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Characterization of Efficient Product Liability Rules: When Consumers are Imperfectly Informed

Ram Singh
Delhi School of Economics

Email : ramsingh@cdedse.ernet.in
ramsingh_dse@yahoo.co.in

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Centre for Development Economics
Department of Economics, Delhi School of Economics

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Abstract

Product liability has acquired immense importance in the last 50 years. Various studies show that when consumers are imperfectly informed about the product related risk, the market mechanism will not lead to an efficient outcome and tort liability is required for economic efficiency. Many product-caused injuries are governed by liability rules. In this paper efficiency properties of the *entire* class of product liability rules when consumers are imperfectly informed about the product related risk are studied in a *unified* framework. A necessary and sufficient condition for efficiency of a product liability rule is derived. The analysis is carried out in a somewhat *more general* framework.

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Keywords: Product Risk, total accident costs, efficient product liability rules, social benefits, negligent consumer's liability, imperfect information, Nash equilibrium.

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1. Introduction

Product liability has acquired immense importance in the last 50 years. Many product-caused injuries are governed by liability rules (Geistfeld, 2000; Harvey and Parry, 2000). Product liability rules are said to have important implications for both producers and consumers.[1] Formal economic analysis of product liability rules has been undertaken in Mckean (1970 a, b), Oi (1973), Goldberg (1976), Hamada (1976), Spence (1975, 1977), Polinsky (1980), Landes and Posner (1987, ch. 10), Shavell (1980, 87 ch 3), Spulberg (1989), Boyd (1994), Miceli (1997, ch 2), Endres and Lüdeke (1998), and Geistfeld (2000), among others. These studies have shown that irrespective of the product liability rule in force, when product market is competitive and consumers have perfect information about the risk associated with the product, market relationship between consumers and firms will ensure efficient outcome. Both, consumers and firms will take efficient care to prevent accident, and the quantity produced and consumed will also be optimum. The price of the product will adjust to reflect the equilibrium residual risk and the liability rule. However, when consumers are imperfectly informed about the product related risk, market mechanism will not lead to efficient outcome and Tort liability is required for economic efficiency (Spence (1977), Polinsky and Rogerson (1983), Schwartz and Wilde (1985), Shavell (1987,

[1] It is also argued that these days efficiency considerations strongly influence the formulation of product liability laws. See Restatement Third of Torts: Products Liability, American Law Institute (1997), and Geistfeld (2000).

p. 52-53), and Endres and Lüdeke (1998)).[2] One of the objectives of this paper is to provide an efficiency characterization of the *entire* class of product liability rules when the consumers' knowledge of the risk is imperfect.

Consumers may be imperfectly informed about the risk associated with the product use because they can not observe the level of care taken by the producer firm. They may also be imperfectly informed about the risk even if they knew the care taken by the firm, because they might not know the value of the associated risk (expected loss) for the given level of care. Existing formal analyses on the subject have largely captured only the first type of imperfect information on the part of consumers.[3] In Polinsky (1980), Shavell (1980, 87, ch 3), and Geistfeld (2000) when the second type of imperfect information is taken into account, the analysis

[2] Alternatively, it has been argued that the firms might signal the information regarding the product related risk to consumers through price and warrantees etc., therefore, imperfect information on the part of consumers might not be a problem (for reference see Bagwell and Riordan, 1991). Many studies, however, have argued that because of inadequate incentives (for informing the consumers about the risk) on the part of firms and limited capacity of the consumers to process the information available, unregulated market transactions will not result in optimum care by the firms and optimum consumption by the consumers, when the latter are imperfectly informed about the risk. Also, under certain conditions consumers might not prefer better information about the quality of the product (Schlee, 1996). For arguments and discussion, besides above mentioned studies see Beales, Craswell and Salop (1981), Priest (1991), Grossman (1981), Landes and Posner (1987, ch. 10), Viscusi (1991), Burrows (1992), Caves and Green (1996), Schwartz (1988), Arlen (2000), and Geistfeld (2000), etc. Leaving aside the issue of relative merits of tort liability for product related accidents, the focus of this paper will exclusively be on the efficiency of the product liability rules.

[3] See Landes and Posner (1985, 87, ch 10), Shavell (1980, 87 ch 3), Miceli (1997, ch 2), Boyd (1994), and Endres and Lüdeke (1998). In the early analyses of product liability rules such as in Mckean (1970a, b), Oi (1973), the consumers were assumed to be fully informed about the product related risk.

is restricted *only* to the rule of negligence and the rule of strict liability, and to the accident contexts wherein only the firms can take care. In this paper we study the efficiency property of *all* the product liability rules when the consumers' knowledge of the product related risk is limited by both, the above mentioned, types of imperfection, and both the consumer and the firm can take care to reduce the expected loss of accident.

A product liability rule determines the proportions in which the consumer and the firm will bear the loss that might result from a product-related accident, as a function of their levels of (non)negligence. When consumers cannot observe the care taken by the firms but know the risk associated with different levels of care, Miceli (1997, ch 2, pp. 29-33) shows that negligence criterion based liability rules such as the rules of negligence, negligence with the defense of contributory negligence, comparative negligence, and strict liability with the defense of contributory negligence are efficient in that these rules induce efficient care and production/consumption of the product under consideration. For the accident contexts wherein care only by the firms can reduce the expected accident loss, Polinsky (1980), Shavell (1980, 87, ch 3, pp. 67-68) and Geistfeld (2000) have shown that when the consumers do not observe the care taken by the firms and also misperceive the expected accident loss, the rule of strict liability is efficient. The rule of negligence, on the contrary, is not efficient as, under this rule, the consumers will consume too much [too little] of the product when they under-estimate [over-estimate] the risk.

This paper provides a complete characterization of efficient product liability rules. The analysis is undertaken in a partial-equilibrium framework. Though very similar to the standard framework of economic analysis of product liability rules, the framework in this paper is different on at least the following three counts. First, it is a *unified* framework. Second, it is somewhat *more general* than the standard framework. No assumptions are imposed on the costs of care and expected loss functions, apart from assuming the existence of a pair of levels of care which minimizes the total costs of product accident. In particular, unlike the standard framework, we allow the possibility of the existence of more than one configuration of care levels at which total accident costs are minimized. Third, it provides a formal analysis of the entire class of product liability rules when both consumers and firms can reduce the expected accident loss, and the consumers' knowledge of risk is limited by both of the above mentioned imperfections.[4]

The main result of the paper shows that when consumers do not observe the level of care taken by the producer firm and also misperceive the value of the expected accident loss for given level of care, a necessary and sufficient condition for a product liability rule to be efficient is to satisfy the condition of *'negligent consumer's liability'*. The condition of negligent consumer's liability requires the rule to be such that

[4] In the literature, formal analysis is restricted only to the rules of negligence and strict liability, and to the accident cases wherein only the firms can take care.

(i) whenever the consumer is nonnegligent, i.e., he is taking at least the due care, the entire loss in the event of accident is borne by the firm irrespective of the level of care taken by the firm, and (ii) when the consumer is negligent and the firm is not, the entire loss in the event of accident is borne by the consumer. Specifically, our results show that when consumers are imperfectly informed about the expected accident loss, the rule of strict liability with the defense of contributory negligence and also the rule of strict liability with the defense of dual contributory negligence induce efficient care, output per firm the number of firms in the industry. The rules of negligence, comparative negligence, and negligence with the defense of contributory negligence, on the other hand, are not efficient.

2. Framework of Analysis

Analysis is undertaken in a simple partial-equilibrium framework of a competitive industry. We consider accidents that might result when the consumers use a product made by the firms. An accident involves two parties, the consumer and the firm. Product-related accidents differ from the accidents generally considered under liability rules in that in product-related accidents injurers (firms) and victims (consumers) have previously engaged in a market exchange, supposedly, with the knowledge that the product might cause injuries to the consumers later on. To start with, both firms and consumers are assumed to be risk-neutral, an assumption to be relaxed finally. In the event of accident the entire loss falls on the consumer. We denote by $x \geq 0$ the cost of care taken by the consumer and by $y \geq 0$ the cost of care taken by the firm. Cost of care is assumed to be strictly increasing function of care level. As a result, cost of care for a party will also represent the level of care for that party. Let $X = \{x \mid x$ is the cost of some feasible level of care which the consumer can take $\}$ and $Y = \{y \mid y$ is the cost of some feasible level of care which the firm can take $\}$. Also, $0 \in X$ and $0 \in Y$. The output of the firm and the amount of purchase made by the consumer will be treated as their respective activity levels.

