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Abstract

Negligence-based liability has been justified on the grounds of its efficiency properties. However, this approach towards liability assignment has been criticized in several recent writings. In a series of articles, causation-based apportionment of liability has been recommended, as an alternative basis for liability assignment. In an interesting paper, Parisi and Fon (2004) have studied various properties of the causation-based liability. In this paper, I review some of their propositions. The main aim of the paper, however, is to investigate the implications of the 'alternative' specification of liability. The paper shows that a combination of negligence-based and causation-based liability makes the diligence strategies dominant choice for the agents.

Keywords: liability rules, negligence-based liability, causation-based liability, comparative causation, economic efficiency

JEL Classification: K 13

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1. Introduction

The literature on liability rules is replete with economic analyses of fault or negligence-based regimes.[1] Negligence-based liability has been rationalized and justified on the grounds of its efficiency properties. However, in a series of articles, this approach towards liability has been severely criticized. Several noted scholars have recommended causation-based apportionment of liability, as an alternative basis for liability assignment.[2] In an interesting contribution, Parisi and Fon (2004) have studied various properties of the causation-based liability assignment. In this paper, I review some of their propositions. The main aim of the paper, however, is to investigate the implications of causation based apportionment of liability.

Under liability rules that use negligence-based approach towards liability assignment, a party usually faces either full liability or no liability at all. For example, under the rule of negligence, an injurer has no liability if he is not negligent. But, his liability jumps from none to full, the moment his care level falls just below the due level of care, even when the victim takes no care at all. Similarly, under the rule of strict liability with the defense of contributory negligence, the victim's liability jumps from none to full, depending on whether his care level is just above the due level or falls just short of that level, irrespective of the care level of the injurer.

While criticizing negligence-based liability, it has been argued that this approach towards liability assignment neglects the causal contributions of the parties involved. Therefore, it does not form a convincing basis for liability assignment, particularly between a non-negligent injurer and a vigilant victim. In addition, the argument goes, it is either inapplicable or unsatisfactory in the cases where multiple causation is involved or where fault is not easy to establish (Strassfeld, 1992; Calabresi and Cooper, 1996; Parisi and

[1] For example, see Polinsky (1989), Landes and Posner (1987), Shavell (1987), Arlen, J (1990), Miceli (1997), Cooter and Ulen (1998), Jain and Singh (2002), etc. For a comprehensive account of the positive theory of torts doctrines see Hylton (2000), and Geistfeld (2001).

[2] See, Calabresi and Cooper (1996).

Fon, 2004).[3] In contrast, under causal apportionment of liability, parties bear accident loss in shares that are proportional to their contribution to the loss. Therefore, causal apportionment of liability is said to be consistent with the principle of equity, which requires loss spreading between parties (Honoré, 1997).[4] Moreover, as various studies have revealed, this approach is being used by some courts in many countries, including France, Germany, Japan and the United States (see, e.g., Yoshihsa (1999), Grimley (2000), Yu (2000), and Parisi and Fon (2004)).

It is in the context of the above-mentioned debates that Parisi and Fon (2004) have studied the desirability or otherwise of the causation-based liability. For several reasons, the paper by Parisi and Fon is an important contribution in tort literature. First, it systematically investigates the effects of causation-based apportionment of liability on care as well as activity levels of the parties involved. Second, it highlights the inappropriateness of negligence-based regimes. Fault-based or negligence-based legal systems do not provide a reasonable criterion for loss sharing, particularly when neither the injurer nor the victim was negligent at the time of accident. Finally, in the context of a formal analysis, it seeks to provide an explanation for the scope of causation-based division of liability. The last exercise is undertaken both for historical as well as contemporary legal regimes.

In order to investigate the efficiency implications of the causation-based liability, Parisi and Fon have introduced and analysed two liability rules. The first liability rule has been defined as the rule of *Pure Comparative Causation*. Under this rule, parties bear accident loss in shares that are proportional to their causal contribution to the loss, regardless of whether at the time accident parties were at fault or not. In their analysis, the authors have shown that since each party bears only a fraction of the loss, there is an incentive to choose less than socially optimal care and more than socially optimal activity levels. That

[3]For criticisms of economic modelling of liability rules on various grounds see Grady (1989), Kahan (1989), Mark (1994), Burrow (1999), and Wright (2002)

[4]Honoré, Tony (1997) has argued that the morality of tort law requires that liability of a party should be proportional to the parties causal contribution. Also see, Calabresi (1965, and 1970).

is, the rule of Pure Comparative Causation induces neither efficient care levels nor efficient activity levels. Next, they discuss the efficiency of what they call the rule of *Comparative Causation Under Negligence*. This rule mixes essential features of traditional negligence-criterion based rules, and of the rule of Pure Comparative Causation. Under this rule, when a party is found solely negligent, the entire loss is borne by that party. Accident loss is shared between the parties in cases wherein both the parties are found negligent, or where both are found non-negligent. In such cases, the loss-sharing takes place as under the rule of Pure Comparative Causation.[5]

Motivation behind introducing the essential feature of negligence-based liability under the rule of comparative causation comes from the mainstream understanding of the need for fault-based liability. Dominant understanding is that "a point of discontinuity in the liability curves faced by the parties must be created to entice both parties to choose optimal care and activity levels."[6] Assuming that the due care levels for the parties are set at the levels that are socially optimal, if this rule could induce both the parties to take the due care and efficient activity levels, it will have the unique virtue of being efficient as well as equitable.

