(c_1, c_2)$ for all $(c_1, c_2) \in C_1 \times C_2$ is the expected cost to party i. We assume that for all $(c_1, c_2), (c_1', c_2') \in C_1 \times C_2$, party i considers (c_1, c_2) to be at least as good as (c_1', c_2') if and only if $E_i(c_1, c_2) \leq E_i(c_1', c_2')$. Thus a simple liability rule induces a two-player simultaneous move game in every application with party 1 and party 2 as the players, C_1, C_2 as the set of strategies and E_1, E_2 as the payoffs.[11] We shall denote the game induced by simple liability rule g in application ω by (g, w) and, whenever possible, represent it by the corresponding payoff matrix. An application of a liability rule f is defined similarly and is denoted by (f, ω).

Example 3. *Let $C_1 = \{0, 4, 8\}$, $C_2 = \{0, 2, 4\}$ and let the expected loss function, $L(c_1, c_2)$ be as given in 2.1 .*

	c_2: 0	2	4
c_1: 0	20	17	16
4	15	10	9
8	13	9	6

TABLE 2.1. Application ω_5

	c_2: 0	2	4
c_1: 0	$(0,0)$	$(0,1)$	$(0,1)$
4	$(1,0)$	$(1,1)$	$(1,1)$
8	$(1,0)$	$(1,0)$	$(1,1)$

TABLE 2.2. (p_1, p_2) matrix for ω_5

Thus C_1, C_2 given above and $L(c_1, c_2)$ specified as in table 2.1 constitutes an application in Ω.[12] *Table 2.2 shows the negligence level for the victim and injurer for every possible configuration of costs of care. If both parties take no care then both would be negligent. Given that the injurer takes no care the victim could have spend 4 on care to reduce expected loss by 5. Given that the victim's takes no care the injurer could have spend 2 on care to reduce expected loss by 3. If victim chooses 4 and the injurer chooses 2 then both are nonnegligent. This follows from the fact that (4, 2) minimizes T. Similarly at (8, 2) the victim is nonnegligent while the injurer is negligent. The victim is already taking the highest level of care possible. Given the victim's care the injurer could have spend an additional 2 on care to reduce expected loss by 3 more units.*

2.4. **Efficiency.** A simple liability rule, g is said to be efficient for ω iff (i) $(\exists(c_1, c_2) \in C_1 \times C_2)[(c_1, c_2)$ is a Nash equilibrium of $(g, \omega)]$ and (ii) $(\forall(c_1, c_2) \in C_1 \times C_2)$[If (c_1, c_2) is a Nash equilibrium of (g, ω) then $(c_1, c_2) \in M]$.[13] A simple liability rule, g is said to be efficient for Ω iff it is efficient for every $\omega \in \Omega$. In other words a simple liability rule, g is said to be efficient for Ω iff for every application ω of g (i) there exists a Nash equilibrium of the game $(g, \omega)]$ and (ii) every Nash equilibrium of $(g, \omega)]$ minimizes T. An efficient liability rule is defined similarly.

Remark 2. *Note that, if $f \in F(g)$ is such that $(\forall p_1, p_2 \in [0, 1])[p_1 < 1 \rightarrow f(p_1, p_2) = f(0, p_2)$ and $p_2 < 1 \rightarrow f(p_1, p_2) = f(p_1, 0)]$ then f is efficient iff g is efficient.*

Let $\underline{\Omega}(g) \subseteq \Omega$ be the set of applications for which g is inefficient. Let G be any class of simple liability rules and R on G be the binary relation *at least as efficient as.* We define R

[11]It has to be noted that the payoffs are non-positive.

[12]We shall, simply, refer to a table representing expected loss function as an application.