Let π be the probability of accident and $H \geq 0$ be the loss in the event of accident. π and H are assumed to be functions of x and y; $\pi = \pi(x, y)$, $H = H(x, y)$. Let L denote the expected loss due to accident. Thus, $L(x, y) = \pi(x, y)H(x, y)$. x, y, π, H, and L are defined *per unit* of the product. Clearly, $L \geq 0$. L is a decreasing function of care level of each party;[5] a larger care by either party, given the care level of the other party, results in lesser or equal expected accident loss. Formally:

Assumption (A1) $(\forall x, x' \in X)(\forall y, y' \in Y)[x > x' \rightarrow L(x, y) \leq L(x', y)$, *and* $y > y' \rightarrow L(x, y) \leq L(x, y')]$.

Total accident costs (TAC) *per unit* of product are the sum of costs

[5] It is generally assumed that only the firms can take care to reduce the risk. As will be discussed later, this becomes a special case in our analysis.

of care by the two parties and the expected loss due to accident; TAC $= x + y + L(x, y)$. Let M be the set of all costs of care configurations which are TAC minimizing; $M = \{(\acute{x}, \acute{y}) \mid \acute{x} + \acute{y} + L(\acute{x}, \acute{y})$ is minimum of $\{x + y + L(x, y) \mid x \in X, y \in Y\}\}$.

Assumption (A2) *X, Y, and L are such that M is non-empty.*

2.1 Social Objective:

As the issue dealt with is of product caused injuries, the product is assumed to be homogeneous in all respects except the risk of loss associated with the product. A product-accident context is characterized by the specification of X, Y, L and M. As far as the care by the consumers is concerned all consumers are assumed to be identical. To focus on the effects of liability rules when consumers misperceive the risk, the product market is assumed to be competitive.[6] There are n identical firms each producing an output of q units. TAC per firm are $q[x + y + L(x, y)]$, and TAC of all products by all firms are $nq[x + y + L(x, y)]$. We denote consumer i's marginal consumption benefit from the product by $u_i(z)$ and $u_i'(z) < 0$. Let, $P(z)$ be the industry's inverse demand function. Let, $C(q)$ denote the production costs for a firm. Throughout the paper it is assumed that $C(q)$ is such that there is a unique positive output level at

[6] As is the case here, it is shown in Epple and Raviv (1978) and Geistfeld (2000) that as long as TAC per unit of product are independent of output level, the results obtained in a competitive setting will hold more or less even when the market is not competitive. For the effects of market-power on the output and care by firms and the related issues see Beals, Craswell and Salop (1981), Schwartz and Wild (1982), Polinsky and Rogerson (1983), Marino (1988 a, b), Spulber (1989, pp.408-410), Faulhaber and Boyd (1989), and Boyd (1994).

which the firm's average costs of production, $C(q)/q$, are minimized.[7] Social surplus is equal to the benefits from nq units of the product that consumers derive (approximated by the area under the industry's inverse demand curve) minus total costs of production (the sum of costs of production and the accident costs). Social objective is to choose x, y, q and n so as to maximize the social surplus[8]

$$\int_0^{nq} P(z)dz - nC(q) - nq[x + y + L(x, y)]. \tag{1}$$

The first order optimization conditions for q and n, respectively, are

$$P(nq) = C'(q) + x + y + L(x, y) \tag{2}$$

and

$$P(nq) = \frac{C(q)}{q} + x + y + L(x, y). \tag{3}$$

Let $\bar{q}$ and $\bar{n}$ uniquely solve (2) and (3) simultaneously. That is, given x and y as levels of care taken by the consumer and the firm, when $n = \bar{n}$, at $\bar{q}$ marginal consumption benefit is equal to marginal total cost of the product - marginal cost of production plus TAC of the product. And, when $q = \bar{q}$, at $\bar{n}$ marginal consumption benefit is equal to average total cost of the product. In other words, given the care taken by the consumer and the firm, $\bar{q}$ is the optimum output per firm, and $\bar{n}$ is the

[7]When $C(.)$ is strictly convex, the assumption that each firm produces same output does not entail any significant loss of generality (see Mas-Colell, Whinston and Green, 1995, ch. 10).

[8]$P(z)$ can be viewed as the marginal social benefit of the product when aggregate quantitity demanded is z. For similar specifications of the social objective function see Miceli (1997, ch. 2), Boyd (1994), Shavell (1987 ch. 3), and Polinsky (1980), also see Endres and Lüdeke (1998).

optimum number of firms in the industry. Since $\bar{q}$ and $\bar{n}$ are functions of x and y, overall efficiency in terms of output and number of firms in the industry requires that both the parties take efficient care. Let $\bar{q} = q^*$ and $\bar{n} = n^*$ when both the parties take efficient - TAC minimizing - care.

Remark 1: Since TAC are assumed to be linear in output, socially optimum choice of x and y is independent of the quantity of the product produced/consumed (see eq. (1)). Therefore, efficiency requires that the parties always take TAC minimizing care. Furthermore, (2) and (3) imply that $C'(q) = C(q)/q$. Thus, $\bar{q}$ is the efficient level of output ($\bar{q} = q^*$), irrespective of what of x and y are.

Consumers may be imperfectly informed about the product related risk either because (i) they do not observe the care taken by the producer firm, and/or (ii) (even if they knew the level of care taken by the firm) they do not know the value of function $L(x, y)$ correctly. We assume that consumers' knowledge is limited by both the types of imperfection: a consumer does not observe the care taken by the firm, and he does not *necessarily* know the function L correctly. Assume that when the expected loss is $L(x, y)$, the consumer perceives it to be $L_c(x, y)$, where L_c may not be equal to L. It will be assumed that firms know the function L correctly but do not observe the care taken by the consumers while using the product.

2.2 Product Liability Rules:

A product liability rule (PLR) uniquely determines the proportions in which the consumer and the firm will share the loss H, in the event of an accident, as a function of the proportions of their (non)negligence. Let I denote the closed unit interval $[0,1]$. Given X, Y, L, and $(x^*, y^*) \in M$, we define functions $g : X \mapsto I$ and $h : Y \mapsto I$ such that:

$$g(x) = x/x^* \text{ if } x < x^*,$$
$$= 1 \text{ otherwise; and}$$
$$h(y) = y/y^* \text{ if } y < y^*,$$
$$= 1 \text{ otherwise.}$$

A PLR may specify the due care levels for both the parties, or for only one of them, or for none.[9] If the rule specifies the due care levels for both the parties, x^* and y^* used in the definitions of functions g and h will be taken to be identical with the legally specified due care levels for the consumer and the firm, respectively. If the rule specifies the due care level for only the firm, y^* used in the definition of function h will be taken to be identical with the legally specified due care level for the firm, and x^* used in the definition of g will be taken as any element of $\{x \in X \mid (x, y^*) \in M\}$. Similarly, if the rule specifies due care level for only the consumer, x^* used in the definition of function g will be taken to be identical with the legally specified due care level, and y^* used in the definition of h will be any element of $\{y \in Y \mid (x^*, y) \in M\}$. If the rule does not specify due care level for any party then any element of M can be used in the definitions of g and h. In any case (x^*, y^*) is TAC

[9]The rules of negligence with defense, strict liability with defense, and strict liability, for example, are respectively the rules with legal due care levels for both the consumer and the firm, for only the consumer, and for none.

minimizing.

In other words, we are assuming that the legal due care standard for a party, wherever applicable, is set at a level commensurate with the objective of minimizing the TAC. This standard assumption is crucial for the efficiency of a PLR.

A PLR can be defined as a rule that specifies the proportions in which the consumer and the firm will bear the loss, in the event of accident, as a function of proportions of their (non)negligence.[10] Formally, a PLR is a function $f : [0,1]^2 \mapsto [0,1]^2$, such that:

$$f(g(x),\ h(y)) = (s,\ t) = (s[g(x),\ h(y)], t[g(x),\ h(y)]), \quad s + t = 1,$$

where $s \geq 0$ [$t \geq 0$] is the proportion of loss that the consumer [firm] will be required to bear.

2.3 Competitive Equilibrium:

As mentioned above, consumers do not observe the care taken by the firms. As regards to consumers' knowledge of the expected loss function L, we assume that though a consumer may not know the exact value of the function L for given x and y, he knows that L is such that TAC are minimum when he opts for x^* and the firm opts for the corresponding optimum level of care, denoted by y^*. In other words, L_c,

[10] Given above definitions of g and h, $h(y) = 1$ would mean that the firm is taking at least the due care and it would be called nonnegligent. $h(y) < 1$ would mean that the firm is negligent. $h(y)$ and $1 - h(y)$ will be its proportions of nonnegligence and negligence, respectively. Similarly, for the consumer.

the expected loss function as perceived by the consumer, is such that (x^*, y^*) solves $min\{x + y + L_c(x, y)\}$. Formally, for any given X, Y, L and $(x^*, y^*) \in M$, L_c, is such that:

Assumption (A3) $(\forall(x, y) \in X \times Y)[x^* + y^* + L_c(x^*, y^*) \leq x + y + L_c(x, y)]$.