However, Parisi and Fon (2004) have stated the following propositions about incentive effects under the rule of Comparative Causation Under Negligence: (i) In equilibrium, parties are never induced to take more than the due care. (ii) Multiple equilibria in which one or both the parties take less than the due care are possible, i.e., in equilibrium, one or both the parties can be negligent. (iii) In some contexts, choice of due care by both the parties is also a possibility. (iv) Though there is an incentive to mitigate activity levels, each party's activity level will be greater than the corresponding socially optimal level.

[5]Proportional loss sharing also takes place under the rule of comparative negligence, but only when both parties are negligent. For an analysis of this rule see Schwartz, G. (1978), Landes and Posner (1980), Cooter and Ulen (1986), Haddock and Curran (1985), Rubinfeld (1987), Rea (1987), Chung (1993), and Edlin (1994). For a critical review of some of these works see Liao and White (2002), and Bar-Gill and Ben-Shahar (2003).

[6]See, Parisi and Fon (2004, p. 359).

(See Parisi and Fon, 2004, pp. 361-62, 364, Table 1). That is, the authors have claimed that the diligent (non-negligent) strategies are not dominant strategies.

In contrast, we will show that under the rule of Comparative Causation Under Negligence, in an equilibrium, parties cannot both be negligent. That is, in an equilibrium, parties both cannot take less than the due care. Indeed, appealing to an existing claim in the literature, we are able to show that, in any equilibrium, neither the injurer nor the victim can be negligent (that is, each party will take at least the due level of care). In other words, we show that diligent strategies are dominant strategies for both the parties. Therefore, multiple equilibria, if exist, will involve *at least* the due care by both the parties.

The framework of analysis in this paper is less restrictive than the standard framework. Regarding variables and functions, our framework has the virtue of relying on a fewer assumptions about continuity, differentiability, functional forms, etc. In particular, our analysis is equally applicable for both continuous as well as discrete variables.[7] Regarding the causation function, the mainstream focus has been on two forms of causal relationship; namely, the cases of *causal complements* and *causal substitutes*. In this paper, we allow a very general form of the causation function. Section 2 introduces the framework of analysis that outlines the notations and assumptions made in the paper. In Section 3, we investigate the efficiency implications of causal apportionment of liability, when both activity levels and care levels are variable. We conclude in Section 4 with remarks on the analysis in the paper.

2. Framework of Analysis

We consider accidents resulting from the interaction of two parties who are strangers to each other. Both parties are assumed to be rational and risk-neutral. Each party's behaviour potentially contributes to causing an accident. However, when an accident takes place, the entire loss falls on one party to be called the victim; the other party will

[7]Feldman and Frost (1998) have argued that the discrete and sometimes dichotomous care is the reality of many accident settings.

be called the injurer. Following Parisi and Fon (2004), parties' choice of activity levels as well as care levels affect the causation of an accident. An accident is less likely to occur if a party decreases its activity level or increases its precaution, and *vice-versa*. In other words, a party's contribution to the causation of an accident increases, if it increases its activity level or decreases its care level. We refer to the parties' individual contributions to causation of an accident as causal inputs. Therefore, a party's causal input will increase with the increase in its activity level, and decrease with the increase in its care level. Causation of an accident depends on the causal inputs of the parties involved. The elements contributing to the overall social cost of accident, are the cost of harm occasioned by an accident, the cost of care, and the cost of reducing the parties' activity levels.

Following the notation in Parisi and Fon (2004), we denote by:[8]

x care level for the injurer,

y care level for the victim,

z activity level for the injurer,

u activity level for the victim,

$X = \{x \mid x \text{ is some feasible level of care for the injurer }\}$,

$Y = \{y \mid y \text{ is some feasible level of care for the victim}\}$,

$Z = \{z \mid z \text{ is some feasible level of activity for the injurer }\}$,

$U = \{u \mid u \text{ is some feasible level of activity for the victim}\}$,

w the benefit function for the injurer,

b the benefit function for the victim,

D loss *per unit* of activity, $D \geq 0$,

c^I the causal input of the injurer,

c^V the causal input of the victim,

C the total causation function,

s the injurer's share in accident loss,

t the victim's share in accident loss, such that $t = 1 - s$.

[8]These are conventional notation (see, e.g. Miceli (1997)).

We assume:

(A1): w is a function of z and x; $w = w(z, x)$. Benefits to the injurer increase with his activity level up to a point, i.e., w initially increases with z but ultimately decreases. w reaches a maximum at $z_p(x)$, for given $x \in X$. Increasing care is costly to the injurer, hence w is a decreasing function of x, for all $z \in Z$. Likewise,

(A2): b is a function of u and y; b=$b(u, y)$. b initially increases with the victim's activity level, u, but ultimately decreases. b reaches a maximum at $u_p(y)$, for given $y \in Y$. b is a decreasing function of y, for all $u \in U$.