[13]Only pure strategy Nash equilibria are considered in this paper.

on G as follows: $R = \{(g, g') \in G^2 \mid \underline{\Omega}(g) \subseteq \underline{\Omega}(g')\}$. Thus, $(g, g') \in R$ if and only if the set of applications for which g is inefficient is a subset of the set of applications for which g' is inefficient. $(g, g') \in R$ would mean g is at least as efficient as g'. $(g, g') \notin R$ if and only if there is an application for which g is inefficient but g' is not. Let $P(R)$ denote the asymmetric part of R. Thus, $P(R) = \{(g, g') \in G^2 \mid (g, g') \in R \text{ and } (g', g) \notin R\} = \{(g, g') \in G^2 \mid \underline{\Omega}(g) \subset \underline{\Omega}(g')\}$. $(g, g') \in P(R)$ would mean g is more efficient than g'.

Remark 3. *It is clear that (i) if g and g' are both efficient then (g, g') and (g', g) both belong to R and (ii) if g is efficient and g' is not then (g, g') belongs to $P(R)$.*

$g \in G$ is said to be best in G with respect to R iff $(\forall g' \in G)[(g, g') \in R]$. $g \in G$ is said to be maximal in G with respect to R iff $(\forall g' \in G)[(g', g) \notin P(R)]$. In other words, a rule $g \in G$ is best if and only if it is at least as efficient as every rule in G and it is maximal in G if and only if there is no other rule in G which is more efficient. Let $M(G, R)$ be the set of maximal elements of G with respect to R and $B(G, R)$ be the set of best elements of G with respect to R. In the next section we consider $G' = \{g_1, g_2, g_3, g_4, g_5\}$ and identify $M(G', R)$ and $B(G', R)$.

3. Negligence as failure to take some cost justified precaution and the Efficiency of simple Liability Rules: An Impossibility

In this section we analyse efficiency properties of simple liability rules with negligence defined as the existence of some cost justified precaution. The main result here establishes that if negligence is defined as failure to take some cost justified precaution then no simple liability rule can always achieve an efficient outcome. The result is stated as Proposition 1 given below:

Proposition 1. *If negligence is defined as failure to take some cost justified precaution then no simple liability rule is efficient for Ω.*

In view of Remarks 1 and 2 it is immediate that Proposition 1 follows as a corollary to Theorem 1 of Jain[10] which states that if negligence is defined as failure to take some cost justified precaution then there is no liability rule which is efficient for Ω.[14] It follows from Proposition 1 that the rules in G' are all inefficient.

4. Choice of rules when negligence is defined as failure to take some cost justified precaution

In this section we focus on G', the set of 5 of the most widely analysed rules for the apportionment of accidental losses, and find out the best and the maximal elements in G' with respect to the binary relation R. The main results of the paper are presented as Theorems 1 and 2. Theorem 1 states that the set of best elements in G' with respect to the binary relation R is empty and Theorem 2 states that the set of maximal elements in G' with respect to the binary relation R is G'. We state and prove 5 intermediate results, Lemmas 1-5 to prove the two theorems.

Lemma 1 states that there is no rule in G' which is at least as efficient as g_1 (the no liability rule). We prove Lemma 1 by providing an example of an application in Ω for which g_1 is efficient but none of the other four rules in G' is efficient. This amounts to showing that the set of applications for which any of the other rules is inefficient is not a subset of the set of the set of applications for which g_1 is inefficient. Lemmas 2, 3, 4 and 5 state that there is no rule in G' which is at least as efficient as g_2 (the rule of strict liability), g_3 (the negligence rule), g_4 (the negligence rule with the defense of contributory negligence) and g_5 (the rule of strict liability

[14]Independent proof of Proposition 1 is similar to the proof of Theorem 1 of Jain[10] and does not provide any new insight.

with the defense of contributory negligence) respectively. Proofs of Lemmas 2-5 are similar to that of Lemma 1. Thus, Lemmas 1-5 together establish that none of the 5 rules is comparable, according to R, to any of the others and therefore while the set of best elements of G' is empty the set of its maximal elements is G'.