It should be noted that the only restriction imposed by (A3) is that L_c be such that the sum $x + y + L_c(x, y)$ is minimum at (x^*, y^*).[11] It is assumed that whenever the risk is positive the consumer perceives it to be so, i.e., $L_c > 0$ whenever $L > 0$. Finally, we make an implicit but otherwise standard assumption that when the consumer opts for x^* and the firm opts for y^*, expected accident loss is positive.

Assumption (A4) *For every* X, Y, L, *and* $(x^*, y^*) \in M$, $L(x^*, y^*) > 0$.

[11] One might argue that when the consumer does not know the function L correctly, he might not know of TAC minimizing pair of care levels; L_c might not satisfy (A3). Here it should be noted that the PLR itself may provide the consumers with the relevant information. As a matter-of-fact some rules, such as the rules of negligence with the defense of contributory negligence, comparative negligence, strict liability with the defense of dual contributory negligence, specify due care standard for both the parties. Since the due levels of care are assumed to be set at levels that are appropriate for efficiency (under such rules at (x^*, y^*)), the consumer - because of this common knowledge - will get to know of TAC minimizing pair, (x^*, y^*), from the legal standards itself. Therefore, the above problem of information will not arise under such rules and L_c should satisfy (A3). Moreover, we will show that a PLR can be efficient *only if* it sets due care standard for the consumer. Under such a rule the consumer, again, will get to know of x^* (the firm of course knows of y^*). In any case we will show that our results will hold even when (A3) is relaxed.

(A4) implies $L_c(x^*, y^*) > 0$. (A3) and (A4) are mainly for the expository purpose. We will show that our results will still hold in most of the cases when (A3) or (A4) is relaxed.

Let, X, Y, L, and $(x^*, y^*) \in M$ be given. If accident with a loss of H materializes, the court will require the firm to bear $t[g(x), h(y)]H(x, y)$, in the form liability payment to be made to the consumer. $t[g(x), h(y)]$ will be determined by the PLR in force. The expected *accident* costs of a party are the sum of the cost of care taken by it plus its expected liability. A firm's expected accident costs, therefore, are: $y + t[g(x), h(y)]\pi(x, y)H(x, y)$, i.e., $y + t[g(x), h(y)]L(x, y)$. As far as the consumer is concerned since he perceives the expected loss to be equal to $L_c(x, y)$, he will perceive the expected liability payment to be equal to $t[g(x), h(y)]L_c(x, y)$. Therefore, from a consumer's perspective his expected accident costs are: $x + L_c(x, y) - t[g(x), h(y)]L_c(x, y)$, i.e., $x + s[g(x), h(y)]L_c(x, y)$, as $1 - t = s$.

Let p be the per unit market price of the product. Assumption of competitive market implies that p is given for both parties and is equal to the marginal total cost of production - marginal cost of production plus marginal expected liability of the firm. When consumers misperceive the risk, the demand for the product will be a function of the perceived full price. Given the relevant PLR and the level of care taken by the firm, perceived full price *per unit* of product is equal to the market price plus the consumer's expected accident costs, i.e, $p+x+s[g(x), h(y)]L_c(x, y)$.

Consumers' problem is equivalent to that of choosing the quantity Q and the care x to maximize

$$\int_0^Q P(z)dz - pQ - Q[x + s[g(x), h(y)]L_c(x, y)] \tag{4}$$

The first order condition (foc) for Q is[12]

$$P(Q) = p + x + s[g(x), h(y)]L_c(x, y) \tag{5}$$

Given the PLR and the care taken by the consumer, a firm's problem is to choose the quantity q and the care y so as to maximize

$$pq - C(q) - q[y + t[g(x), h(y)]L(x, y)] \tag{6}$$

The first order condition for q is

$$p = C'(q) + y + t[g(x), h(y)]L(x, y)] \tag{7}$$

Free entry condition implies that profit of each firm will be zero, i.e.,

$$pq = C(q) + q[y + t[g(x), h(y)]L(x, y)] \tag{8}$$

From $(4)\&(5)$ it is clear that optimum level of care by the consumers is independent of their levels of consumption. Therefore, for given y, a rational and risk-neutral consumer will choose x that minimizes his expected accident costs, $x + s[g(x), h(y)]L_c(x, y)$, in the light of the PLR in force, independent of his level of consumption. Analogous argument in

[12] Note that a consumer i's problem is to choose the quantity q_i and the level of care x to maximize $\int_0^{q_i} u_i(z)dz - pq_i - q_i[x+s[g(x), h(y)]L_c(x, y)]$ resulting in foc as $u_i(q_i) = p+x+s[g(x), h(y)]L_c(x, y)$. This means that given consumers' misperception about L, when consumers optimally choose their demand for the product, at these individual demand levels each consumer's marginal benefit, $u_i(z)$ is equal to $P(Q)$. Therefore, (4) is maximized w.r.t. Q if *ceteris-paribus* each consumer chooses his demand for the product optimally.

view of $(6)\&(7)$ implies that, for given x, the firm will choose y that independently minimizes its expected accident costs, $y+t[g(x),h(y)]L(x,y)$. An equilibrium is defined as a tuple $<\hat{Q},\hat{p},\hat{q},\hat{n},\hat{x},\hat{y}>$ such that: $\hat{Q}=\hat{n}\hat{q}$; and $\hat{Q}$, $\hat{p}$, and $\hat{q}$ satisfy (5), (7) and (8); and $(\hat{x},\hat{y})$ is Nash Equilibrium (N.E.).

Now, from $(5)\&(7)$ in equilibrium we have

$$P(Q)=P(nq)=C'(q)+x+y+sL_c(x,y)+tL(x,y) \tag{9}$$

and from (5) and (8) we get

$$P(Q)=P(nq)=\frac{C(q)}{q}+x+y+sL_c(x,y)+tL(x,y) \tag{10}$$

where $s=s[g(x),h(y)]$ and $t=t[g(x),h(y)]$.

2.4 Efficient Product Liability Rules:

Given the care taken by the consumers and firms, socially optimum quantity per firm and the number of firms in the industry are given by (2) and (3). However, when consumers misperceive the risk, the actual output per firm and the number of firms are given by (9) and (10). Generally the solution to $(9)\&(10)$ will be different from that of $(2)\&(3)$. $(9)\&(10)$, however, imply that $C'(q)=C(q)/q$, i.e., in equilibrium output per firm will be efficient (Remark 1). But, from (9) and (10), even if we assume that both the parties are taking efficient care, when consumers misperceive the risk, i.e., when $L_c\neq L$ the number of firms in the industry will not necessarily be efficient. Therefore, a PLR may cause inefficiency on the following two counts: (a) it may induce the parties to take inefficient care, and (b) it may induce inefficient (total) production and hence consumption. From the above discussion it should be noted that the second kind of inefficiency might occur even when that of the first type is not there.

Remark 2: If under the rule $s = 0$ or $t = 1$ in equilibrium, $(9)\&(10)$ will exactly be the same as $(2)\&(3)$ and, therefore, given the care taken by the parties both the quantity produced and the number of firms will be efficient. Further, if the rule induces efficient care then the rule will be efficient in terms of care, output and the number of firms. Just opposite will be the case when $s \neq 0$, in equilibrium.

An application of a PLR is characterized by the specification of X, Y, L, $(c^*, d^*) \in M$, and $C(q)$. As mentioned earlier, a PLR can be (in)efficient in two respects; one the care taken by the parties and, two, the total quantity of the product produced/consumed. As regards to care, a rule is said to be efficient iff in equilibrium it induces efficient care by both the parties, or iff every Nash Equilibrium is TAC minimizing, and there exists at least one Nash Equilibrium.[13] To be efficient on both the counts, the rule should also induce efficient output for the industry.