(A3): D is a function of x and y; $D = D(x, y)$. Clearly, $D \geq 0$. D 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 accident loss. As D is loss per unit of activity, for given z and u total loss will be $zuD(x, y)$.

(A4): c^I is a function of z and x; $c^I = c^I(z, x)$. c^I increases with z and decreases with x.

(A5): c^V is a function of u and y; $c^V = c^V(u, y)$. c^V increases with u and decreases with y.

(A4) and (A5) imply that by increasing its activity level or reducing its care level, a party increases its contribution to the causation of an accident, i.e., make the accident more likely, and *vice-versa*.

(A6): C, the total causation function, is an increasing function of both c^I and c^V; $C = C(c^I, c^V)$. Therefore, C is an increasing function of both z and u, and a decreasing function of x and y.

(A7): Social benefits from activity of a party are fully internalized by that party.

(A8): Social goal is to maximize the net social benefits from the activities of the parties; the net social benefits are equal to the total social benefits minus the total social costs of accident.

(A9): Benefit, cost, and causation functions are such that there is a unique tuple of z, u, x, and y, denoted by $((z^*, x^*), (u^*, y^*))$ that is socially optimal. In other words, net social benefits are maximized, if the injurer chooses z^* as his activity level and x^* as his care level, and the victim opts for u^* as his activity level and y^* as his care level. Therefore, z^* and x^*, respectively, denote the activity level and the care level for the injurer

that are optimal from social point of view; and u^* and y^*, respectively, are the activity level and the care level of the victim that are optimal from social point of view.

(A10): The legal due care standard (i.e., the negligence standard) for the injurer, wherever applicable (say under the rule of negligence), is set at x^*. Similarly, the legal negligence standard of care for the victim, wherever applicable (say under the rule of strict liability with defense) is set at y^*.

(A11): $c^I(.),\ c^V(.),\ C(.)\ D(.)$ are all positive.

It should be noted that assumptions (A1)-(A11) are standard assumptions.[9] However, on several counts, our framework is less restrictive than the standard framework. For one, regarding the variables and functional forms, in mainstream analyses it is generally taken that the care levels as well as the activity levels are continuous variables, and various functions (e.g., the benefit function, the expected loss functions, and so on) are differentiable. Our modelling, in contrast, does not impose any such condition, and is more general in that it is equally applicable for continuous as well as discrete variables. For another, regarding the causation function, Parisi and Fon (2004) have considered only two forms of $C(c^I(z,x), c^V(u,y))$, namely when $C(c^I(z,x), c^V(u,y)) = c^I(z,x).\ c^V(u,y)$, and when $C(c^I(z,x), c^V(u,y)) = c^I(z,x) + c^V(u,y)$. The first one is called the case of *causal complements* and the second one is called the case of *causal substitutes*. However, in the literature it has been argued that causal inputs of the parties can affect the causation of an accident in several different ways. In some cases causal inputs affect causation of an accident additively, while in other cases they can do so multiplicatively, or some times even a mix thereof (Parisi and Fon 2004; Landes and Posner, 1983).[10] In this paper, we allow a very general form of the causation function. In fact, the only restriction imposed is the assumption (A6).

The social objective is to maximize the net social benefits from the activities. There-

[9] e.g., see Miceli (1997), and Parisi and Fon (2004).

[10] Also see Rizzo and Arnold (1980 and 1986), Kaye and Aickin (1984), Wright (1985), and Kruskal (1986).

fore, the social optimization problem is given by:[11]

$$\max_{z,x,u,y} \quad w(z,x) + b(u,y) - C(c^I(z,x), c^V(u,y))zuD(x,y).$$

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 and activity levels. Depending on the care and activity levels of the victim and the injurer, a liability rule uniquely determines the proportions in which they are to bear the accident loss. That is, given the choice of z and x by the injurer, and u and y by the victim, a liability rule determines the injurer's share, $s(z,x,u,y)$, and the victim's share, $t(z,x,u,y)$, of accident loss.[12] For a party, payoff from engaging in an activity depends on its activity level, its care level, and the proportion of accident loss it will be required to bear under the liability rule in force. Therefore, choice of care and activity level by a party will depend on the liability rule in force, as well as the care and activity levels of the other party. For any given pair (u,y) opted by the victim and depending on the rule, the injurer being rational and risk-neutral will choose a pair (z,x) that maximizes his expected payoff. In other words, given $(u,y) \in U \times Y$ opted by the victim, problem facing the injurer is

$$\max_{z,x} \quad w(z,x) - s(z,x,u,y)C(c^I(z,x), c^V(u,y))zuD(x,y).$$

Likewise, given $(z,x) \in Z \times X$ opted by the injurer, problem facing the victim is

$$\max_{u,y} \quad b(u,y) - t(z,x,u,y)C(c^I(z,x), c^V(u,y))zuD(x,y),$$

where $s(z,x,u,y)$ and $t(z,x,u,y)$ are determined by the relevant liability rule, but are such that $s + t = 1$.