Lemma 1. *$(g, g_1) \notin R$ for all $g \in G' - \{g_1\}$.*

Proof. Let ω_1 be the application given in Table 4.1. Note that $M = \{(4, 0)\}$.

		c_2	
		0	4
	0	20	18
c_1	4	15	13
	6	15	10

TABLE 4.1. Application ω_1

		c_2	
		0	4
	0	$(0,1)$	$(0,1)$
c_1	4	$(1,1)$	$(0,1)$
	6	$(1,0)$	$(1,1)$

TABLE 4.2. (p_1, p_2) matrix for ω_1

Table 4.2 is the (p_1, p_2) matrix for ω_1. Now we consider ω_1 as an application of each of the five rules in G'.

g_1 is efficient for ω_1 as (4, 0) $\in M$ is the unique Nash equilibrium of (g_1, w_1). (1.1)

g_2 is inefficient for ω_1 because 0 is the dominant strategy for the victim in (g_2, ω_1). (1.2)

(6, 4) is the unique Nash equilibrium for (g_3, ω_1) and therefore g_3 is inefficient for ω_1. (1.3)

As there is no configuration of costs at which the victim and the injurer are both negligent, (g_4, ω_1) is the same as (g_3, ω_1). Thus the g_4 is also inefficient for ω_1. (1.4)

(6, 4) is also the unique Nash equilibrium of (g_5, ω_1) and therefore g_5 is inefficient for ω_1. (1.5)

		c_2	
		0	4
	0	$(20, \underline{0})$	$(18, 4)$
c_1	4	$(\underline{19}, \underline{0})$	$(17, 4)$
	6	$(21, \underline{0})$	$(\underline{16}, 4)$

TABLE 4.3. (g_1, ω_1)

		c_2	
		0	4
	0	$(20, \underline{0})$	$(18, 4)$
c_1	4	$(19, \underline{0})$	$(17, \underline{4})$
	6	$(\underline{6}, 15)$	$(\underline{16}, \underline{4})$

TABLE 4.4. Payoff matrix for (g_3, ω_1) and (g_4, ω_1)

		c_2	
		0	4
	0	$(20, \underline{0})$	$(18, 4)$
c_1	4	$(\underline{4}, 15)$	$(17, \underline{4})$
	6	$(6, 15)$	$(\underline{6}, \underline{14})$

TABLE 4.5. Payoff matrix for (g_5, ω_1)

(1.1) and (1.2) imply that $(g_2, g_1) \notin R$, (1.1) and (1.3) imply that $(g_3, g_1) \notin R$, (1.1) and (1.4) imply that $(g_4, g_1) \notin R$ and (1.1) and (1.5) imply that $(g_5, g_1) \notin R$.

$\square$

Lemma 2. $(g, g_2) \notin R$ *for all* $g \in G' - \{g_2\}$.

Proof. Let ω_2 be the application given in Table 4.6. Note that $M = \{(0, 4)\}$.

c_1 \ c_2	0	4	6
0	20	15	15
4	18	13	10

TABLE 4.6. Application ω_2

c_1 \ c_2	0	4	6
0	$(1, 0)$	$(1, 1)$	$(0, 1)$
4	$(1, 0)$	$(1, 0)$	$(1, 1)$

TABLE 4.7. (p_1, p_2) matrix for ω_1

Table 4.7 is the (p_1, p_2) matrix for ω_2. We consider ω_2 as an application of each of the rules in G'.
g_2 is efficient for ω_2 as (0, 4) $\in M$ is the unique Nash equilibrium for (g_2, ω_2). (2.1)
g_1 is inefficient for ω_2 because, for (g_2, ω_2), 0 is the dominant strategy for the injurer. (2.2)
(4, 6) $\notin M$ the unique Nash equilibrium in (g_3, ω_2) and therefore g_3 is inefficient for ω_2. (2.3)
As there is no configuration of costs at which the victim and the injurer are both negligent, (g_4, ω_2) is the same as (g_3, ω_2). Thus the g_4 is also inefficient for ω_2. (2.4)
(4, 6) is the unique Nash equilibrium for (g_5, ω_2) also and therefore g_5 is inefficient for ω_2. (2.5)

c_1 \ c_2	0	4	6
0	$(\underline{0}, 20)$	$(\underline{0}, \underline{19})$	$(\underline{0}, 21)$
4	$(4, 18)$	$(4, 17)$	$(4, \underline{16})$

