Optimal Negligence Rules When Costs of Care Differ

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There has been considerable controversy about the efficiency of tort liability negligence rules. Until recently, it had been widely accepted that the contributory negligence rule, which excused the injurer if the victim were negligent, was efficient, even if it was unfair to victims. On the other hand, the comparative negligence rule, which allocated the damages based on the relative negligence of the parties, was considered inefficient.

This view has been challenged by legal scholars such as Haddock and Curran (1985), Cooter and Ulen (1986), and Rubinfeld (1987). It is now the consensus that, if individuals all have the same cost of taking care and those costs are known, then the comparative and contributory negligence rules have the same effect on care, and a comparative negligence rule is efficient.

Rubinfeld considers a more realistic model where individuals face different costs of taking care. He argues that comparative negligence could not be less efficient than contributory negligence since the latter is a special case of the former. He also claims that comparative negligence provides greater incentives for potential injurers to take care because they are at least partially liable in more circumstances.

Rubinfeld compares a comparative negligence with a contributory negligence rule in a numerical example where potential victims experience the same costs of taking care while the cost of taking care for injurers varies over a known range. He shows that the comparative negligence rule results in a more efficient outcome. We show, however, that Rubinfeld did not consider the most efficient standard of care in his example. When the standard is set at an optimal level, contributory negligence cannot be improved upon, and will dominate any comparative negligence rule other than the optimal contributory negligence rule.

We also examine the symmetric case to Rubinfeld, where there is a injurers experience a single cost of care, but the cost of taking care for potential victims varies over a known range. We show that in this case, too, the legal standards of care can be chosen to ensure that the contributory negligence rule achieves the first best outcome.

An important application of this symmetric case involves a single firm facing a group of potential victims with a range of costs of taking care.[1] There is no consensus on whether the injurer should be required to take care that is appropriate for the least cost, the highest cost or the average potential victim. *Prosser and Keeton on the Law of Torts*[2] argue that a person has a duty to take precautions against the negligence of others. This may imply that one cannot be exempted from liability as a result of negligence of the other party. Restatement (Second) of Torts §466 expresses a similar view. Judge Posner, however, in *Pomer v. Schoolman*[3] stated:

> A person cannot be deemed negligent for failing to take precautions against an accident that potential victims could avoid by the exercise of elementary care; negligence is the failure to take care necessary and proper to prevent injury to reasonably careful persons.

In *McCarty v. Pheasant Run*,[4] he said:

> It is a bedrock principle of negligence law that due care is that care which is optimal given that the potential victim is himself reasonably careful; a careless person cannot by his carelessness raise the standard of those he encounters.[5]

Our results on the efficient standard of care support Posner's position.

In the more general case where both injurers and victims differ in their costs of care, we find in a wide range of numerical examples that the best contributory negligence rule leads to expected costs that are quite close to the unattainable first best. As a result, there is little room to improve upon the efficiency of contributory negligence.

In particular, we show that while comparative negligence can in theory achieve a better outcome than contributory negligence, in practice it is unlikely to do so. The choice of care is difficult to predict under feasible comparative negligence rules. As a result, the optimal comparative negligence rule often cannot be determined, even in very simple cases. When an optimal rule is difficult to determine, the courts may drift aimlessly from one standard to another. A consensus on the appropriate standards of care in different situations is unlikely to develop.

By contrast, the optimal contributory negligence standards of care can be determined under very

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1. More generally, even when there are several firms in the same industry, they are likely to have access to the same technology for controlling risks, and they should face similar costs for employing that technology.

2. Keeton 5th ed. (1984)

3. 875 F.2d 1262 (7th Cir. 1989)

4. 826 F.2d 1554 (7th Cir. 1987)

5. See Barnes and Stout (1992) at p. 110.

general circumstances. There is therefore a greater likelihood that courts may eventually settle on appropriate standards through a gradual, decentralized process that builds on precedents. The single legal standard under contributory negligence will assist such an evolutionary process by reducing the number of dimensions along which decisions can vary.

We show in a wide range of numerical examples that almost all injurers meet their legal standard of care under the optimal contributory negligence rule. Furthermore, those who choose not to meet the standard will display a level of care that is considerably below the legal standard. Parties who have not met the legal standard thus are easy to identify and unnecessary litigation is therefore discouraged in the remaining cases. By contrast, the lower predictability of outcomes of cases under comparative negligence may encourage potential litigants to gamble on obtaining a sympathetic judge or jury even when their case appears weak.

In the very special cases where we can calculate optimal comparative negligence standards, we do find that the optimal comparative negligence regime is more efficient than the optimal contributory negligence regime. However, we also find that the optimal comparative negligence rule can be dominated by a modified contributory negligence rule in these cases.

An interesting implication of our results is that the optimal contributory negligence rule fails to achieve the first best outcome primarily because it encourages injurers to take *too much* care. While contributory negligence appears to favor injurers in cases that come to trial, it actually favors victims in the ex-ante sense that injurers are encouraged to over-invest in care. The fairness of legal rules needs to be judged not only on the basis of how those rules apportion costs in the event that litigation occurs but also on the way the rules affect the distribution of expenditures undertaken to avoid litigable outcomes.

1. Model

Assume there are two classes of risk neutral individuals, injurers and victims. The probability of an accident is $P(x,y)$, $0 < P(x,y) \leq 1$, where x is the care taken by an injurer and y is the care taken by a victim.[6] For most of the paper,[7] we assume:

6. "Care" is likely to include the level of participation in potentially dangerous activities in addition to actions that reduce the accident probability while undertaking those activities. However, including participation in an activity in the standard of care would involve the judge or jury making judgements about the social utility of an individual's activity. Note that strict liability forces potential injurers to internalize the level of their activity.

A1. $P_x(x,y)<0$, $P_y(x,y)<0$, $P_{xx}(x,y)>0$ and $P_{yy}(x,y)>0$.

A1 says that increased care by either party always decreases the accident probability, but the reduction in accident probability from additional care declines as the care already being taken increases. We thus implicitly assume that individuals take the most effective preventive measures first. We allow P_{xy} to be positive or negative, so care by one party can increase or decrease the effectiveness of care by the other party.[8]

Let $D > 0$ be the expected loss resulting from an accident. To simplify the analysis, we assume D is independent of x and y. We can then normalize by dividing through by D and expressing costs as a *proportion* of the expected loss.

When both parties have heterogeneous costs of care, we assume the injurer's cost of care as a proportion of D is c_1nx, and the victim's cost of care as a proportion of D is c_2my, where m and n have probability distributions $F(m)$ and $G(n)$ on the interval [0,1]. Hence, $c_1 > 0$ and $c_2 > 0$ represent the maximum marginal costs of taking care as a proportion of the expected loss D. We assume that the distributions of the costs as reflected in $F(m)$, $G(n)$, c_1 and c_2 are public knowledge.

Care x and y are assumed to be at least *ex-post* measurable or capable of being determined through litigation. Following Rubinfeld (1987), we assume, however, that in any particular case, m and n, and therefore the costs of taking care as a proportion of D, are known only to the individuals. As Rubinfeld observes, the costs of care and damages could all involve non-monetary factors or depend on circumstances that are difficult to monitor. Both the legal standards of care and the decisions of potential injurers or victims should then be based on the *distributions* of costs (relative to D) for injurers and victims.

1.1 The Social Optimum

The expected costs cannot be lower than in the *hypothetical* situation where costs are verifiable and all individuals can be forced to exercise their individually optimal amount of care. These "socially optimal" care levels $x(n)$ and $y(m)$ would minimize the *expected* cost of the accident *plus*

[7] In the numerical analysis, we also consider the special case where own-care is ineffective when the other party is taking no care at all. Algebraically, we then have $P_x = 0$, $P_{xx} = 0$ when $y = 0$, and $P_y = 0$, $P_{yy} = 0$ when $x = 0$.