A PLR, f, is said to be efficient for a given application iff, in equi-

[13]Through out the paper whenever we refer to N.E., the strategy of a party will refer to the level of care taken by this party. In this paper we consider only the pure strategy Nash Equilibria.

librium it induces efficient care by both the parties, output per firm and number of firms in the industry. Formally, f is efficient for given X, Y, L, $(c^*, d^*) \in M$, and $C(q)$, iff: $(\forall(\bar{x}, \bar{y}) \in X \times Y)$ $[(\bar{x}, \bar{y})$ is a N.E. $\rightarrow (\bar{x}, \bar{y}) \in M]$ & $(\exists(\bar{x}, \bar{y}) \in X \times Y)[(\bar{x}, \bar{y})$ is a N.E.]; and in equilibrium q^* and n^* solve (9) and (10), simultaneously. A PLR, f, is defined to be ***efficient*** iff it is efficient for every possible choice of X, Y, L, $(c^*, d^*) \in M$, and $C(q)$.

3. Characterization of efficient product liability rules

3.1 When consumers know the value of expected loss function L:

When consumers know the expected loss function $L(x, y)$ correctly, $L_c = L$. As a result, $(9)\&(10)$ will be identical with $(2)\&(3)$ and, therefore, $\bar{q}$ and $\bar{n}$ will solve $(9)\&(10)$. Thus, when consumers know $L(x, y)$ correctly, given the care by consumers and firms, both the quantity produced and the number of firms will be efficient irrespective of the PLR in force and the question of efficiency is reduced to whether or not the rule induces efficient care. It can be shown that when each party observe L correctly but does not observe the care taken by the other party, a liability rule f will induce efficient care in its every application satisfying (A1) and (A2), iff f is such that:[14] $g < 1 \rightarrow [f(g, 1) = (1, 0)]$, and $h < 1 \rightarrow [f(1, h) = (0, 1)]$. In view of this result, we can make the following claim.

[14]For proof and detailed discussion see Jain and Singh (2002), and Singh (2001).

Theorem 1 *When $L_c = L$, a product liability rule is efficient for every possible choice of X, Y, L, $(x^*, y^*) \in M$, satisfying (A1) and (A2), and every $C(q)$ iff,*

$$g < 1 \rightarrow [f(g,1) = (1,0)], \textit{ and } h < 1 \rightarrow [f(1,h) = (0,1)].$$

As a corollary to Theorem 1, we get the results proved in Shavell (1987, ch. 3), Landes and Posner (1987, ch. 10), Miceli (1997, pp. 29-33) that when the consumers know the risk associated with different care levels (but do not observe the care taken by the firm), various negligence criterion based rules induce efficient care by both the parties and hence are efficient.

3.1 When consumers observe the value of expected loss function L with error:

In this section we provide complete characterization of efficient PLRs when consumers observe L with error, i.e., when $L_c \neq L$. Of course, they do not observe the care taken by the firms. We provide a necessary and sufficient condition for efficiency of a PLR. Formally, we show that when $L_c \neq L$, a PLR f is efficient iff f satisfies the condition of 'negligent consumer's liability' (NCL). First, we define the condition NCL.

Condition of Negligent Consumer's Liability (NCL):

A product liability rule f is said to satisfy the condition NCL iff its structure is such that (i) whenever the consumer is nonnegligent, i.e., he is taking at least the due care, the entire loss in the event of accident is borne by the firm irrespective of the level of care taken by the firm, and (ii) when consumer is negligent and the firm is not, the entire loss in the event of accident is borne by the consumer. Formally, a product liability rule f satisfies condition NCL iff:

$$(\forall h \in [0,1])[f(1,h) = (0,1)] \ and \ (\forall g \in [0,1))[f(g,1) = (1,0)].$$

Proposition 1 *If a product liability rule satisfies condition NCL then for every possible choice of X, Y, L, $(x^*, y^*) \in M$, and L_c, satisfying (A1)-(A4), (x^*, y^*) a Nash Equilibrium.*

Proof: Let the PLR, f, satisfy the condition NCL. Take any arbitrary X, Y, L, $(x^*, y^*) \in M$, and L_c, satisfying (A1)- (A4). As f satisfies condition NCL, $f(1,1) = (0,1)$. Let $y = y^*$ be opted by the firm. Then, for all $x \geq x^*$ expected accident costs of the consumer are $x + s[g(x), h(y^*)]L_c(x, y^*) = x$, as when $x \geq x^*$, $s[g(x), h(y^*)] = 0$ by NCL. Therefore, if the consumer chooses x^* his expected accident costs are only x^*. Now, consider a choice of $x' \neq x^*$ by the consumer. First, consider the case when $x' > x^*$. In this case his expected accident costs clearly are x', and he will be strictly worse-off choosing x' rather than x^*.

Next, consider the case $x' < x^*$. For $x' < x^*$ expected accident costs of the consumer are $x' + s[g(x'), (y^*)]L_c(x', y^*)$, i.e., $x' + L_c(x', y^*)$, as when $x' < x^*$, $s[g(x'), (y^*)] = 1$ by condition NCL. But, x' can be better than x^* for the consumer only if $x' + L_c(x', y^*) < x^*$, i.e., only if $x' + y^* + L_c(x', y^*) < x^* + y^*$. This implies $x' + y^* + L_c(x', y^*) < x^* + y^* + L_c(x^*, y^*)$. But, in view of (A3) this is a contradiction.

Thus, given that y^* is opted by the firm, x^* is a best response by the consumer. Similarly, it can easily be demonstrated that given x^* opted by the consumer, y^* is a best response by the firm. Which establishes that (x^*, y^*) is a N.E. •

Proposition 2 *If a product liability rule satisfies condition NCL then for every possible choice of X, Y, L, $(x^*, y^*) \in M$, and L_c, satisfying (A1)-(A4),*

$$(\forall(\bar{x}, \bar{y}) \in X \times Y)[(\bar{x}, \bar{y}) \text{ is a Nash Equilibrium} \rightarrow (\bar{x}, \bar{y}) \in M].$$

Proof: Let PLR f satisfy condition NCL. Take any arbitrary X, Y, L, $(x^*, y^*) \in M$, and L_c, satisfying (A1)- (A4). Suppose $(\bar{x}, \bar{y}) \in X \times Y$ is a N.E. $(\bar{x}, \bar{y})$ is a N.E. implies that if $\bar{y}$ is opted by the firm, expected accident costs of the consumer are minimum at $\bar{x}$, i.e.,

$$(\forall x \in X)[\bar{x} + s[g(\bar{x}), h(\bar{y})]L_c(\bar{x}, \bar{y}) \leq x + s[g(x), h(\bar{y})]L_c(x, \bar{y})] \quad (11)$$

and if $\bar{x}$ is opted by the consumer, expected accident costs of the firm are minimum at $\bar{y}$, i.e.,

$$(\forall y \in Y)[\bar{y} + t[g(\bar{x}), h(\bar{y})]L(\bar{x}, \bar{y}) \leq y + t[g(\bar{x}), h(y)]L(\bar{x}, y)] \quad (12)$$

Now, (11), in particular, $\rightarrow \bar{x}+s[g(\bar{x}), h(\bar{y})]L_c(\bar{x}, \bar{y}) \leq x^*+s[g(x^*), h(\bar{y})]L_c(x^*, \bar{y})$, i.e.,

$$\bar{x} + s[g(\bar{x}), h(\bar{y})]L_c(\bar{x}, \bar{y}) \leq x^* \quad (13)$$

as $s[g(x^*), h(\bar{y})] = 0$ by condition NCL. And, (12)$\rightarrow$

$$\bar{y} + t[g(\bar{x}), h(\bar{y})]L(\bar{x}, \bar{y}) \leq y^* + t[g(\bar{x}), h(y^*)]L(\bar{x}, y^*) \quad (14)$$

Adding (13) and (14)

$$\bar{x}+\bar{y}+s[g(\bar{x}),h(\bar{y})]L_c(\bar{x},\bar{y})+t[g(\bar{x}),h(\bar{y})]L(\bar{x},\bar{y}) \leq x^*+y^*+t[g(\bar{x}),h(y^*)]L(\bar{x},y^*) \tag{15}$$

Case 1: $\bar{x} \geq x^*$:

$(\forall h \in [0,1])[f(1,h) = (0,1)]$ by condition NCL. Thus, when $\bar{x} \geq x^*$, $s[g(\bar{x}),h(\bar{y})] = 0$, $t[g(\bar{x}),h(\bar{y})] = 1$, and $t[g(\bar{x}),h(y^*)] = 1$. Therefore, from (15), $(\bar{x},\bar{y})$ is a N.E. $\rightarrow \bar{x}+\bar{y}+L(\bar{x},\bar{y}) \leq x^*+y^*+L(\bar{x},y^*)$. Now, $\bar{x} \geq x^* \rightarrow L(\bar{x},y^*) \leq L(x^*,y^*)$. Therefore, we get $\bar{x}+\bar{y}+L(\bar{x},\bar{y}) \leq x^*+y^*+L(x^*,y^*)$. But, $\bar{x}+\bar{y}+L(\bar{x},\bar{y}) \geq x^*+y^*+L(x^*,y^*)$, as $(x^*,y^*) \in M$. This implies that $\bar{x}+\bar{y}+L(\bar{x},\bar{y}) = x^*+y^*+L(x^*,y^*)$. Which means $(\bar{x},\bar{y}) \in M$. Thus,

$$\bar{x} \geq x^* \& (\bar{x},\bar{y}) \ is \ a \ N.E. \rightarrow (\bar{x},\bar{y}) \in M \tag{16}$$