TABLE 4.8. Payoff matrix for (g_2, ω_2)

c_1 \ c_2	0	4	6
0	$(\underline{0}, 20)$	$(15, \underline{4})$	$(15, 6)$
4	$(4, 18)$	$(\underline{4}, 17)$	$(\underline{14}, \underline{6})$

TABLE 4.9. Payoff matrix for (g_3, ω_2) and (g_4, ω_2)

c_1 \ c_2	0	4	6
0	$(\underline{0}, 20)$	$(\underline{0}, 19)$	$(15, \underline{6})$
4	$(4, 18)$	$(4, 17)$	$(\underline{4}, \underline{16})$

TABLE 4.10. Payoff matrix for (g_5, ω_2)

(2.1) and (2.2) imply that $(g_1, g_2) \notin R$, (2.1) and (2.3) imply that $(g_3, g_2) \notin R$, (2.1) and (2.4) imply that $(g_4, g_2) \notin R$ and (2.1) and (2.5) imply that $(g_5, g_2) \notin R$. □

Lemma 3. $(g, g_3) \notin R$ *for all* $g \in G' - \{g_3\}$.

Proof. Let ω_3 be the application given in Table 4.11. Note that $M = \{(2, 4)\}$. Table 4.12 is the (p_1, p_2) matrix for ω_3.

We consider ω_3 as an application of each of the rules in G'.
g_3 is efficient for ω_3 as (2, 4) $\in M$ is the unique Nash Equilibrium (g_3, ω_3). (3.1)
g_1 is inefficient for ω_3 because 0 is the dominant strategy for the injurer in (g_1, ω_3). (3.2)
g_2 is inefficient for ω_3 because 0 is the dominant strategy for the victim in (g_2, ω_3). (3.3)

c_1 \ c_2	0	4	8
0	20	15	13
2	17	10	9
4	14	9	6

TABLE 4.11. Application ω_3

c_1 \ c_2	0	4	8
0	$(0,0)$	$(0,1)$	$(0,1)$
2	$(0,0)$	$(1,1)$	$(0,1)$
4	$(1,0)$	$(1,1)$	$(1,1)$

TABLE 4.12. (p_1, p_2) matrix for ω_3

There is no Nash equilibrium in (g_4, ω_3) and therefore g_4 is inefficient for ω_3. (3.4)
There is no Nash equilibrium in (g_5, ω_3) and therefore g_5 is inefficient for ω_3. (3.5)

c_1 \ c_2	0	4	8
0	$(\underline{0}, 20)$	$(15, \underline{4})$	$(13, 8)$
2	$(2, 17)$	$(\underline{12}, \underline{4})$	$(11, 8)$
4	$(4, 14)$	$(13, \underline{4})$	$(\underline{10}, 8)$

TABLE 4.13. Payoff matrix for (g_3, ω_3)

c_1 \ c_2	0	4	8
$\underline{0}$	$(20, \underline{0})$	$(15, 4)$	$(13, 8)$
2	$(19, \underline{0})$	$(\underline{12}, 4)$	$(11, 8)$
4	$(\underline{4}, 14)$	$(13, \underline{4})$	$(\underline{10}, 8)$