[8] For example, placing "child-proof" locks on bottles could make parents less careful about where they leave medicines. On the other hand, providing clear instructions can help consumers take more effective action to prevent accidents.

the total expenditure on care:

$$\int_0^1\int_0^1 P(x(n),y(m))dF(m)dG(n)+c_1\int_0^1 nx(n)dG(n)+c_2\int_0^1 my(m)dF(m)\,. \tag{1}$$

The first order conditions for the first best solution are, for each n,

$$\int_0^1 P_x(x(n),y(m))dF(m)+c_1 n=0 \tag{2}$$

and, for each m,

$$\int_0^1 P_y(x(n),y(m))dG(n)+c_2 m=0\,. \tag{3}$$

1.2 Liability Rules

In practice, the courts can only assign liability for an accident once it has occurred. Let $r(x,y)$ be the fraction of damages borne by the injurer and $\rho(x, y)$ the fraction borne by the victim. Ignoring punitive damages, and assuming litigation costs are in D, we must have $r(x, y) = 1 - \rho(x, y)$.

In response to rule $r(x,y)$, an injurer with marginal cost of care $c_1 n$ would choose $x(n)$ to minimize

$$\int_0^1 r(x,\tilde{y}(m))P(x(n),\tilde{y}(m))dF(m)+c_1 nx(n) \tag{4}$$

where $\tilde{y}(m)$ is the care of victims with cost $c_2 m$. Similarly, if $\tilde{x}(n)$ is the care of injurers with cost $c_1 n$, a victim with marginal cost of care $c_2 m$ would choose $y(m)$ to minimize

$$\int_0^1 \rho(\tilde{x}(n),y(m))P(\tilde{x}(n),y(m))dG(n)+c_2 my(m)\,. \tag{5}$$

1.3 Contributory Negligence

The defence of contributory negligence absolves an injurer from liability whenever there was any negligence on the part of the victim. The function $r(x,y)$, illustrated in Figure 1, is defined as

$$r(x,y)=\begin{cases}1 & x<\hat{x} \text{ and } y\geq\hat{y}\\ 0 & \text{elsewhere}\end{cases} \tag{6}$$

where $\hat{x}>0$ and $\hat{y}>0$ are the legal standards of care.

The victim share, ρ(*x*, *y*) = 1 −*r*(*x*, *y*), is

$$\rho(x,y) = \begin{cases} 1 & x \geq \hat{x} \text{ or } y < \hat{y} \\ 0 & \text{elsewhere} \end{cases} \tag{7}$$

Contributory negligence has been criticized for being unfair to victims. In particular, if both parties have met their respective standards of care, or both are deemed negligent, the victim cannot recover any compensation from the defendant.

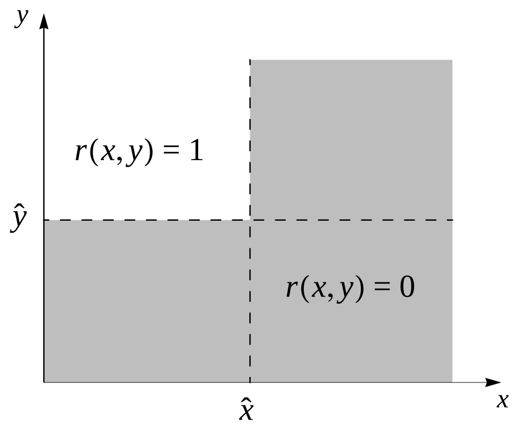

FIGURE 1. Liability of injurers under contributory negligence

Optimal Standards. If $x^*(n,\hat{x},\hat{y})$ and $y^*(m,\hat{x},\hat{y})$ denote the care taken in response to standards $\hat{x}$ and $\hat{y}$, then optimal legal standards, $\hat{x}$ and $\hat{y}$ minimize the expected social cost

$$V(\hat{x},\hat{y}) = \int_0^1\int_0^1 P(x^*,y^*)dF(m)dG(n) + c_1\int_0^1 nx^*dG(n) + c_2\int_0^1 y^*mdF(m) \tag{8}$$

2. One class homogeneous

Throughout this section, we assume, in addition to A1 above:

A2. The first best problem has a unique solution requiring care by some people in each party.

Theorem 1: If the injurers are heterogeneous, and the victims are homogeneous, in their cost of care, and the problem satisfies A1, A2 and also $P_{xy}(x,y) > 0$, then a contributory negligence rule can achieve the efficient allocation by picking the legal standard of the victim to be the solution of the first best problem and the legal standard of the injurer to be such that no injurer will achieve it.
Proof: If the victims meet the legal standard, an injurer who does not meet the legal standard will be liable. The injurer would then choose the level of care that minimizes the expected cost of the

accident plus the cost of care, which results in the first best level of care. If all injurers choose a level of care below their legal standard $\hat{x}$, victims would not choose care above their legal standard $\hat{y}$ since the additional care would bring no additional benefits while incurring an additional cost. Victims also would not take less than the legal standard of care. In particular, if all victims but one choose the legal standard (which is also the first best care for victims), the remaining victim's costs will be minimized by choosing the legal standard. This follows since the first order condition for the lone deviant victim is identical to the first order condition for the first best problem, and A2 ensures that the first best problem has a unique solution. Finally, if *all* victims choose less than the legal standard of care, injurers would not be liable and would minimize costs by choosing zero care. Since P_{xy} and $P_{yy} > 0$, the marginal benefit of care by victims is then higher than it would be if they were solving the first best problem (where at least some $x > 0$) and they would choose a $\tilde{y} > y^*$. But then their costs would exceed their costs when they choose y^*, which would only be cy^* since they do not bear the cost of the accident when $\tilde{y} = \hat{y} = y^*$.

Remark. A1 is needed so that the optimization problem faced by the individuals is well behaved. Neither party can benefit from deviation from the optimum level of care when A1 holds, so the optimum is a Nash equilibrium. A2 is necessary for existence of the legal standard.

Remark. Since the standard for injurers is set so that none of them will achieve it, the optimal contributory negligence rule in this case is equivalent to a regime where the injurer is exempt from liability *only if* $y < \hat{y}$.

The symmetric case, where injurers are homogeneous and victims are heterogeneous, includes situations where the injurer is a firm, or a group of firms with similar costs of controlling risks, and the possible injured are customers.

Theorem 2: If the injurers are homogeneous and the victims are heterogeneous in their cost of care, and the problem satisfies A1 and A2, then a contributory negligence rule can achieve the first best allocation by setting the legal standard of the injurer to be the solution of the first best problem and the legal standard of the victim to be zero.

Proof: Since the victim always meets the legal standard, the injurer will be liable unless care meets the legal standard. The legal standard was chosen to be the first best level of care, and thus the level of care that minimizes the expected cost of the accident plus the cost of care for the injurer. When the injurer is liable, therefore, expected private costs for the injurer are minimized by choosing the legal standard. If the injurer meets the legal standard, however, each victim will bear the cost and will choose the level of care that minimizes the expected cost of the accident plus the cost of care, which is the first best level of care. Property A1 ensures that neither party can benefit by deviating from this level of care so it is a Nash equilibrium.

Remark. Since the legal standard of the victim is zero, the optimal contributory negligence rule in this case is equivalent to a negligence rule without a defense of contributory negligence.