Case 2: $\bar{x} < x^*$:

Subcase 1: $\bar{y} \geq y^*$: As $(\forall g \in [0,1))[f(g,1) = (1,0)$ by condition NCL, in this case $s[g(\bar{x}),h(\bar{y})] = 1$, $t[g(\bar{x}),h(\bar{y})] = 0$ and $t[g(\bar{x}),h(y^*)] = 0$. So, (15), reduces to $\bar{x}+\bar{y}+L_c(\bar{x},\bar{y}) \leq x^*+y^*$. Thus, $\bar{x}+\bar{y}+L_c(\bar{x},\bar{y}) < x^*+y^*+L_c(x^*,y^*)$, since (A4) implies $L_c(x^*,y^*) > 0$. Which is a contradiction in view of (A3). Therefore,

$$if \ \ \bar{x} < x^* \& \bar{y} \geq y^*, \ (\bar{x},\bar{y}) \ cannot \ be \ a \ N.E. \tag{17}$$

Subcase 2: $\bar{y} < y^*$: Suppose $f(g(\bar{x}),h(\bar{y})) = (\bar{s},\bar{t})$. Let

$$t^* = \frac{y^*-\bar{y}}{(x^*-\bar{x})+(y^*-\bar{y})} \ \ and \ \ s^* = \frac{x^*-\bar{x}}{(x^*-\bar{x})+(y^*-\bar{y})}.$$

There are two possible cases: (i) $\bar{t} \geq t^*$, or (ii) $\bar{t} < t^*$. When (i) holds, from (14), $(\bar{x},\bar{y})$ is a N.E. $\rightarrow \bar{y}+\bar{t}L(\bar{x},\bar{y}) \leq y^*$, since when $\bar{x} < x^*$,

$t[g(\bar{x}), h(y^*)] = 0$ by NCL. That is, we get $\bar{t}L(\bar{x}, \bar{y}) \leq y^* - \bar{y}$, i.e.,

$$\frac{y^* - \bar{y}}{(x^* - \bar{x}) + (y^* - \bar{y})} L(\bar{x}, \bar{y}) \leq y^* - \bar{y}, \ as \ \bar{t} \geq t^* \rightarrow t^* L(\bar{x}, \bar{y}) \leq \bar{t}L(\bar{x}, \bar{y}).$$

So, when (i) holds $(\bar{x}, \bar{y})$ is a N.E. $\rightarrow \bar{x} + \bar{y} + L(\bar{x}, \bar{y}) \leq x^* + y^*$, i.e., $\bar{x} + \bar{y} + L(\bar{x}, \bar{y}) < x^* + y^* + L(x^*, y^*)$, since $L(x^*, y^*) > 0$, by (A4). Which is a contradiction because $(x^*, y^*) \in M$.

When (ii) holds, i.e., when $\bar{t} < t^*$, $\bar{s} + \bar{t} = 1 = s^* + t^*$ implies $\bar{s} > s^*$. When $\bar{s} > s^*$, from (13) $(\bar{x}, \bar{y})$ is a N.E. $\rightarrow \bar{s}L_c(\bar{x}, \bar{y}) \leq x^* - \bar{x}$. Since $L_c(\bar{x}, \bar{y}) > 0$,[15] $s^* < \bar{s} \rightarrow s^* L_c(\bar{x}, \bar{y}) < \bar{s}L_c(\bar{x}, \bar{y})$. Thus, in this subcase $(\bar{x}, \bar{y})$ is a N.E. implies $s^* L_c(\bar{x}, \bar{y}) < x^* - \bar{x}$, i.e.,

$$\frac{x^* - \bar{x}}{(x^* - \bar{x}) + (y^* - \bar{y})} L_c(\bar{x}, \bar{y}) < x^* - \bar{x}, \ \ i.e., \ \ \bar{x} + \bar{y} + L_c(\bar{x}, \bar{y}) < x^* + y^*,$$

a contradiction in view of (A3). Therefore,

$$if \ \ \bar{x} < x^* \& \bar{y} < y^*, (\bar{x}, \bar{y}) \ cannot \ be \ a \ N.E. \tag{18}$$

Finally, (16) - (18) $\rightarrow [(\bar{x}, \bar{y})$ is a N.E. $\rightarrow (\bar{x}, \bar{y}) \in M]$. •

From the proof of Proposition 2 we have the following remark.

Remark 3: If a PLR satisfies condition NCL then for every possible choice of X, Y, L, $(x^*, y^*) \in M$, and L_c, satisfying (A1)- (A4), $(\bar{x}, \bar{y})$ is a N.E. implies that $\bar{x} = x^*$. That is, in every accident context in equilibrium the consumer will opt for x^*, the due level of care.

[15] That $L(\bar{x}, \bar{y}) > 0$ is easy to see. $L(\bar{x}, \bar{y}) \geq 0$ and when $\bar{x} < x^* \& \bar{y} < y^*$, $L(\bar{x}, \bar{y}) = 0$ would imply that $(x^*, y^*) \notin M$, a contradiction. Thus, $L(\bar{x}, \bar{y}) > 0$, and by assumption $L_c(\bar{x}, \bar{y}) > 0$.

Propositions 1 and 2 show that NCL is a sufficient condition for a PLR to be TAC minimizing, or to induce efficient care by both the parties. Next, we show that NCL is a necessary condition for efficiency of a PLR.

Lemma 1 *For a PLR f, if $[f(1,1) = (0,1)]\&\ (\exists h \in [0,1))[f(1,h) \neq (0,1)]$, then there exist X, Y, L, $(x^*, y^*) \in M$, and L_c, satisfying (A1)-(A4), such that f is not TAC minimizing.*

Proof: Given $f(1,1) = (0,1)$ and $(\exists h \in [0,1))[f(1,h) \neq (0,1)]$. Suppose, $f(1,h) = (s_1, t_1)]$, where $t_1 \in [0,1)$. Let $k > 0$. As $t_1 < 1$, $t_1 k < k$. Choose $r > 0$ such that $t_1 k < r < k$. Now, consider the accident context characterized by the following specification of X, Y, L and L_c: $X = \{0, x_0\}$, $x_0 > 0$,
$Y = \{0, hy_0, y_0\}$, where $y_0 = r/(1-h)$,
$L(0,0) = \Delta + x_0 + hy_0 + k + \delta$, where $\Delta \geq 0$, and $\delta > 0$,
$L(x_0, 0) = \Delta + hy_0 + k$, $L(0, hy_0) = \Delta + x_0 + k + \delta$, $L(0, y_0) = \Delta + x_0 + \delta$,
$L(x_0, hy_0) = \Delta + k$, and $L(x_0, y_0) = \Delta$.
It is clear that (x_0, y_0) is a unique TAC minimizing configuration. Let $(x^*, y^*) = (x_0, y_0)$. Suppose L_c satisfies (A3). Given x_0 opted by the consumer, $f(1,1) = (0,1)$ implies that if firm chooses y_0 its expected accident costs are $y_0 + \Delta$. And, if it chooses hy_0, its expected costs are $hy_0 + t_1(\Delta + k)$. But, $y_0 - hy_0 > t_1 k$ or $y_0 > hy_0 + t_1 k$. Thus, $y_0 + \Delta > hy_0 + t_1(\Delta + k)$, since $t_1 < 1$. That is, given x_0 opted by the consumer, the firm is better-off choosing hy_0 rather than y_0 and, hence the uniquely TAC minimizing configuration, $(x^*, y^*) = (x_0, y_0)$ is not a

N.E. Therefore, there exist X, Y, L, $(x^*, y^*) \in M$, and L_c, satisfying (A1)- (A4), such that f is not TAC minimizing. •

Lemma 2 *For a PLR f if $(\exists g \in [0, 1))$ $[f(g, 1) \neq (1, 0)]$ holds, then there exist X, Y, L, $(x^*, y^*) \in M$, and L_c, satisfying (A1)- (A4) such that f is not TAC minimizing.*

Proof: Given $(\exists g \in [0, 1))[f(g, 1) \neq (1, 0)]$. Let, $f(g, 1) = (s_1, t_1)$ where $s_1 < 1$. For any $k > 0$, $s_1 k < k$. Choose $r > 0$ such that $s_1 k < r < k$. Now consider the following specification of X, Y and L:

$X = \{0,\ gx_0,\ x_0\}$, where $x_0 = r/(1 - g)$,

$Y = \{0,\ y_0\}$, $y_0 > 0$,

$L(0, 0) = \Delta + gx_0 + k + y_0 + \delta$, where $\delta > 0$, and $\Delta \geq 0$

$L(gx_0, 0) = \Delta + k + y_0 + \delta$, $\quad L(x_0, 0) = \Delta + y_0 + \delta$,

$L(0, y_0) = \Delta + gx_0 + k$, $\quad L(gx_0, y_0) = \Delta + k$, $\quad L(x_0, y_0) = \Delta$.