[11] This formulation of social optimization problem is as in Parisi and Fon (2004).

[12] It should be noted that in the standard literature, these share depend on only the care levels of the parties involved. Since I want to re-examine the results in Parisi and Fon (2004), share are assumed to depend on care as well as activity levels of the parties. Later, however, we show that results in this paper hold, even when these share are determined only on the basis of the care levels of the parties.

A liability rule is said to be efficient iff it motivates both the parties to take socially efficient care and activity levels. Formally, a liability rule is efficient iff $((z^*, x^*), (u^*, y^*))$ is a unique Nash equilibrium (N.E.) under the rule.[13]

3. Comparative Causation

In this section, we consider the two rules introduced and analyzed in Parisi and Fon (2004); the rule of Pure Comparative Causation, and the rule of Comparative Causation Under Negligence.

Pure Comparative Causation

Under the rule of Pure Comparative Causation, as defined by Parisi and Fon, for given (z, x) and (u, y) opted by the injurer and the victim, respectively, the injurer's share in accident loss is equal to $\frac{c^I(z,x)}{c^I(z,x)+c^V(u,y)}$. Therefore, the victim's share is given by $\frac{c^V(u,y)}{c^I(z,x)+c^V(u,y)}$. Formally, the rule of Pure Comparative Causation, can be defined as follows:

For $(z, x) \in Z \times X$ and $(u, y) \in U \times Y$,

$$s(z, x, u, y) = \frac{c^I(z, x)}{c^I(z, x) + c^V(u, y)} \quad \text{and} \quad t(z, x, u, y) = \frac{c^V(u, y)}{c^I(z, x) + c^V(u, y)}.$$

In their analysis, Parisi and Fon have argued that under this rule, the injurer [the victim] will choose some $x < x^*$ [$y < y^*$] as care level and some $z > z^*$ [$u > u^*$] as activity level (see Parisi and Fon, 2004, pp. 355, 357, 364). They have argued that since each party bears only a fraction of the loss, there is an incentive to choose less than socially optimal care and more than socially optimal activity level. In other words, the rule of Pure Comparative Causation induces neither efficient care levels nor efficient activity levels. Next, we consider the rule of Comparative Causation Under Negligence, as proposed by Parisi and Fon.

[13] We consider only pure strategy Nash equilibria. A tuple $((\bar{z}, \bar{x}), (\bar{u}, \bar{y}))$ is said to be a N.E. iff given $(\bar{u}, \bar{y})$ opted by the victim, $(\bar{z}, \bar{x})$ is a best response from the view point of the injurer, and *vice-versa*. The use of the notion of N.E. as prediction for equilibrium outcome is very common in the literature on liability rules.

Under this rule, when a party is found solely negligent, the entire loss is borne by this party. In other words, whenever the injurer is negligent and the victim is not, the victim receives full compensation for the loss. If the victim is negligent and the injurer is not, the victim bears the entire loss. Accident loss is shared between the parties only in cases where parties are either both negligent or when both are non-negligent. In such cases, the loss-sharing is done as under the rule of Pure Comparative Causation. This rule, therefore, captures an essential feature of traditional negligence-criterion based rules; a solely negligent party bears the entire accident loss, and the other (non-negligent) party bears none of it. Yet, the rule allows sharing of accident loss that is consistent with the rule of Pure Comparative Causation, when neither of the parties is unilaterally negligent. Summing up, under this rule, given $(u, y) \in U \times Y$ opted by the victim, the problem faced by the injurer is given by the following:

$$\max_{z,\ x} \begin{cases} w(z,x) \qquad \text{if } \ x \geq x^* \text{ and } y < y^*; \\ w(z,x) - \frac{c^I(z,x)}{c^I(z,x)+c^V(u,y)} C(c^I(z,x), c^V(u,y)) zuD(x,y) \\ \qquad \text{if } \ x \geq x^* \text{ and } y \geq y^*, \ \text{ or } \ x < x^* \text{ and } y < y^*; \\ w(z,x) - C(c^I(z,x), c^V(u,y)) zuD(x,y) \qquad \text{if } \ x < x^* \text{ and } y \geq y^*. \end{cases}$$

Similarly, under the rule, the problem facing the victim is:

$$\max_{u,\ y} \begin{cases} b(u,y) \qquad \text{if } \ x < x^* \text{ and } y \geq y^*; \\ b(u,y) - \frac{c^V(u,y)}{c^I(z,x)+c^V(u,y)} C(c^I(z,x), c^V(u,y)) zuD(x,y) \\ \qquad \text{if } \ x \geq x^* \quad \text{and } y \geq y^*, \text{or } \ x < x^* \quad \text{and } y < y^*; \\ b(u,y) - C(c^I(z,x), c^V(u,y)) zuD(x,y) \qquad \text{if } \ x \geq x^* \quad \text{and } y < y^*. \end{cases}$$

Note that under the rule of Comparative Causation Under Negligence if both the parties take efficient care, then they share accident loss according to the requirement of pure comparative causation. Therefore, if this rule could induce both the parties to take efficient care and activity levels, it will have the unique virtue of being efficient as well as

equitable.