Theorem 3: All comparative negligence rules are weakly dominated by the optimal contributory negligence rule, with equality holding only when the comparative negligence rule mimics the contributory negligence rule.

Proof: Since the optimal contributory negligence rule can achieve first best, it can never be dominated by a comparative negligence rule and any comparative negligence rule that results in a different level of care than the optimal contributory negligence rule will not do as well.

2.1 Appropriate standards of care when only victims are heterogeneous

The Hand Rule from *Carroll Towing*[9] or the marginal version of the Hand Rule suggested by Posner, serve to define the legal standard of care when individuals are homogeneous. The appropriate level of care is more difficult to define when individuals are heterogeneous.

We conclude from Theorem 2 that *the standard of care for the injurer should be set at the first best level of care, while the standard of care for the victims is set at zero*. The first best level of care for the injurer involves choosing x^* to minimize

$$V = \int_0^1 P(x, y^*(m))dF(m) + cx + c_2\int_0^1 my^*(m)dF(m) \tag{9}$$

where $y^*(m)$ is the first best level of care of victims. The first order condition for x^* satisfies

$$\int_0^1 P_x(x, y^*(m))dF(m) + c = 0\,. \tag{10}$$

Now choose $y^*(\hat{m})$ such that

9. United States v. Carroll Towing Co 159 F.2d 169 (2d Cir. 1947)

$$\int_0^1 P_x(x^*, y^*(m))dF(m) = P_x(x^*, y^*(\hat{m})) . \tag{11}$$

From Theorem 2, $y^*(\hat{m})$ can be thought of as the "representative" victim care applicable for calculating the optimal contributory negligence legal standard for an injurer. Specifically, when victims are heterogeneous, *the injurer should be held to a standard of care that equates the marginal costs and benefits of injurer care assuming victims take a level of care equal to* $y^*(\hat{m})$. We designate $\hat{m}$ as a measure of the cost of care of the "reasonably careful potential victim."

2.2 The "reasonably careful" versus the "average" potential victim

The mathematical model allows us to distinguish the member of the group who has average costs of taking care and the member who makes an average level of expenditures on care. In practice, judges and juries are unlikely to have the data necessary to make such fine distinctions. However, the model does provide support for a traditional common law definition of the reasonably prudent person as average.[10]

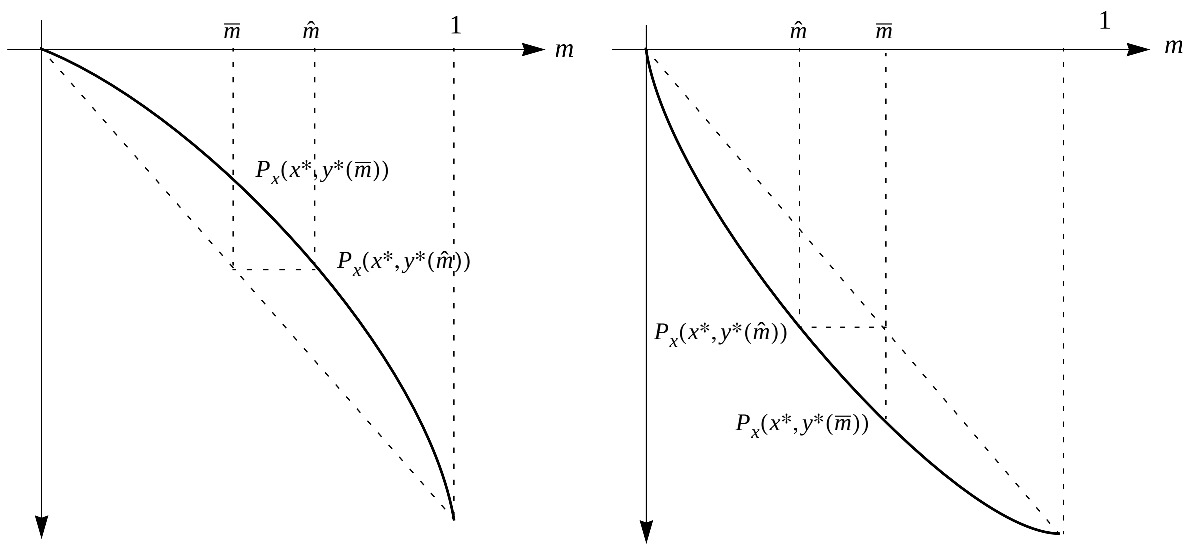

FIGURE 2. The relationship between $\hat{m}$ and $\overline{m}$ when care is substitutable

The relationship between $c_2\hat{m}$ and the average cost of care for victims $c_2\overline{m}$ when care is substitutable can be explained with the aid of Figure 2. Essentially, it depends on the degree of concavity or convexity of P_x as a function of m and on the degree of dispersion of the distribution $F(m)$ of

10. See Posner (1992) at 167.

victims by their cost of care.

For a given x^*, the first order condition for the choice of victim care $y^*(m)$ satisfies

$$P_y(x^*, y^*(m)) + c_2 m = 0\,. \qquad (12)$$

If $P_{yy} > 0$, increases in m will reduce $y(m)$. Then, if care by injurers and victims is substitutable, $P_{xy} > 0$ and $P_x(x^*, y^*(m))$ will be a decreasing function of m.

If victims did not differ in their cost of care, $F(m)$ would have all its probability mass concentrated at a single point m^* and we would have $\hat{m} = \overline{m} = m^*$. If we now consider mean-preserving spreads in the distribution $F(m)$, $\hat{m}$ will rise above $\overline{m}$ for P_x a concave function of m (left side of Figure 2) and fall below $\overline{m}$ for P_x a convex function of m (right side of Figure 2). Figure 2 illustrates the situation of maximum dispersion in $F(m)$ where probability mass is allocated only to the extremes $m = 0$ or $m = 1$ in such a way that the mean of m is $\overline{m}$.

If care by injurers and victims complement each other, $P_{xy} < 0$ and $P_x(x^*, y^*(m))$ increases in m. The relationship between $\hat{m}$ and $\overline{m}$ and the concavity or convexity of $P_x(x^*, y^*(m))$ is then reversed from the situation in Figure 2. If $P_x(x^*, y^*(m))$ is approximately linear in m, $\hat{m}$ will be very close to $\overline{m}$ regardless of the dispersion in the distribution $F(m)$.

These results suggest that $\hat{m}$ is unlikely to differ greatly from $\overline{m}$. To say more, however, we need to specify the technology $P(x,y)$ for reducing accident probabilities. Three particular technologies are examined in appendix 1. The results indicate that the appropriate level of care is that which is adequate for the *average* member of the population. This result supports Judge Posner's position rather than the position taken by Restatement (Second) of Torts §466 on the appropriate level of care. This point can be illustrated by the following cases.

In *McCarty v Pleasant Run, Inc*. the plaintiff was a woman who was attacked in her hotel room by an intruder who entered by way of a sliding glass door that had been left unlocked. Posner argues:

> A notice in every room to lock all doors would be cheap, but *most people* know better than to leave the door to a hotel room unlocked when they leave the room …[11] [emphasis added]

This is a case where care of both parties is complementary. A "lock to foil a Houdini … would have thus done her no good …"[12] if she failed to lock the door.

11. 826 F.2d 1554,1557.

12. 826 F.2d 1554,1560.

This decision can be contrasted to *O'Brien V. Muskin Corp.*[13] where a twenty-three year old man dove (possibly from the roof of an eight foot garage) into an above ground swimming pool that was four foot deep. This case was reversed and remanded under a risk-utility theory where the jury would evaluate:

> whether, because of the dimensions of the pool and the slipperiness of the bottom, the risks of injury so out weighted the utility of the product as to constitute a defect.[14]

However, if the average adult knows that diving into a four foot above ground swimming pool is not prudent, then it is not optimal to impose on the manufacturer the duty to guard against such behavior. Evaluating what one can expect of the average adult is easier for the jury than evaluating the social utility of a swimming pool.