Again, (x_0, y_0) is a unique TAC minimizing configuration. Let $(x^*, y^*) = (x_0, y_0)$. For simplicity assume that $L_c = \beta L$, where $\beta > 0$. Now, let y_0 be opted by the firm. When $\Delta = 0$, it is easy to see that when $\beta \in (0, 1]$, the consumer will be better off choosing gx_0 rather than x_0. In particular, even when $\beta = 1$, i.e., $L_c = L$, uniquely TAC minimizing pair $(x^*, y^*) = (x_0, y_0)$ is not a N.E. When $\Delta > 0$, if the consumer chooses x_0 his expected accident costs are at least x_0. And, if he chooses gx_0, his expected costs are $gx_0 + s_1\beta(\Delta + k)$. Now, whenever $k/(\Delta + k) \geq \beta > min\{x_0/(gx_0 + k),\ y_0/(y_0 + \delta)\}$ it is easy to see that L_c satisfies (A3) and $gx_0 + s_1\beta(\Delta + k) \leq gx_0 + s_1 k$. As $gx_0 + s_1 k < x_0$ by construction, $gx_0 + s_1\beta(\Delta + k) < x_0$. Thus, $(x^*, y^*) = (x_0, y_0)$ is not a N.E. Therefore, there exist X, Y, L, $(x^*, y^*) \in M$, and L_c, satisfying (A1)- (A4) such that when $(\exists g \in [0,1))[f(g,1) \neq (1,0)]$ holds, (x^*, y^*) is not a N.E. Finally, the fact that in the above context, (x^*, y^*) is uniquely TAC minimizing implies that in this context f is not TAC minimizing. •

Proposition 3 *A product liability rule is efficient for every possible choice of X, Y, L, $(x^*, y^*) \in M$, L_c, satisfying (A1)- (A4), and every $C(q)$ only if it satisfies condition NCL.*

Proof: Suppose not. Suppose there exists a PLR, f, such that f violates NCL and is efficient for every possible choice of X, Y, L, $(x^*, y^*) \in M$, L_c, satisfying (A1)- (A4), and every $C(q)$. f violates NCL $\rightarrow$
(i) $(\exists h \in [0,1])[f(1,h) \neq (0,1)]$, or (ii) $(\exists g \in [0,1))$ $[f(g,1) \neq (1,0)]$.
Case 1: Suppose, (i), i.e., $(\exists h \in [0,1])[f(1,h) \neq (0,1)]$holds. In this case there are only two mutually exclusive possibilities: $f(1,1) = (0,1)$ or $f(1,1) \neq (0,1)$.
Subcase 1: $f(1,1) = (0,1)$: When $f(1,1) = (0,1)$ is true, $(\exists h \in [0,1])[f(1,h) \neq (0,1)] \rightarrow (\exists h \in [0,1))[f(1,h) \neq (0,1)]$. But, when $f(1,1) = (0,1)$ and $(\exists h \in [0,1))[f(1,h) \neq (0,1)]$, from Lemma 1, f cannot be TAC minimizing for all its applications. As a consequence, f cannot be efficient for every X, Y, L, $(x^*, y^*) \in M$, L_c, satisfying (A1)-(A4), and every $C(q)$.
Subcase 2: $f(1,1) \neq (0,1)$: Let $f(1,1) = (s_1, t_1)$, where $s_1 > 0$. Now, consider any X, Y, L, $(x^*, y^*) \in M$, and L_c, satisfying (A1)- (A4), such that (x^*, y^*) is uniquely TAC minimizing. In such contexts whenever there is no N.E., or when (x^*, y^*) is not a unique N.E., f is not TAC

minimizing and therefore not efficient. And, when (x^*, y^*) is a unique N.E., though TAC minimizing, f is not efficient. Because in equilibrium $s = s_1 > 0$, so $(9)\&(10)$ will be different from $(2)\&(3)$. Therefore outcome will not be efficient in terms of total quantity produced (Remark 2).

Case 2: Let (ii) hold. In this case also f not efficient for every X, Y, L, $(x^*, y^*) \in M$, L_c, satisfying (A1)- (A4), and every $C(q)$, because, from Lemma 2, for some X, Y, L, $(x^*, y^*) \in M$, and L_c, satisfying (A1)-(A4), f is not TAC minimizing.

Therefore it cannot be the case that f violates condition NCL and is still efficient for every possible X, Y, L, $(x^*, y^*) \in M$, L_c, satisfying (A1)-(A4), and every $C(q)$. •

Theorem 2 *A product liability rule is efficient for every possible X, Y, L, $(x^*, y^*) \in M$, L_c, satisfying (A1)- (A4), and every $C(q)$ iff it satisfies the condition NCL.*

Proof: Take any arbitrary X, Y, L, $(x^*, y^*) \in M$, L_c, satisfying (A1)-(A4), and $C(q)$. Suppose PLR, f satisfies condition NCL. By Propositions 1 and 2, f is TAC minimizing. Furthermore, under f, $(\bar{x}, \bar{y})$ is a N.E. $\rightarrow \bar{x} = x^*$ (Remark 3). $\bar{x} = x^*$ and condition NCL imply that in equilibrium $s = 0$ and $t = 0$. As a consequence $(9)\&(10)$ will be identical with $(2)\&(3)$. This, in view of the fact that both the parties will opt for TAC minimzing care, implies that q^* and n^* will solve $(9)\&(10)$, simultaneously (Remark 2). Hence f is efficient.

On the other hand, if a PLR is efficient for every possible choice of X,

Y, L, $(x^*, y^*) \in M$, L_c, satisfying (A1)- (A4), and $C(q)$, by Proposition 3 it satisfies NCL. •

Theorem 2 establishes that the PLRs that satisfy condition NCL are efficient for every possible application irrespective of the consumers' misperception about the risk as long as L_c satisfies (A3). On the contrary, the PLRs that violate the condition cannot be efficient in every possible application. The rule of strict liability with the defense of contributory negligence holds the consumer liable iff he was negligent. The rule can be defined as: $(g = 1 \to s = 0)$, and $(g < 1 \to s = 1)$. Similarly, the rule of strict liability with the defense of dual contributory negligence can be defined as (Dari Mattiacci (2002)): $(g = 1 \to s = 0)$ and $(g < 1 \& h < 1 \to s = 0)$ and $(g < 1 \& h = 1 \to s = 1)$. It is easy to check that both of these rule satisfy the condition NCL and therefore are efficient. Based upon fulfillment or otherwise of the condition NCL, we immediately get the following corollary from Theorem 2.

Corollary 1 *The rules of strict liability with the defense of contributory negligence, and strict liability with the defense of dual contributory negligence, are efficient (in terms of care, output per firm and the number of firms in the industry) for every possible choice of X, Y, L, $(x^*, y^*) \in M$, L_c, satisfying (A1)- (A4), and every $C(q)$. On the other hand, the rules of no liability, strict liability, negligence, negligence with the defense of contributory negligence, and comparative negligence are not.*

Assumption (A5) *X, Y, and L are such that $\sharp M = 1$, i.e., (x^*, y^*)*

is a uniquely TAC minimizing pair.

Remarks 4: In the literature on liability rules, (A5) is the standard assumption about X, Y, and L. Also the results of Theorem 2, will hold if in stead of our more general assumption (A1) and (A2) we assume (A5). In the latter case sufficiency results follow immediately. Necessity claim will follow from observing that the necessity proofs, in addition to being consistent with $(A2)$, are such that the TAC minimizing configuration is unique.