However, regarding the behaviour of the parties under the rule of Comparative Causation Under Negligence, Parisi and Fon (2004) have stated the following propositions: (1) In equilibrium, parties are never induced to take more than the due care; (2) Multiple equilibria in which one or both the parties take less than the due care are possible; (3) In some contexts, the choice of the due care by both the parties is also a possibility; (4) Though there is an incentive to mitigate activity levels, each party's activity level will be greater than the corresponding socially optimal level. (See Parisi and Fon, 2004, pp. 361-62, 364, Table 1). That is, the authors have concluded that for the parties the diligent (non-negligent) strategies are not dominant strategies. Therefore, in an equilibrium, the level of care taken the injurer, x, and the level of care taken the victim, y, will be such that $x \leq x^*$ and $y \leq y^*$.[14] In particular, in an equilibrium, any of the following can hold: (i) $x < x^*$ and $y < y^*$, (ii) $x < x^*$ and $y = y^*$, (iii) $x = x^*$ and $y < y^*$, and (iv) $x = x^*$ and $y = y^*$.

In contrast, we will show that under the rule of Comparative Causation Under Negligence, the claims (i)-(iii) cannot be true. We show that in any equilibrium, $x < x^*$ and $y < y^*$, i.e., the claim (i) above, can never hold. Appealing to an already existing claim in the literature, we show that claims (ii) and (iii) cannot hold. Indeed, care levels x and y can be part of an equilibrium, only if $x \geq x^*$ and $y \geq y^*$. In other words, we show that diligent strategies are dominant strategies for both the parties.

First of all, note that an essential feature of negligence-criterion based rules is captured by the following property:

Property (P1): A non-negligent party has no liability, if the other party is negligent.

In the following, we investigate the behavior of parties under rules that satisfy property

[14] See Parisi and Fon, 2004, pp. 362, 364, Table 1.

(P1). To start with, we show that under a liability rule that satisfies property (P1), the parties cannot both be negligent in a N.E., no matter how the liability is assigned when both parties are negligent.[15] In other words, in any Nash equilibrium, $x < x^*$ and $y < y^*$ can never hold.

To see why, take any $((z, x), (u, y))$ such that $x < x^*$ and $y < y^*$. Suppose, the injurer opts for (z, x) and the victim for (u, y). At $((z, x), (u, y))$, let $s(z, x, u, y)$ be the injurer's share of loss, where $0 \leq s(z, x, u, y) \leq 1$. So, $t(z, x, u, y) = 1 - s(z, x, u, y)$. As a result, suppressing the arguments of s and t, at $((z, x), (u, y))$, the payoff of the victim is

$$b(u, y) - t\ C(c^I(z, x), c^V(u, y))zuD(x, y).$$

On the other hand, given that (z, x) is opted by the injurer, if the victim instead opts for (u^*, y^*), then the injurer will be solely negligent. In that case, in view of (P1), the injurer's liability is full and that of the victim is none. Therefore, given that (z, x) is opted by the injurer, if the victim opts for (u^*, y^*), his payoff will be $b(u^*, y^*)$. Similarly, at $((z, x), (u, y))$ the payoff of the injurer are $w(z, x) - s\ C(c^I(z, x), c^V(u, y))zuD(x, y)$. But, given that (u, y) is opted by the victim, should the injurer opt instead for (z^*, x^*), his payoff will be $w(z^*, x^*)$. At $((z, x), (u, y))$ if $w(z^*, x^*) > w(z, x) - sC(c^I(z, x), c^V(u, y))zuD(x, y)$, a unilateral deviation by the injurer to (z^*, x^*) will be strictly profitable. In that case, $((z, x), (u, y))$ cannot be a N.E. Thus, if $((z, x), (u, y))$ is a N.E., then a unilateral deviation by the injurer to (z^*, x^*) cannot be strictly profitable. Therefore, assume that

$$w(z, x) - sC(c^I(z, x), c^V(u, y))zuD(x, y) \geq w(z^*, x^*) \tag{1}$$

Since $((z, x), (u, y)) \neq ((z^*, x^*), (u^*, y^*))$, by assumption, we know that

$$\begin{aligned} w(z^*, x^*) + b(u^*, y^*) - C(c^I(z^*, x^*), c^V(u^*, y^*))z^*u^*D(x^*, y^*) > \\ w(z, x) + b(u, y) - C(c^I(z, x), c^V(u, y))zuD(x, y). \end{aligned} \tag{2}$$

Subtracting $w(z^*, x^*)$ from the LHS and $w(z, x) - s(c^I(z, x), c^V(u, y))zuD(x, y)$ from the RHS of (2), in view of (1), we get

[15] It should be noted that an equilibrium in Parisi and Fon (2004) will be a N.E.

$$b(u^*, y^*) - C(c^I(z^*, x^*), c^V(u^*, y^*))z^*u^*D(x^*, y^*) > b(u, y) - tC(c^I(z, x), c^V(u, y))zuD(x, y). \quad (3)$$

Now, since $C(c^I(z^*, x^*), c^V(u^*, y^*))z^*u^*D(x^*, y^*) \geq 0$, from (3) we have $b(u^*, y^*) > b(u, y) - tC(c^I(z, x), c^V(u, y))zuD(x, y)$. That is, given $(z, x < x^*)$ opted by the injurer, payoff of the victim is strictly greater if he chooses (u^*, y^*) rather than (u, y), i.e., the victim will be better off opting (u^*, y^*) rather than (u, y). Again, $((z, x), (u, y))$ cannot be a N.E.