3. Both classes heterogeneous

When both injurers and victims differ in their costs of care, in general no liability or negligence regime will induce all parties to take efficient care. We find for a very wide range of examples, however, that the best contributory negligence rule attains expected costs that are *very close* to the efficient levels.

3.1 The choice of care under a contributory negligence rule

The following results show that no injurer will take more than the legal standard level of care, while care by both injurers and victims is likely to be discontinuous.

Theorem 4: Under contributory negligence, no injurer would choose $x > \hat{x}$.

Proof: For $x \geq \hat{x}$, $r(x, y) = 0$, and expected costs $c_1 nx$ would be minimized by setting $x = \hat{x}$.

Theorem 5: Under contributory negligence, if $y < \hat{y}$ for all victims, then $x = 0$ for all injurers. If $y \geq \hat{y}$ for some victim then either $x = \hat{x}$ for all injurers, or x will jump discontinuously at $\hat{x}$.

Proof: If $y < \hat{y}$ for all $m \in [0,1]$, $r(x, y) = 0$, and expected costs $c_1 nx$ would be minimized by $x = 0$. If $y(m^*) \geq \hat{y}$ for some $m^* \in [0,1]$, then $y(m) \geq \hat{y}$ for all $m \leq m^*$. Let m_1 be the maximum value of m such that $y(m) \geq \hat{y}$. An injurer choosing $x < \hat{x}$ would, from (4), solve:

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13. 94 N.J. 169, 463 A.2d 298.

14. A careful analysis of the risk utility theory is beyond the scope of this paper. However, elementary economics suggests that if the purchaser is willing to buy the product, then the utility of the product must exceed the price the individual paid. This observation does not account for possible externalities associated with the use of the product. However, we conjecture that the purchaser is usually in a better position than the manufacturer to mitigate most of these externalities.

$$\int_0^{m_1} P_x(x,\tilde{y}(m))dF(m) = -c_1 n \qquad (13)$$

Since $P_{xx} < 0$, for a given $\tilde{y}(m)$ the solution of (13) for $x(n)$ will be decreasing in n. In particular, if $x(1) \geq \hat{x}$ then $\tilde{x}(n) = \hat{x}$ for all $n \in [0,1]$. Now assume that $x(1) < \hat{x}$, as illustrated in Figure 3:

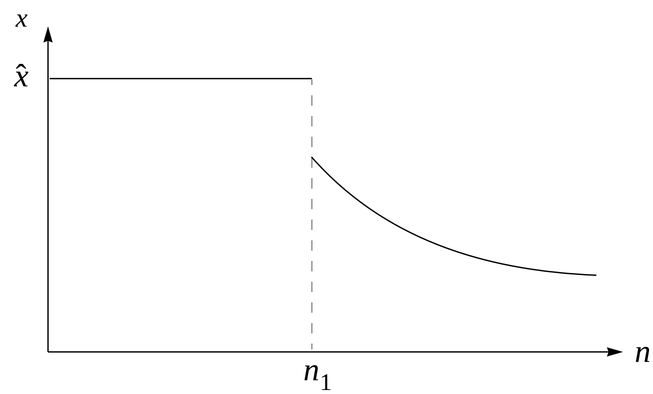

FIGURE 3. Care taken by injurers in the discontinuous case

As n decreases, $x(n)$ will increase. Since $P_x < 0$ is monotonic increasing, as $n \to 0$, there must be a solution of (13) for $x(n) > \hat{x}$, but by Theorem 4 low n individuals would choose $\hat{x}$. An injurer would switch from $x < \hat{x}$ to $x = \hat{x}$ for n_1 given by

$$\int_0^{m_1} P(x(n_1),\tilde{y}(m))dF(m) + c_1 n_1 x(n_1) = c_1 n_1 \hat{x}, \qquad (14)$$

$\tilde{x}(n) = x(n)$ for $n > n_1$, while $\tilde{x}(n) = \hat{x}$ for $n \leq n_1$. But $x(n)$ is discontinuous at n_1 since

$$\int_0^{m_1} P(x(n_1),\tilde{y}(m))dF(m) > 0$$

with (14) implies that $\hat{x} > x(n_1)$.

Lemma 1: If some injurers and victims have arbitrarily small marginal costs of care, then under contributory negligence some injurers will choose $x = \hat{x}$ and some victims will choose $y > \hat{y}$.

Proof: A victim setting $y < \hat{y}$ will have $\rho(x,y) = 1$ and will choose y to solve:

$$\int_0^1 P_y(\tilde{x}(n),y(m))dG(n) = -c_2 m \qquad (15)$$

For a given $\tilde{x}(n)$, since $P_y < 0$ and monotonic increasing, as $m \to 0$ there must be a solution to (15) for $y(m) \geq \hat{y}$. Thus, some victims will choose $y \geq \hat{y}$. Then by Theorem 5, some injurers, say those with $n < n_1 \leq 1$, will choose $x = \hat{x}$. For $y \geq \hat{y}$, $\rho(x,y) = 0$ for $n > n_1$ and $\rho(x,y) = 1$ for $n \leq n_1$. Hence, a victim choosing $y \geq \hat{y}$ would solve

$$\int_0^{n_1} P_y(\hat{x}, y)\, dG(n) = -c_2 m \tag{16}$$

Again for $P_y < 0$ and monotonic increasing, as $m \to 0$ there must be a solution to (16) for $y > \hat{y}$.

Theorem 6: Under contributory negligence, if some victims choose $y < \hat{y}$ and some injurers choose $x < \hat{x}$, then care by victims will be discontinuous at $\hat{y}$ as graphed in Figure 4.

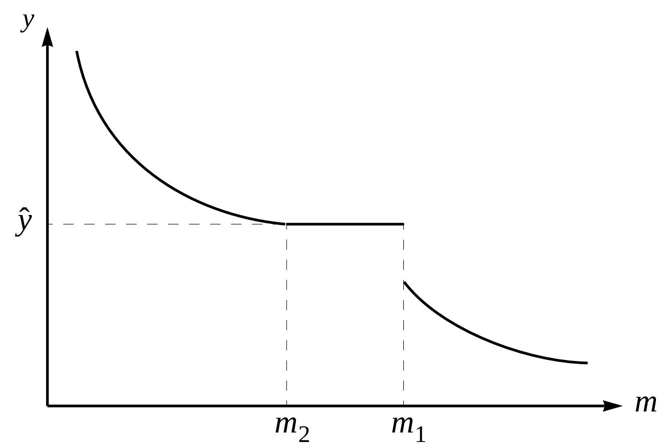

FIGURE 4. Care taken by victims

Proof: From Lemma 1, some victims will choose $y(m) \geq \hat{y}$ to solve (16). Since $P_{yy} > 0$, the solution $y(m)$ to (16) will be decreasing in m. Since, by assumption, some victims choose $y < \hat{y}$, there must be a value of m, say $0 < m_2 < 1$, such that $y(m_2) = \hat{y}$ and $y(m) < \hat{y}$ for all $m > m_2$. However, a victim choosing $y < \hat{y}$ would bear the costs of all accidents regardless of injurer care. Since some injurers choose $x < \hat{x}$, there will be some $0 < n_1 < 1$ such that all injurers with $n \leq n_1$ choose $x = \hat{x}$. Victim care would then be determined by the solution to

$$\int_0^{n_1} P_y(\hat{x}, y)\, dG(n) + \int_{n_1}^{1} P_y(\tilde{x}(n), y)\, dG(n) = -c_2 m\,. \tag{17}$$