TABLE 4.14. Payoff matrix for (g_4, ω_3)

c_1 \ c_2	0	4	8
$\underline{0}$	$(20, \underline{0})$	$(15, 4)$	$(13, 8)$
2	$(19, \underline{0})$	$(\underline{2}, 14)$	$(11, 8)$
4	$(\underline{4}, 14)$	$(4, \underline{13})$	$(\underline{4}, 14)$

TABLE 4.15. Payoff matrix for (g_5, ω_3)

(3.1) and (3.2) imply that $(g_1, g_3) \notin R$, (3.1) and (3.3) imply that $(g_2, g_3) \notin R$, (3.1) and (3.4) imply that $(g_4, g_3) \notin R$ and (3.1) and (3.5) imply that $(g_5, g_3) \notin R$.

$\square$

Lemma 4. *$(g, g_4) \notin R$ for all $g \in G' - \{g_4\}$.*

Proof. Let ω_4 be the application given in Table 4.16. Note that $M = \{(2, 4)\}$. Table 4.17 is the is the (p_1, p_2) matrix for ω_4. We consider ω_4 as an application of each of the rules in G'.

c_1 \ c_2	0	4	8
0	20	15	10
2	17	10	9
4	16	9	6

TABLE 4.16. Application ω_4

c_1 \ c_2	0	4	8
0	$(0,0)$	$(0,0)$	$(1,1)$
2	$(1,0)$	$(1,1)$	$(0,1)$
4	$(1,0)$	$(1,1)$	$(1,1)$

TABLE 4.17. (p_1, p_2) matrix for ω_4

g_4 is efficient for ω_4 as (2, 4) $\in M$ is the unique Nash equilibrium for (g_4, ω_4). (4.1)
g_1 is inefficient for ω_4 because 0 is the dominant strategy for the injurer in (g_1, ω_4). (4.2)

		c_2 0	4	8
	0	$(20, \underline{0})$	$(15, 4)$	$(\underline{10}, 8)$
c_1	2	$(\underline{2}, 17)$	$(\underline{12}, \underline{4})$	$(11, 8)$
	4	$(4, 16)$	$(13, \underline{4})$	$(\underline{10}, 8)$

TABLE 4.18. Payoff matrix for (g_4, ω_4)

		c_2 0	4	8
	0	$(\underline{0}, 20)$	$(\underline{0}, 19)$	$(\underline{10}, \underline{8})$
c_1	2	$(2, 17)$	$(12, \underline{4})$	$(11, 8)$
	4	$(4, 16)$	$(13, \underline{4})$	$(\underline{10}, 8)$

TABLE 4.19. Payoff matrix for (g_3, ω_4)

		c_2 0	4	8
	0	$(20, \underline{0})$	$(15, 4)$	$(\underline{0}, 18)$
c_1	2	$(\underline{2}, 17)$	$(\underline{2}, 14)$	$(11, \underline{8})$
	4	$(4, 16)$	$(4, \underline{13})$	$(4, 14)$

TABLE 4.20. Payoff matrix for (g_5, ω_4)

g_2 is inefficient for ω_4 because 0 is the dominant strategy for the victim in (g_2, ω_4). (4.3)
g_3 is inefficient for ω_4 as (0, 8) $\notin M$ is the unique Nash equilibrium of (g_3, ω_4). (4.4)
g_5 is also inefficient for ω_4 as there is no Nash equilibrium in (g_5, ω_4). (4.5)

(4.1) and (4.2) imply that $(g_1, g_4) \notin R$, (4.1) and (4.3) imply that $(g_2, g_4) \notin R$, (4.1) and (4.4) imply that $(g_3, g_4) \notin R$ and (4.1) and (4.5) imply that $(g_5, g_4) \notin R$.