In other words, under a liability rule satisfying (P1), from any $((z, x), (u, y))$ such that $x < x^*$ & $y < y^*$, either the injurer will find unilaterally deviation to (z^*, x^*) profitable, or the victim will find unilaterally deviation to (u^*, y^*) profitable. Hence, we have the following result.

Proposition 1 *If a liability rule satisfies property (P1), then*

$(\forall((z, x), (u, y)))$ $[x < x^*$ & $y < y^* \Rightarrow ((z, x), (u, y))$ *cannot be a N.E.*$]$.

Note that how a liability rule assign liability when parties are both negligent has no implications for the validity of Proposition 1. Moreover most of the negligence criterion based rules discussed in the literature (e.g., the rule of negligence, the rule of negligence with the defense of contributory negligence, the rule of strict liability with the defense of contributory negligence) satisfy property (P1). Therefore, under all these rules both the parties cannot be negligent in an equilibrium. In particular, the rule of Comparative Causation Under Negligence, as defined in Parisi and Fon (2004), satisfies property (P1). Hence, we can make the following claim about the rule.

Proposition 2 *Under the rule of Comparative Causation Under Negligence,*

$(\forall((z, x), (u, y)))$ $[x < x^*$ & $y < y^* \Rightarrow ((z, x), (u, y))$ *cannot be a N.E.* $]$.

Remark 1: Suppose a liability rule satisfies property (P1). When $x \geq x^*$ and $y < y^*$, the victim is solely negligent. In such an event, due to property (P1), the injurer has no liability. So, for given z his payoff is $w(z, x)$. Note that $w(z, x)$ increases with z and deceases with x. Therefore, regardless of the z opted by him whenever $x > x^*$, the injurer can increase his payoff simply by reducing x until he reaches at x^*. This means that the injurer will be better off opting x^* rather than any $x > x^*$. As a result, any

tuple $((z,x),(u,y))$, such that $x > x^*$ & $y < y^*$, cannot be a N.E. In fact, when the rule satisfies property (P1), in the region of $x \geq x^*$ and $y < y^*$, $w(z,x)$ is uniquely maximized at (x^*, z_p^*), where $z_p^* = z_p(x^*)$. Therefore, under the rule, when $x \geq x^*$ and $y < y^*$, a tuple $((z,x),(u,y))$ can be a N.E. only if $(z,x) = (z_p^*, x^*)$. Similarly, under a rule satisfying property (P1), when $x < x^*$ and $y \geq y^*$, a tuple $((z,x),(u,y))$ can be a N.E. only if $(u,y) = (u_p^*, y^*)$, where $u_p^* = u_p(y^*)$.

It will be interesting to compare the incentive effects of the rule of Comparative Causation Under Negligence with those of the standard rules discussed in the literature. Regarding the standard negligence-criterion based rules the following claim exists in the literature (e.g., see Miceli, 1997 p. 29, Dari Mattiacci (2002), Parisi and Fon, 2004 Table 1, p. 364).[16]

Claim (C1): Both the rule of negligence as well as the rule of strict liability with the defense of contributory negligence induce efficient care levels from both the parties. That is, the claim is that under these rules, there exist an equilibrium in which the injurer and the victim opt for x^* and y^*, respectively.

Remark 2: It should be noted that the Claim (C1) is only regarding the care levels; activity levels are not claimed to be efficient. Moreover, equilibrium under the rule of negligence will be different from that under the rule of the strict liability with the defense of contributory negligence. The claim, however, implies that under both the rules, when $(x,y) \neq (x^*, y^*)$, a tuple $((z,x),(u,y))$ cannot be a N.E.

Equipped with the claim (C1), Proposition 3 shows that under the rule of Comparative Causation Under Negligence, in equilibrium, neither of the parties can be negligent. In an equilibrium, both parties will take at least the due level of care. Formally, care levels x and y can be part of a N.E., only if $x \geq x^*$ and $y \geq y^*$.

[16] Also see Landes and Posner (1987) and Shavell (1987) as cited in Parisi and Fon (2004).

Proposition 3 *Given that* $(C1)$ *holds, under the rule of Comparative Causation Under Negligence,* $((z,x),(u,y))$ *is a N.E.* $\Rightarrow x \geq x^*$ & $y \geq y^*$.