Denote the solution to (17) for y by $Y(m)$. Since $P_{yy} > 0$, $Y(m)$ will be decreasing in m. Because some injurers choose $y < \hat{y}$ we must have $Y(1) < \hat{y}$, but $Y(m)$ will increase as m decreases. Victims would switch from $Y(m) < \hat{y}$ to $Y(m) = \hat{y}$ when the *total* expected costs of the actions are equal. Since $\rho(x(n),\hat{y}) = 0$ for $n > n_1$ and $\rho(x(n),\hat{y}) = 1$ for $n \leq n_1$, total costs will be equal at m_1 given by

$$\int_0^{n_1} P(\hat{x}, Y(m_1))dG(n) + \int_{n_1}^{1} P(\tilde{x}(n), Y(m_1))dG(n) + c_2 m_1 Y(m_1) = \int_0^{n_1} P(\hat{x}, \hat{y})dG(n) + c_2 m_1 \hat{y}\,. \qquad (18)$$

Since $\tilde{x}(n) < \hat{x}$ for $n > n_1$, and P is decreasing in x, (18) implies

$$c_2 m_1(\hat{y} - Y(m_1)) > P(\hat{x}, Y(m_1)) - P(\hat{x}, \hat{y})G(n_1)\,. \qquad (19)$$

Since P is also decreasing in y and $G(n_1) \le 1$, (19) implies that $Y(m_1) < \hat{y}$. Since, for the same value of y, the left hand side of (17) is necessarily more negative than the left hand side of (16), the value of m such that $Y(m) = \hat{y}$, say m^*, will exceed m_2 where $y(m_2) = \hat{y}$. Then since $Y(m)$ is decreasing in m, we conclude that $m_1 > m^* > m_2$. Care therefore will be discontinuous at m_1:

$$\tilde{y}(m) = \begin{cases} y(m) > \hat{y} & \text{for } m < m_2 \\ \hat{y} & \text{for } m_2 \le m \le m_1 \\ Y(m) < \hat{y} & \text{for } m_1 < m \end{cases} \qquad (20)$$

3.2 A comparative negligence rule

We model a comparative negligence rule as a choice by the courts of an injurer liability function:

$$r(x,y) = \begin{cases} 1 & \text{for} & x \le \hat{x}_1, y \ge \hat{y}_1 \\ \sigma(x) & \text{for} & \hat{x}_1 \le x \le \hat{x}_2, y \ge \hat{y}_1 \\ \tau(y) & \text{for} & x \le \hat{x}_1, \hat{y}_1 \le y \le \hat{y}_2 \\ \sigma(x)\tau(y) & \text{for} & \hat{x}_1 \le x \le \hat{x}_2, \hat{y}_1 \le y \le \hat{y}_2 \\ 0 & \text{for} & x \ge \hat{x}_2 \text{ or } y \le \hat{y}_1 \end{cases} \qquad (21)$$

that involves two standards of care $\hat{x}_1$ and $\hat{x}_2$ for injurers, two standards $\hat{y}_1$ and $\hat{y}_2$ for victims, and two “sharing functions” $\sigma(x)$ and $\tau(y)$ that are fractions between zero and one.[15] The function is graphed in Figure 5.

An injurer taking care $x > \hat{x}_2$ will not be liable regardless of the care taken by the victim. A victim choosing $y < \hat{y}_1$ will be unable to recover damages regardless of the care x taken by the injurer. An injurer setting $x < \hat{x}_1$ will face full liability if the victim has chosen $y > \hat{y}_2$, while if y is

15. There are two other rules that have been adopted. One is the equal fault under which a victim cannot recover if his fault is equal to or greater than the injurer. The other is the greater fault rule under which the victim is barred from recovering if his fault is greater than that of the injurer (Prosser and Keeton at 472).

between $\hat{y}_1$ and $\hat{y}_2$, the liability borne by the injurer, $\tau(y)$, will approach zero as y decreases to $\hat{y}_1$ and approach one as y increases to $\hat{y}_2$. When $y \geq \hat{y}_2$ and x is between $\hat{x}_1$ and $\hat{x}_2$, injurer liability $\sigma(x)$ will be between zero and one and will approach zero as $x \to \hat{x}_2$ and approach one as $x \to \hat{x}_1$. When both parties have exercised care between the two legal standards, the liability borne by the injurer $r(x,y)$ has to be $\sigma(x)^a\tau(y)^b$ for a, $b > 0$ if liability is to be a continuous monotonic function of care levels (as specified in (21), we shall only consider $a = b = 1$). Then the liability borne by an injurer, $r(x,y) \to \sigma(x)$ as $y \to \hat{y}_2$ while $r(x,y) \to \tau(y)$ as $x \to \hat{x}_1$.

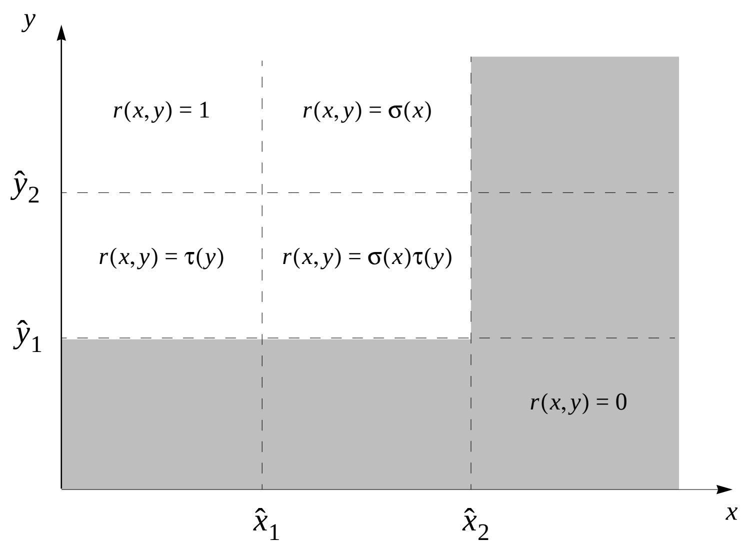

FIGURE 5. Injurer liability under comparative negligence

Rubinfeld (1987) observed that contributory negligence is a special case of comparative negligence where, in our notation, $\hat{x}_1 = \hat{x}_2$ and $\hat{y}_1 = \hat{y}_2$. Since the sharing rules $\sigma(x)$ and $\tau(y)$ are undefined in the limiting case, however, contributory negligence may not be a member of the set of comparative negligence standards with sharing rules of a particular functional form.

It might be thought that, since comparative negligence phases in liability gradually, care is likely to be continuous. The following results show, however, that this intuition is not valid.

Lemma 2: The cost minimizing x and y under comparative negligence are not continuous unless the *derivatives* of $r(x,y)$ and $\rho(x,y)$ are continuous.

Proof: The cost minimizing x and y are determined by equating the marginal benefits to the marginal costs of care. The marginal benefits depend on the derivatives of $r(x,y)$ and $\rho(x,y)$.

Theorem 7: Functions σ(x) and τ(y) that phase in responsibility linearly over the ranges $[\hat{x}_1, \hat{x}_2]$ and $[\hat{y}_1, \hat{y}_2]$ (and so assign liability in proportion to fault) will not have continuous derivatives.