Theorem 2 is proved under the assumptions (A1)-(A4). Only restrictive assumptions are (A3) and (A4). First, consider the implications for efficiency of a PLR when assumption (A4) - X, Y, L are such that $L(x^*, y^*) > 0$ - is relaxed. ((A4), again, is a standard assumption). As $L(x^*, y^*) \geq 0$ always, relaxing (A4) would mean that $L(x^*, y^*) \geq 0$. When (A4) is relaxed our results will still hold when (A5) holds. (In that case the semi-equality in assumption (A3) will be replaced by strict inequality). To see this, note that while proving Proposition 1 the argument that $L(x^*, y^*) > 0$ is not used at all. While proving Proposition 2 this argument is used only in Case 2, when $\bar{x} < x^*$. In this case, the claims will still hold if instead of (A4) we use the argument that (x^*, y^*) is uniquely TAC minimizing.[16] Also, as noted in the relevant proofs,

[16]In Subcase 1, instead of inequality $\bar{x} + \bar{y}(= y^*) + L_c(\bar{x}, \bar{y}) < x^* + y^* + L_c(x^*, y^*)$, we will get the semi-inequality $\bar{x} + \bar{y}(= y^*) + L_c(\bar{x}, \bar{y}) \leq x^* + y^* + L_c(x^*, y^*)$, and in Subcase 2, instead of inequality $\bar{x} + \bar{y} + L(\bar{x}, \bar{y}) < x^* + y^* + L(x^*, y^*)$, we will get the semi-inequality $\bar{x} + \bar{y} + L(\bar{x}, \bar{y}) \leq x^* + y^* + L(x^*, y^*)$. Both of which are contradictions as (x^*, y^*) is uniquely TAC minimizing.

Proposition 3 holds even when $L(x^*, y^*) \geq 0$.

Remark 5: From the definition of condition NCL it is clear that the condition, in particular, requires that the rule sets the (non)negligence standard for the consumer, at a level that is appropriate for the objective of TAC minimization. When the rule does not set the negligence standard for the consumer, condition NCL cannot be fulfilled.

Theorem 3 shows that the characterization of efficient PLRs does not change even if we relax (A3) and (A4), provided (A5) holds. Violation of the assumption (A3) would mean that L_c may not satisfy (A3). First we prove a Lemma.

Lemma 3 *Under a PLR, f, if* $(\forall h \in [0,1])[g < 1 \rightarrow f(g,h) = (1,0)$ & $g = 1 \rightarrow f(g,h) = (0,1)]$ *holds then for every X, Y, L, $(x^*, y^*) \in M$, L_c, and every $C(q)$, f is efficient.*

Proof: Let PLR, f, be as in the claim. Take any X, Y, L and $(x^*, y^*) \in M$ satisfying (A5). Under f the consumer will never opt for $x > x^*$, i.e., the consumer will always choose a x such that $x \leq x^*$. Knowing this, the firm will not choose $y > y^*$,[17] i.e., the firm will always choose a y such that $y \leq y^*$. In this backdrop, even when a consumer does not know of the y that along with x^* will make the TAC minimizing pair, a rational consumer will know that the firm's care will be less than or equal to the level that is appropriate for the objective of TAC minimization. Now, if

[17]When (x^*, y^*) is uniquely TAC minimizing, in this subcase $y = y^*$ $[y = 0]$ is a uniquely best response for the firm given x^* $[x < x^*]$ opted by the consumer.

the consumer opts for x^* his expected costs are simply x^*, on the other hand, if he opts for some $x < x^*$ his expected costs will be $x + L_c(x, y)$. Therefore, the consumer will opt for a $x < x^*$ only if $x + L_c(x, y) \leq x^*$, i.e., only if $x + y + L_c(x, y) \leq x^* + y$. Since the consumer knows that the y opted by the firm is less than or equal to the socially optimum level of care for the firm, he will know that the sum $x^* + y$ is less than or equal to the minimum TAC. Thus, $x + y + L_c(x, y) \leq x^* + y$ implies that the consumer knows that $x + y + L_c(x, y)$ is less than or equal to the minimum TAC. But, this is a contradiction since when $x \neq x^*$, as is the case here, the consumer already knows that irrespective of y, TAC at (x, y) are greater than the minimum TAC.[18] Thus, he will be better-off choosing x^* rather than any $x \neq x^*$, i.e., opting x^* is a strictly dominant strategy for the consumer. This gives us $s = 0$, in equilibrium. Knowing this the firm will realise that it will be bearing the entire expected loss and will take efficient care. Finally, in view of $s = 0$, $(9)\&(10)$ will be identical with $(2)\&(3)$. Therefore, f is efficient.

Theorem 3 *A product liability rule is efficient for every possible X, Y, L, $(x^*, y^*) \in M$, L_c, satisfying (A5), and every $C(q)$ iff it satisfies the condition NCL.*

Proof: Under any PLR, f, there are two mutually exclusive and jointly exhaustive possibilities: (i) the rule specifies the due care level for the

[18]When the TAC minimizing pair (x^*, y^*) is unique, the assumption that due care for a party (here, the consumer) is set the level appropriate for the objective of TAC minimization implies that the consumer knows x^* from the legal standard, and he knows that whenever $x \neq x^*$, irrespective of the y opted by the firm, TAC at (x, y) will be greater than the minimum TAC, i.e., the sum $x+y+L_c(x, y)$ will be greater than the minimum TAC whenever $x \neq x^*$.

consumer, (ii) it does not.

Case 1: Suppose (ii) holds: When the rule does not specify the due care for the consumer condition NCL cannot be fulfilled (Remark 5). From Proposition 3, this implies that the rule cannot be efficient even when (A3) is satisfied, and the violation of (A3) would further add to the inefficiency of the rule. Thus, when (ii) is true our results hold.

Case 2: Suppose (i) holds: When (i) holds, under any rule, two possibilities arise: either the rule sets the negligence standard for both the parties, or it does not. That is, either the rule sets due standards (Subcase 1) for both the parties, or (Subcase 2) for only the consumer.

Subcase 1: Under this subcase, as is argued before (note n.) the assumption that due standards are set at the efficient levels implies that the consumer will get to know of the TAC minimizing pair of care levels, (x^*, y^*), from the legal standards, which are a part of common knowledge. Therefore, even when $L_c \neq L$, in this case - in view of (A5) - for a rational consumer L_c will be such that $(\forall (x, y) \in X \times Y)[x^* + y^* + L_c(x^*, y^*) \leq x + y + L_c(x, y)]$. Which is same as satisfying (A3). Therefore, assumption (A3) is not needed, in this subcase L_c satisfies the desired property by implication. Also, as argued before, when (A5) holds and L_c is as in (A3), assumption (A3) is not needed. That is, in the subcase, when (A5) holds, (A3) and (A4) are not required. Therefore, in view of Theorem 2 and Remark 4, a PLR is efficient for every X, Y, L, $(x^*, y^*) \in M$, L_c, and every $C(q)$ iff it satisfies the condition NCL.

Subcase 2: In this subcase as there is no legal standard for the firm, the liability assignment cannot be conditioned on the care level of the firm; it will have to be conditioned only on the care level of the consumer. Here, condition NCL would imply that the rule, f, be such that a negligent consumer bears the entire accident loss and a nonnegligent consumer none, i.e., $(\forall h \in [0,1])[g < 1 \rightarrow f(g,h) = (1,0)$ & $g = 1 \rightarrow f(g,h) = (0,1)]$. But, then by Lemma 3, f, is efficient. condition NCL ensures efficiency in this subcase also.

Violation of NCL in this case would mean that: (i) there exists $g \in [0,1)$ such that $[f(g,h) \neq (1,0)]$ irrespective of h, or (ii) $[f(1,h) \neq (0,1)]$, irrespective of h. Now, (i), in particular, implies that there exists $g \in [0,1)$ such that $[f(g,1) \neq (1,0)]$, and (ii), in particular, implies that $f(1,1) \neq (0,1)$.[19] When (i) holds, arguing as in the proof for Lemma 2, it can easily be demonstrated that f cannot be efficient in all contexts. When (ii) holds, as is shown the proof of Proposition 3, even if f is TAC minimizing it cannot be efficient. •

4. Concluding Remarks

The main result of the paper, Theorem 2, establishes that when the consumers' knowledge of the risk is imperfect a necessary and sufficient

[19] Note that when a rule sets due care standard for only one party, say the consumer, (as is the case here) then the care level of the other party, the firm, does not play any role in liability assignment at all, i.e., we are assuming that under a PLR, f, if for some particular h, $f(g,h) = (x', y')$ then $(\forall h \in [0,1])[f(g,h) = (x', y')]$. That is, f is depends only on the proportion of negligence of the party with due care standard, on g in this case. As a matter-of -fact all of the PLRs that set due standard for only one party such as the rules of negligence and the strict liability with defense are like this.

condition for efficiency of a product liability rule is to satisfy the condition NCL. Irrespective of the magnitude of under or over estimation of the risk by the consumers, if a product liability rule f satisfies condition NCL then in every accident context satisfying (A1)-(A4), it is efficient in terms of care, output per firm, and the number of firms in the industry. If f violates the condition then in at least some accident contexts[20] and for some error on the part of the consumers, it will not be efficient in terms of care, output per firm, and the number of firms in the industry.