Proof: In view of Proposition 1, a tuple $((z,x),(u,y))$ such that $x < x^*$ and $y < y^*$, cannot be a N.E. Thus, to prove the claim, it will be sufficient if we can show that under the rule, a tuple $((z,x),(u,y))$ such that $x \geq x^*$ and $y < y^*$, or $x < x^*$ and $y \geq y^*$ cannot be a N.E.

Consider a tuple $((z,x),(u,y))$ such that $x \geq x^*$ and $y < y^*$. Since the rule in question satisfies (P1), in view of Remark 1, when $x \geq x^*$ and $y < y^*$, a tuple $((z,x),(u,y))$ can be a N.E. only if $(z,x) = (z_p^*, x^*)$, where $z_p^* = z_p(x^*)$. Therefore, to show that a tuple $((z,x),(u,y))$ such that $x \geq x^*$ and $y < y^*$ cannot be a N.E., we just have show that tuple $((z_p^*, x^*),(u,y))$, where $y < y^*$, cannot be a N.E. Similarly, to show that a tuple $((z,x),(u,y))$, such that $x < x^*$ and $y \geq y^*$, cannot be a N.E., we just have show that tuple $((z,x),(u_p^*, y^*))$, where $x < x^*$ and $u_p^* = u_p(y^*)$, cannot be a N.E.

First, we consider whether a tuple $((z_p^*, x^*),(u,y))$, such that $y < y^*$, is a N.E. or not. Suppose, (z_p^*, x^*) is opted by the injurer. Notice that under the rule of Comparative Causation Under Negligence, when (z_p^*, x^*) is opted by the injurer, if the victim chooses some (u, y^*) then both the parties are non-negligent. So, the victim's payoff will be $b(u,y^*) - \frac{c^V(u,y^*)}{c^I(z_p^*,x^*)+c^V(u,y^*)} C(c^I(z_p^*,x^*), c^V(u,y^*)) z_p^* u D(x^*, y^*)$. And, if he instead chooses some (u,y), such that $y < y^*$, he will be solely negligent. In that case, under the rule he will be required to bear the entire accident loss. Therefore, when (z_p^*, x^*) is opted by the injurer, if the victim chooses some (u,y) such that $y < y^*$, his payoff will be $b(u,y) - C(c^I(z_p^*,x^*), c^V(u,y)) z_p^* u D(x^*, y)$. In the following, we show that given (z_p^*, x^*) opted by the injurer, the victim will be better off opting y^* along with a suitable $u \in U$, rather than any $y < y^*$.

We are given that Claim (C1) holds, i.e., under the rule of negligence, in equilibrium, the injurer opts for x^* and the victim opts for y^*. When $x = x^*$, the injurer is non-negligent. Therefore, under the rule of negligence he has no liability, i.e., for given z his payoff is $w(z, x^*)$, which is uniquely maximized at $z = z_p^*$, where $z_p^* = z_p(x^*)$. In other words, the claim implies that under the rule of negligence, the injurer will opt for (z_p^*, x^*).

On the other hand, when $x = x^*$, the victim bears the entire loss. Therefore, if he opts for some (u, y) his payoff is $b(u, y) - C(c^I(z_p^*, x^*), c^V(u, y))z_p^* uD(x^*, y)$. In view of Claim (C1), along with y^*, the victim will choose a $u \in U$, say $\bar{u}$, that maximizes his payoff.[17] In other words, given that the injurer has opted for (z_p^*, x^*), under the rule of negligence $(\bar{u}, y^*)$ is a best choice for the victim. Formally put, the claim implies that there exists $\bar{u} \in U$ such that between $(\bar{u}, y^*)$, on the one hand, and any $(u, y) \in U \times Y$, on the other, the following relationship exists:

$$b(u, y) - C(c^I(z_p^*, x^*), c^V(u, y))z_p^* uD(x^*, y) \leq \\ \mathrm{b}(\bar{u}, y^*) - C(c^I(z_p^*, x^*), c^V(\bar{u}, y^*))z_p^* \bar{u}D(x^*, y^*). \tag{4}$$

But, since $\frac{c^V(\bar{u}, y^*)}{c^I(z_p^*, x^*) + c^V(\bar{u}, y^*)} < 1$ and $C(c^I(z_p^*, x^*), c^V(\bar{u}, y^*))z_p^* \bar{u}D(x^*, y^*) > 0$, we get

$$b(\bar{u}, y^*) - C(c^I(z_p^*, x^*), c^V(\bar{u}, y^*))z_p^* \bar{u}D(x^*, y^*) < \\ b(\bar{u}, y^*) - \frac{c^V(\bar{u}, y^*)}{c^I(z_p^*, x^*) + c^V(\bar{u}, y^*)} C(c^I(z_p^*, x^*), c^V(\bar{u}, y^*))z_p^* \bar{u}D(x^*, y^*). \tag{5}$$