Proof: In this case, the functions σ(x) and τ(y) are given by

$$\sigma(x) = \frac{\hat{x}_2 - x}{\hat{x}_2 - \hat{x}_1} \text{ and } \tau(y) = \frac{y - \hat{y}_1}{\hat{y}_2 - \hat{y}_1}$$

and the derivatives of σ(x) and τ(y) at $\hat{x}_1$ and $\hat{y}_2$ are

$$\sigma'(\hat{x}_1) = \frac{-1}{\hat{x}_2 - \hat{x}_1} < 0 \text{ and } \tau'(\hat{y}_2) = \frac{1}{\hat{y}_2 - \hat{y}_1} > 0 \ .$$

However, as $x \to \hat{x}_1$ from below, $r_x(x,y) = 0$ and as $y \to \hat{y}_2$ from above $r_y(x,y) = 0$.

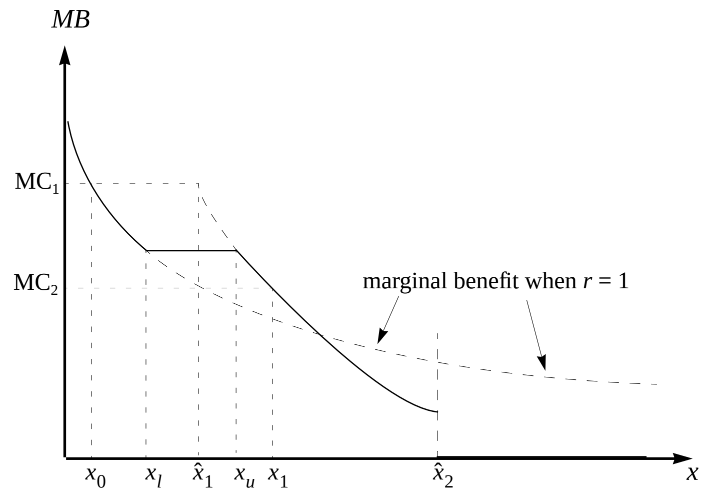

FIGURE 6. Marginal benefit of injurer care

Marginal Benefit of Injurer Care. When $x > \hat{x}_2$, the marginal benefit of care is zero. Also, when $x < \hat{x}_1$ the marginal benefit of care reflects only the reduction in accident probability whereas in the intermediate range $[\hat{x}_1, \hat{x}_2]$, the marginal benefit of care also reflects a reduction in cost *share*. The marginal benefit of additional care therefore is likely to increase discontinuously at $\hat{x}_1$ and decrease discontinuously at $\hat{x}_2$ as graphed in Figure 6.

Theorem 8: When σ(x) is continuous at $\hat{x}_1$ but has a discontinuous derivative, injurer care under comparative negligence would jump discontinuously from x_l to x_u where $x_l < \hat{x}_1 < x_u$.

Proof: If the *marginal* cost of care equals MC_1 in Figure 6, marginal benefit and marginal cost can be equated by choosing $x = x_0 < \hat{x}_1$ or $x = \hat{x}_1$. Since σ(x) is continuous at $\hat{x}_1$, the *total* benefits of care are also continuous at $\hat{x}_1$. When the marginal cost of care equals MC_1, however, private expected accident cost *plus* the cost of care are *minimized* in region $[0, \hat{x}_1)$ by setting $x = x_0$

and hence are lower when $x = x_0$ than when $x = \hat{x}_1$. If the marginal cost of care equals MC_2 in Figure 6, marginal benefit and marginal cost can be equated by choosing $x = x_1 > \hat{x}_1$ or $x = \hat{x}_1$. Private expected costs are *minimized* in region $[\hat{x}_1, \hat{x}_2]$ by setting $x = x_1$, while the private expected costs of $x = \hat{x}_1$ are identical in the two regions. Therefore, private net costs are lower at x_1 than they would be at $\hat{x}_1$. Thus, when the marginal cost of care is MC_1, the cost minimizing x lies in $[0, \hat{x}_1)$, and when the marginal cost of care is MC_2, the cost minimizing x lies in $[\hat{x}_1, \hat{x}_2]$. An injurer would increase x from $x_l < \hat{x}_1$ to $x_u > \hat{x}_1$ at some marginal cost between MC_1 and MC_2 where the private expected costs of choosing x_l or x_u are equal.

Corollary: Continuity in the derivatives of $\sigma(x)$ and $\tau(y)$ is not sufficient to guarantee continuity in the cost minimizing levels of care under comparative negligence.

Proof: A smooth hump in the marginal benefit curve can lead to a jump in the cost-minimizing care as illustrated for an injurer in Figure 7.

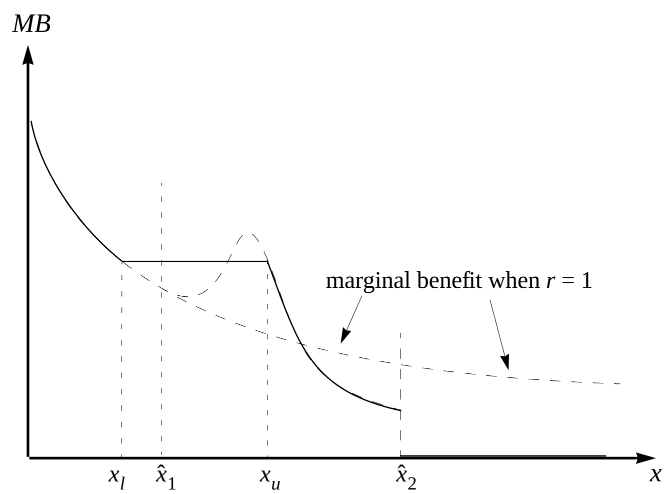

FIGURE 7. Marginal benefit of injurer care

To determine appropriate legal standards $\hat{x}_1, \hat{x}_2, \hat{y}_1, \hat{y}_2$, and forms of partial liability $\sigma(x)$ and $\tau(y)$, we need to predict how care will respond to our choices. This is a very complicated problem.

3.3 Numerical analysis for a particular accident probability function

In appendix 2, we solve the contributory and comparative negligence, and hypothetical first best social cost minimization problems, where

$$P(x, y) = \frac{1}{2-\gamma}[e^{-x} + e^{-y} - \gamma e^{-(x+y)}] \quad (22)$$

The parameter γ determines the complementarity or substitutability between x and y. When $\gamma = 1$, if one party is taking no care the other party cannot prevent the accident. Protective actions are complementary. When $\gamma = 0$, protective action by either party has an independent effect on $P(x,y)$. As $\gamma \to -\infty$, $P(x,y)$ depends on the *sum* of the care exercised by the two parties, so their actions become perfect substitutes. This is the technology Rubinfeld (1987) examined, although in contrast to Rubinfeld, we consider non-degenerate distributions of the costs of care for *both* parties.

Our numerical analysis is also restricted to a limited range of distributions for the costs of care.[16] However, we examined many alternative values for the maximum costs of care for injurers and victims and the degree of complementarity or substitutability between injurer and victim care.

We can find the optimal contributory negligence standards for *arbitrary* distributions $F(m)$ and $G(n)$ and hence, since we can re-scale x and y, in a *very wide range* of examples. In contrast, we could solve the optimal comparative negligence rule when $P(x,y)$ has the form (22) *only* when $F(m)$ and $G(n)$ are uniform distributions. Even then, we also had to restrict $\sigma(x)$ and $\tau(y)$ to take very special (and unrealistic) exponential forms. In particular, it proved impossible to solve for the optimal comparative negligence rule when $F(m)$ and $G(n)$ are uniform and $\sigma(x)$ and $\tau(y)$ are linear.