Now consider the accident contexts wherein either the economic efficiency requires no care by the consumers, or the consumers can take no care, i.e., $X = \{0\}$. Such accident contexts are called unilateral-care accident. In such contexts, $x^* = 0$ and a rule f will satisfy condition NCL iff: $(\forall h \in [0,1])[f(g,h) = (0,1)]$, since in such contexts $g = 1$ always and the case $g < 1$ will not arise. Therefore, a PLR will satisfy NCL iff it holds the firm to be fully liable for accident loss irrespective of the care taken by the two parties, or iff the rule is of strict liability. From the existing literature we know that the rule of strict liability is efficient in such contexts [Polinsky (1980), Shavell (1987, ch 3, pp. 67-68) and Geistfeld (2000)]. In our analysis, condition NCL guarantees efficiency. From Propositions 1 and 2 we know that both the parties will take efficient care with consumer taking no care at all.[21] In view of this,

[20] From the proof of Proposition 3 it should be noted that in principle one can construct infinitely many such contexts.

[21] Note that Propositions 1 and 2 are valid when $x^* = 0$. Of course, when $x^* = 0$ or when $X = \{0\}$, the cases like $x < x^*$ will be trivial logically.

sufficiency of NCL follows from the fact that in such accident contexts, $s = 0$ always, making $(9)\&(10)$ identical with $(2)\&(3)$ as is required by the economic efficiency.

When a rule satisfies condition NCL since the consumer can ensure full compensation in the event of accident merely by taking the due (efficient) level of care, even a risk-averse consumer will not take excessive care. Risk-averse consumer, however, will have a stronger incentive to take due care in order to avoid the risk of bearing accident loss. Therefore, our results will be strengthened if we assume consumers to be risk-averse.

References

Arlen, J (2000), Damages in Encyclopedia of Law and Economics, Bouckaert, Boudewijn and De Geest, Gerrit (eds.), Cheltenham, Edward Elgar.

American Law Institute (1997), *Restatement of the Law (Third) of Torts: Products Liability*, Philadelphia, The American Law Institute.

Arlen, Jennifer H. (1992), 'Book Review: W. Kip Viscusi, Reforming Products Liability', 30 *Journal of Economic Literature*, 2170 ff. Review, 669-717.

Bagwell, Kyle and Riordan, Michael H. (1991), 'High and Declining Prices Signal Product Quality', 81 *American Economic Review*, 224-239.

Beales, J. Howard, III, Craswell, Richard and Salop, Steven C. (1981), 'The Efficient Regulation of Consumer Information', 24 *Journal of Law and Economics*, 491-539.

Beales, J. Howard, III, Craswell, Richard and Salop, Steven C. (1981), 'Information Remedies for Consumer Protection', 71*American Economic Review. Papers and Proceedings*, 410-413.

Ben-Shahar, Omri (1997), 'Should Products Liability be Based on Hindsight?', Working Paper No. 14-97, The Foerder Institute for Economic Research, Tel Aviv University.

Boyd, (1994), Product Risk, liability and Monopoly, *International Journal of Business Economics and Finance*, Vol. 1.

Burrows, Paul (1992), 'Consumer Safety under Products Liability and Duty to Disclose', 12 *International Review of Law and Economics*, 457-

478.

Burrows, Paul (1994), 'Products Liability and the Control of Product Risk in the European Community', 10 *Oxford Review of Economic Policy*, 68-83. Caves, R.E. and Greene, D.P. (1996), 'Brands' Quality Levels, Prices, and Advertising Outlays: Empirical Evidence on Signals and Information Costs', 14 *International Journal of Industrial Organization*, 29-52.

Dari Mattiacci, G (2002), 'Tort Law and Economics', in Hatzis A. ed., *Economics Analysis of Law: A European Perspective*, Edward Elgar.

Epple, Dennis and Raviv, Artur (1978), 'Product Safety: Liability Rules, Market Structure, and Imperfect Information', 68 *American Economic Review*, 80-95.

Geistfeld, Mark (1995a), 'Manufacturer Moral Hazard and the Tort Contract Issue in Products Liability', 15 *International Review of Law and Economics*, 241-257.

Goldberg, Victor P. (1974), 'The Economics of Product Safety and Imperfect Information', 5 *Bell Journal of Economics and Management Science*, 683-688.

Grossman, Sanford J. (1981), 'The Informational Role of Warranties and Private Disclosure about Product Quality', 24 *Journal of Law and Economics*, 461-483.

Hamada, Koichi (1976), 'Liability Rules and Income Distribution in Products Liability', 66 *American Economic Review*, 228-234.

Harvey, Brian, H. and Parry Deborah, L. (2000), *The Law of Consumer Protection and Fair Trading*, 6th Edi., Butterworth, London.

Jain, S.K and Singh, R. (2002), "Efficient Liability Rules: Complete Characterization", Vo. 75, No 2, 105-124.

Jones, P. and Hudson, J. (1996), 'Signalling Product Quality: When is Price Relevant?', 30 *Journal of Economic Behavior and Organization*, 257-66.

Kambhu, John (1982), 'Optimal Product Quality under Asymmetric Information and Moral Hazard', *Bell Journal of Economics,* 483-492.

Landes, W. M. and Posner, R. A. (1987), The Economic Structure of Tort Law, Cambridge (MA), Harvard University Press.

Marino, Anthony M. (1988a), 'Products Liability and Scale Effects in a Long-Run Competitive Equilibrium', 8 *International Review of Law and Economics,* 97-107.

Marino, Anthony M. (1988b), 'Monopoly, Liability and Regulation', 54 *Southern Economic Journal*, 913-927.

McKean, Roland N. (1970b), 'Products Liability: Implications of Some Changing Property Rights', 84 *Quarterly Journal of Economics*, 611-626.

Miceli, T. J. (1997), Economics of the Law: Torts, Contracts, Property, Litigation, Oxford, Oxford University Press.

Milgrom, Paul R. and Roberts, John (1986), 'Price and Advertising Signals of Product Quality', 94 *Journal of Political Economy*, 796-821.

Oi, Walter Y. (1973), 'The Economics of Product Safety', 4 *Bell Journal of Economics*, 3-28.

Polinsky, A. M (1980), 'Strict Liability versus Negligence in a Market Setting', 70 *American Economic Review*

Priest, George L. (1991), 'The Modern Expansion of Tort Liability: Its

Sources, Its Effects, and Its Reform', 5(3) *Journal of Economic Perspectives*, 31-50.

Rose-Ackerman, Susan (1994), 'Product Safety Regulation and the Law of Torts', in Hunziker, Janet R. and Jones, Trevor O. (eds), *Product Liability and Innovation: Managing Risk in an Uncertain*

Satterthwaite, Mark A. (1979), 'Consumer Information, Equilibrium Industry Price, and the Number of Sellers', 10 *Bell Journal of Economics*, 483-502.

Schlee, Edward E. (1996), 'The Value of Information about Product Quality', 27*RAND Journal of Economics*, 803-815.

Schwartz, Alan (1995), 'Legal Implications of Imperfect Information in Consumer Markets', 151 *Journal of Institutional and Theoretical Economics*, 31-48.

Schwartz, Alan and Wilde, Louis L. (1985), 'Product Quality and Imperfect Information', 52 *Review of Economic Studies*, 251-262.

Shavell, S. (1987), Economic Analysis of Accident Law, Cambridge (MA), Harvard.

Simon, Marilyn J. (1981), 'Imperfect Information, Costly Litigation, and Product Quality', 12 *Bell Journal of Economics*, 171-184.

Smallwood, Dennis E. and Conlisk, John, (1979) 'Product Quality in Markets Where Consumers are Imperfectly Informed', 93 *Quarterly Journal of Economics*, 1-23.

Spence, A. Michael (1975), 'Monopoly, Quality and Regulation', 6 Bell Journal of Economics, 417-429.

Spence, A. Michael (1977), 'Consumer Misperception, Product Failure and Product Liability', 44 *Review of Economic Studies*, 561-572.

Viscusi, W. Kip (1991a), Reforming Products Liability, Cambridge, MA, Harvard University Press.

Viscusi, W. Kip (1991b), 'Product and Occupational Liability', 5(3) *Journal of Economic Perspectives*, 71-91.