Now, (4)&(5) $\Rightarrow$ for all $(u, y) \in U \times Y$, we get $b(u, y) - C(c^I(z_p^*, x^*), c^V(u, y))z_p^* uD(x^*, y) < b(\bar{u}, y^*) - \frac{c^V(\bar{u}, y^*)}{c^I(z_p^*, x^*) + c^V(\bar{u}, y^*)} C(c^I(z_p^*, x^*), c^V(\bar{u}, y^*))z_p^* \bar{u}D(x^*, y^*)$. In particular, for all $(u, y) \in U \times Y$, such that $y < y^*$, we have

$$b(u, y) - C(c^I(z_p^*, x^*), c^V(u, y))z_p^* uD(x^*, y) < \\ \mathrm{b}(\bar{u}, y^*) - \frac{c^V(\bar{u}, y^*)}{c^I(z_p^*, x^*) + c^V(\bar{u}, y^*)} C(c^I(z_p^*, x^*), c^V(\bar{u}, y^*))z_p^* \bar{u}D(x^*, y^*). \tag{6}$$

In other words, for all $(u, y < y^*) \in U \times Y$, there exists $(\bar{u}, y^*) \in U \times Y$ such that (6) holds. Note that under the rule of Comparative Causation Under Negligence if we assume that the injurer has opted for (z_p^*, x^*), then the left hand side of (6) denotes the payoff of the victim when he opts for some $(u, y) \in U \times Y$, such that $y < y^*$. The right hand side of (6) denotes the payoff of the victim, when he instead opts for $(\bar{u}, y^*)$. But, (6) implies that given that (z_p^*, x^*) is opted by the injurer, the victim is better off opting $(\bar{u}, y^*)$ rather than any (u, y) such that $y < y^*$. Thus, under the rule of Comparative Causation Under Negligence, any $((z_p^*, x^*), (u, y))$, such that $y < y^*$, cannot be a N.E.

[17] We assume that such u exists. In that case, it should be noted that Claim 1 implies that under the rule of negligence, $((z_p^*, x^*), (\bar{u}, y^*))$ is a N.E.

Similarly, appealing to the claim that under the rule of strict liability with the defense of contributory negligence, the injurer opts for x^* and the victim opts for y^*, and arguing as above, we can show the following: Under the rule of Comparative Causation Under Negligence, given that (u_p^*, y^*) is opted by the victim, the injurer will not choose any (z, x) such that $x < x^*$. That is, a tuple $((z, x), (u_p^*, y^*))$, such that $x < x^*$, cannot be a N.E.

Thus, under the rule, any $((z, x), (u, y))$ such that $x < x^*$ & $y \geq y^*$, or $x \geq x^*$ & $y < y^*$ cannot be a N.E. •

Remark 3: It should be noted that for Propositions 1 and 2 to hold, the sufficient condition is the Property (P1). The condition concerns liability assignment when one party is negligent and the other is not, regardless of the activity levels of the parties. Therefore, for these claims to hold, liability assignment need not be based on the activity levels of the parties. For Proposition 3, the sufficient condition is provided by the Property (P1) along with Claim (C1). Again, it can be checked that liability need not depend on the activity levels of the parties.[18]

4. Concluding Remarks

Parisi and Fon (2004) is an important contribution to the tort literature in that it is first systematic study of the liability assignment based on comparative causation. However, we have shown that some of the propositions in the study need re-examination. We have shown that under the rule of Comparative Causation Under Negligence, in an equilibrium, choice of less than the due care by both parties is not possible. In fact, in any equilibrium, neither of the parties can be negligent. It immediately follows from out results that multiple equilibria, if they exist, will involve *at least* the due care by both the parties. Therefore, the search for the existence of an equilibrium should focus on the cases which involve the due or more than the due care by both the parties; not on the cases wherein one or both the parties are negligent, as Parisi and Fon suggest.

[18]Of course, to the extant that liability does not depend on the activity levels of the parties, liability assignment will be different from what is required under the rules of comparative causation.

Note that under the rule of Comparative Causation Under Negligence, when both parties take at least the due care, a party bears only a fraction of the total accident loss. Now, when both parties are non-negligent, suppose a party increases its activity level beyond the socially optimal level for this party. In such a scenario, this party will bear only a fraction of the resulting increase in the social costs. On the other hand, all the benefits from increased activity level will accrue to the party. As a result, excess activity levels seem to be a possibility. Regarding the care levels, however, the opposite in true; a party bears full cost of the care taken by it, while sharing the benefits of care with the other party. This means that there are incentives for parties to take less care. But, at the same time, under the rule the following is also true. When a party increases its care level beyond the due level, the loss that will be shared as well as the party's share in the loss come down. This means there are some incentives for the parties to take excess care. Moreover, it can be shown that productivity of care increases with the increase in the activity levels of the parties. Therefore, in the non-negligence region parties face various prospects with conflicting implications. In such a scenario, whether there will be a unique equilibrium, no equilibrium, or multi-equilibria, is an important question that requires further research.

Finally, it should be noted that while proving Propositions 1-3, we have not restricted the functional form of the causation function. Therefore, our results hold in a more general context of the causal relationship. The Propositions are, of course, valid for the cases of *causal substitutes* and *causal complements*, which are two special forms of the causation function.

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