□

Lemma 5. *$(g, g_5) \notin R$ for all $g \in G' - \{g_5\}$.*

Proof. Let ω_5 be the application given in Table 2.1. Note that $M = \{(4, 2)\}$. Table 2.2 is the (p_1, p_2) matrix for ω_5.

		c_2 0	2	4
	0	$(20, \underline{0})$	$(17, 2)$	$(16, 4)$
c_1	4	$(\underline{4}, 15)$	$(\underline{4}, \underline{12})$	$(\underline{4}, 13)$
	8	$(8, 13)$	$(8, 11)$	$(8, \underline{10})$

TABLE 4.21. Payoff matrix for (g_5, ω_5)

		c_2 0	2	4
	0	$(\underline{0}, 20)$	$(17, \underline{2})$	$(16, 4)$
c_1	4	$(4, 15)$	$(14, \underline{2})$	$(\underline{13}, 4)$
	8	$(8, 13)$	$(\underline{8}, 11)$	$(14, \underline{4})$

TABLE 4.22. Payoff matrix for (g_3, ω_5)

		c_2 0	2	4
	0	$(20, 0)$	$(17, \underline{2})$	$(16, 4)$
c_1	4	$(\underline{4}, 15)$	$(14, \underline{2})$	$(\underline{13}, 4)$
	8	$(8, 13)$	$(\underline{8}, 11)$	$(14, \underline{4})$

TABLE 4.23. Payoff matrix for (g_4, ω_5)

We consider ω_5 as an application of each of the rules in G'.
g_5 is efficient for ω_5 as (4, 2) $\in M$ is the unique Nash equilibrium (g_5, ω_5). (5.1)

g_1 is inefficient for ω_5 because 0 is the dominant strategy for the injurer in (g_1, ω_5). (5.2)
g_2 is inefficient for ω_5 because 0 is the dominant strategy for the victim in (g_2, ω_5). (5.3)
There is no Nash equilibrium in (g_3, ω_5) and therefore g_3 is inefficient for ω_5. (5.4)
There is no Nash equilibrium in (g_4, ω_5) and therefore g_4 is inefficient for ω_5. (5.5)

(5.1) and (5.2) imply that $(g_1, g_5) \notin R$, (5.1) and (5.3) imply that $(g_2, g_5) \notin R$, (5.1) and (5.4) imply that $(g_3, g_5) \notin R$ and (5.1) and (5.5) imply that $(g_4, g_5) \notin R$.

□

Theorem 1. $B(G', R) = \phi$.

Proof. It follows from Lemmas 1-5 that $(\forall g \in G')[(\forall g' \in G' - \{g\})[(g, g') \notin R]$ and therefore $B(G', R) = \phi$. □

Theorem 2. $M(G', R) = G'$.

Proof. Immediate from Lemmas 1-5. □

5. Concluding Remarks

Law and economics as a discipline tries to explain and evaluate laws in terms of economic efficiency. In the context of rules for the assignment of liabilities for accidental losses, while the positive of the law and economics approach has tried to give an efficiency based explanation for adoption of some rules to the exclusion of others, the normative has tried to determine the desirability or otherwise of such rules on the basis of their efficiency properties. In this paper we focus on five of the most widely analyzed rules and demonstrate that if negligence is defined as failure to take some cost justified precaution then it is not possible to make meaningful pairwise comparisons between these rules based on the notion of efficiency to be able to explain why some rules are (ought to be) chosen over the others.

It has to be noted that the results obtained here are restricted to a set of 5 rules only and it would interesting to see if the results hold when we extend our analysis to the set of all possible simple liability rules. Further, it has to be noted that the results of the paper are due to the fact that for any pair of rules $g, g' \in G'$ there exist two applications $\omega, \omega' \in \Omega$ such that while g is efficient for ω and inefficient for ω', g' is efficient for ω' and inefficient for ω. Thus, pairwise comparisons between rules is not possible if the set of permissible applications is Ω. It is not immediately clear if the results hold for a set of permissible applications which is a subset of Ω. Therefore, it appears that the possibility of an efficiency based choice of rules for the assignment of liabilities for a restricted class of applications is worth exploring.

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