3.4 Costs under the best contributory negligence rules

Table 1 presents a selection of our numerical results from the appendix for $F(m)$ and $G(n)$ uniform. The first best costs as a proportion of damages D in the first column equal the average accident probability plus the average costs of care as a percentage of D. We chose a range of values for c_1 and c_2 to give final accident probabilities ranging between 5% and 15%.

Across the range of examples we examined, we found that the sum of the costs of care and the expected accident costs under the best contributory negligence rule were surprisingly close to the expected costs that would be attained if care were efficient. For example, for a category of accidents where the expected damages are on the order of \$1 million, the *excess* costs under the best contributory negligence rule ranged from a little over \$1,000 to a little over \$9,000. Expressed as a percentage of the expected costs under efficient care, the *excess* costs under the best contributory

16. Our analysis is, however, more general than it appears. Since x and y do not have any "natural" units we may be able to re-scale these variables, and appropriately alter $F(m)$ and $G(n)$ or the maximum costs c_1 or c_2, to guarantee $P(x,y)$ has the form (22). The distributions of costs we examined included a range of uniform distributions and also families of humped-shaped distributions.

negligence rule ranged from less than 0.5% to slightly above 7.25% with a average of about 2.5%.

TABLE 1. Costs and excess costs as a percentage of expected damages

(c_1, c_2)	**First Best costs as % of D**	**Contributory Negligence as % D**	**Excess costs as % of First Best**
	Care is substitutable (γ = -5)		
(0.015, 0.015)	5.7907	5.9356	2.50
(0.015, 0.095)	12.5897	12.7345	1.15
(0.095, 0.015)	12.5897	13.5058	7.28
(0.095, 0.095)	21.9102	22.8273	4.19
	Care is complementary (γ = 1)		
(0.015, 0.015)	8.5439	8.6888	1.70
(0.015, 0.095)	22.5441	22.6889	0.64
(0.095, 0.015)	22.5441	23.4605	4.07
(0.095, 0.095)	36.3746	37.2919	2.52

The size of the excess costs under the best contributory negligence rules depends mainly on c_1, the costs of injurer care. The best contributory negligence rule performs relatively better when injurers have lower average costs of care. Contributory negligence also performs relatively better (in percentage terms) when care is complementary. In all our examples, care taken under the best contributory negligence rule deviated from the efficient levels by inducing *injurers* as a group to supply *excessive* care. This is less costly when injurer costs are lower since the *efficient* solution would in that case require relatively higher care from injurers. It is also less costly when care is complementary because again the efficient solution would require relatively high care from both parties regardless of their relative costs.

3.5 Care under the best contributory negligence rules

When costs are uniformly distributed, more than 99.5% of injurers meet the legal standard under the best contributory negligence rules. Even when the distribution of costs is skewed toward low values (so it is best to set a high standard to encourage the many low cost injurers to take substantial care) more than 96% of injurers meet the standard. Injurers have a strong incentive to meet the standard, even when it is high, since by doing so they are exempt from liability.

If *all* injurers met their legal standard, victims would effectively be in an assumption of risk regime where they could not expect to recover damages. As a result, they would have an incentive to optimally trade-off the costs and benefits of care and thus choose the efficient amount of care.[17,18] Thus, it is not surprising that we also find for all distributions and parameter values that victims choose close to the efficient amounts of care under the best contributory negligence rules.

We conclude that *excessive care from injurers* is responsible for the excess costs under contributory negligence. In addition, we find that when injurers and victims have the same costs of care, the standard of care for injurers is higher than the standard of care for victims. Thus, although the best contributory negligence rule appears to "favor injurers" in terms of *ex-post* settlements, it "favors victims" in terms of the *ex-ante* amounts of care the rule tends to produce. The critics of contributory negligence focused on the distribution of damages in those cases that came to trial while ignoring the effects of the rule on the distribution of expenditures on accident avoidance.

3.6 Implementation of contributory negligence

We show in appendix 2 that the best contributory negligence rule can be calculated in a very wide range of circumstances. This may of little use, however, if there is no simple "rule of thumb" that would enable the courts to get tolerably close to that rule.

In the case of victims, the courts can apply a Hand rule for a "reasonably careful" potential victim. The legal standard of victim care should be set so that the incremental cost of care for an *average* victim would equal the reduction in expected accident losses assuming *all* injurers take their legal standard of care. If standards are set appropriately, the legal standard for victims should also approximate the *average observed* care of victims.

Something else is required, however, for injurers. Most injurers would take exactly the legal standard of care under a wide range of contributory negligence rules. Furthermore, any injurers who take less care will fall short of the standard by a discrete margin. The lack of variation in observed care levels would make it difficult to determine the marginal costs and benefits of injurer care. It therefore also will be difficult to determine the *appropriate* legal standard. If the legal standard were set at the *average observed* care of potential injurers, the standard would decline until *all*

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17. This is shown formally in appendix 2 for the uniform distribution case. For other distributions, the victims may choose care that is only approximately efficient, even if all injurers meet their legal standard, because the *average* efficient care of injurers need not equal the care under the legal standard.

18. When almost all injurers meet their legal standard, victims also have close to the right incentives to choose the appropriate level of *participation* in the potentially dangerous activity. Hence, the best contributory negligence rule will also perform well if the accident probability is sensitive to victim, but not injurer, participation.

injurers found it worthwhile to meet it.

The notion of "customary care" may provide a suitable way of determining an appropriate legal standard for injurers. Customary care is a level of care that is commonly exercised by most individuals in a group. We have already seen that the care taken by potential injurers should be much more uniform than their costs of care. A legal standard of care would emerge as a customary level of care observed by the vast majority of potential injurers.

In the numerical examples in appendix 2, the best contributory negligence standard is one where, typically, fewer than 3% of potential injurers find it worthwhile to deviate and choose less care. A suitable "rule of thumb" for choosing a legal standard for injurers might be to aim for the *maximum* standard of care that is consistent with no more than, say, 1 out of 40 potential injurers choosing less than that standard of care.

The courts cannot be bound, however, by a fixed customary standard of care. For example, technological change that lowers the costs of care for all potential injurers should increase the legal standard. This problem was addressed by Judge Learned Hand in *The T.J. Hooper.*[19] In this case, the operator of two tugboats was found negligent for not using radio receivers that would have warned of approaching bad weather and led the tugs to take shelter (as did four other tugs that were equipped with receivers). Judge Learned Hand commented:

> It is not fair to say that there was a general custom among coastwise carriers so to equip their tugs. One line alone did it; as for the rest, they relied upon their crews, so far as they can be said to have relied at all. An adequate receiving set suitable for a coastwise tug can now be got at small cost and is reasonably reliable if kept up; obviously it is a source of great protection to their tows … Is it then a final answer that the business had not yet generally adopted receiving sets? There are no doubt cases where courts seem to take the general practice of the calling the standard of proper diligence … but strictly it is never its measure; a whole calling may have unduly lagged in the adoption of new and available devices … there are precautions so imperative that their universal disregard will not excuse their omission. But here there was no custom at all as to receiving sets; some had them, some did not; the most that can be urged is that they had not yet become general. Certainly in such a case we need not pause; when some have thought a device necessary, at least we may say that they were right, and the others too slack.

The evidence in the case suggests that, if coastwise tugboats were required to carry working radio receivers in order to avoid negligence, at most a very small fraction of owners would fail to comply. Such a requirement therefore ought to be made part of the legal standard.

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19. 60 F.2d 737 (2d Cir. 1932).

3.7 Comparative negligence when both parties are heterogeneous

We attempted to find best *comparative* negligence rules when the accident probability function took the same exponential form (22). We found that it is extremely difficult to find a theoretically ideal liability sharing rule. It is very difficult, if not impossible, to predict the effect of most sharing rules on equilibrium care. We were able to do so only where the costs of care for both injurers and victims were uniformly distributed *and* the sharing rules $\sigma(x)$ and $\tau(y)$ were of a special exponential form. In particular, we could not determine equilibrium care under simple linear sharing rules, even for uniform distributions of the costs of care.

The exponential sharing rule where we could determine likely behavior, and thus decide on a best feasible set of legal standards, would be extremely difficult to implement. However, simple rules are likely to have unpredictable effects on behavior. There is little rational basis, therefore, for choosing a sharing rule in a comparative negligence regime. Standards of care sufficient to absolve one from a given share of damages are likely to vary greatly from one trial to the next. This in turn will make it difficult for injurers or victims to choose appropriate care.

3.8 Amount of litigation under comparative and contributory negligence

The effect of a negligence rule on litigation costs is another important consideration in judging its efficiency. Since more material facts need to be established in order to apportion damages, the costs of each litigation will be higher under a comparative negligence regime. Our analysis also suggests there will be much more litigation under a comparative negligence regime.

The greater difficulty of interpreting and applying comparative negligence may make outcomes less predictable. This could in turn increase litigation by encouraging victims to gamble on obtaining a sympathetic judge or jury even when their case appears weak. By comparison, the single standard of care under contributory negligence will encourage consistent decisions.

The choice of care by injurers and victims under the two regimes will also tend to produce more litigation in a comparative negligence regime. Almost all injurers will meet their legal standard of care under the best contributory negligence rules. In addition, there is a discrete gap between the legal, or customary, standard of care and the care of those injurers who do not meet the standard. Hence, negligent injurers should be easy to identify. Litigation should only occur in the small percentage of accidents where the injurer has not met the legal standard.

On the other hand, in the only examples where we can calculate equilibrium behavior under best comparative negligence rules, the fraction of injurers supplying care in the “middle” region, where liability is shared, ranges from 70 to 95% with an average value of 89%. The fraction of victims in the middle region ranges from 40 to 70%, with an average value of 62%. Litigation probably would be needed to apportion damages in all accidents where injurers or victims have taken care in the middle region.

We conclude that high legal costs are probably the only reason most accidents are not litigated in a comparative negligence regime. In recent research, Low and Smith (1995) examine torts relating to automobile accidents in different states in the United States. They find that, after controlling for other influences, the joint probability of retaining an attorney and filing a law suit under a comparative negligence regime is *double* the probability for a contributory negligence regime.

3.9 Comparative negligence as a form of insurance

When individuals are risk averse it might be thought that the sharing of damages under comparative negligence provides an offsetting efficiency benefit relative to contributory negligence. However, comparative negligence is an inefficient method of providing insurance. Danzon (1991 p 52) reports that the overhead on $1.00 of compensation using the tort system has been estimated at 120% as compared to 20% for large group insurance programs. Similarly, Rogers (1994 p 31) reports that the 1973 (Pearson) Royal Commission on Civil Liability and Personal Injury estimated that the cost of operating the tort system in the UK was 85% of the value of compensation paid through the system, while the corresponding figure for social security (excluding collection costs borne by the employer) was about 11%.

3.10 A symmetric contributory negligence rule

There is another interesting implication of the result that the efficiency of contributory negligence depends largely on the costs of care for injurers. The expected costs of accidents plus care can be minimized by reversing roles when injurers have higher average costs of care. That is, when injurers *as a group* have higher average costs of care, a particular injurer should *not* be liable *only if* $x \geq \hat{x}$ *and* $y < \hat{y}$. Otherwise, the injurer would be liable for all damages regardless of the care exercised by the victim. Brown (1973) refers to this rule as “strict liability with dual contributory negligence”. Calabresi and Hirschoff (1972) refer to it as the “reverse” Hand rule with a “reverse contributory negligence test.”[20]

We can define a “symmetric contributory negligence” rule as one where contributory negligence applies when injurers have lower average costs of care, but strict liability with dual contributory negligence applies when victims have lower average costs.[21] The party *likely* to have lower costs of taking care is given the stronger incentive to meet their standard $\hat{x}$ or $\hat{y}$. This is achieved by eliminating their responsibility once they have met the standard. With almost all members of the low cost group meeting their standard, the high cost group effectively is in a strict liability (or assumption of risk) regime, but the usual implications of strict liability (or assumption of risk) for insufficient care by the other party have been avoided.[22] In the examples examined in appendix 2, costs under such a symmetric rule were usually well within 4% of the costs under efficient care.

While the symmetric rule is more efficient than negligence with a defence of contributory negligence, it could also be regarded as more equitable. It treats individuals symmetrically according to what is objectively known about their *ex-ante* circumstances.

4. Conclusion

The tort liability rules in operation before the introduction of comparative negligence performed remarkably well in providing individuals with appropriate incentives to take care to avoid accidents. They also tended to discourage unnecessary litigation. Since the rules were simple, they were applied consistently by the courts. The appropriate legal standards of care in different situations became widely known. The legal standard of care for injurers tended to become a customary level of care as almost all injurers had a strong incentive to meet it. Those injurers not meeting the standard had an incentive to take distinctly less care. The negligent injurers were then easy to identify, and those injurers taking customary care were protected from unnecessary litigation.

In contrast, the apportionment rules under comparative negligence are unlikely to give clear signals about appropriate standards of care. They are also likely to reduce efficiency by encouraging

20. Calabresi and Hirschoff incorrectly claim that the *only* difference between the “reverse” and “standard” rule is distributional.

21. Compare our best liability *rules* with the “least cost avoider” approach to assigning *liability* as expressed by Demsetz (1972), p28: “It is difficult to suggest any criterion for deciding liability other than placing it on the party able to avoid the costly interaction most easily.” In our case, an individual from the group with the *lower average* cost should be responsible for damages *only* when they are negligent *and* the other party is not.

22. We noted above that the best negligence with contributory negligence rule will encourage close to efficient participation decisions if only victim participation affects the accident probability. Similarly, the best strict liability with dual contributory negligence rule will encourage close to efficient participation decisions by injurers.

excessive litigation. If it were not for high legal costs, most accidents would result in litigation under a comparative negligence regime.

Comparative negligence was introduced because it was thought to be “fairer” than the older forms of liability. In particular, comparative negligence was designed to achieve *ex-post* outcomes that more closely reflected the relative care taken by the parties involved in an accident. We showed, however, that while contributory negligence appeared to favor injurers in terms of *ex-post* outcomes, it nevertheless favored victims in an *ex-ante*, and less visible, sense by encouraging injurers as a group to exercise *too much* care. A complete view of the equity implications of a negligence rule can only be obtained by examining its effects on the distribution of expenditures on care in addition to the distribution of damages in cases that come to trial.

5. Appendix 1 - The “reasonably careful” potential victim for three technologies

In the technology examined by Rubinfeld, care by victims is a perfect substitute for care by the injurer and $P_x(x+y) = P_y(x+y) = P'(x+y)$. Let m_1 be individual who is indifferent to taking no care so that $y^*(m) = 0$ if $m \geq m_1$. The first order condition for $y^*(m)$ then implies, for $m < m_1$,

$$P_x(x^*+y^*(m)) = P_y(x^*+y^*(m)) = -c_2 m \tag{23}$$

while the Kuhn-Tucker condition implies that, for $m \geq m_1$

$$P_x(x^*) = P_y(x^*) \geq -c_2 m \tag{24}$$

If we substitute (23) into the left side of (11), we get

$$\int_0^1 P_x(x^*+y^*(m))dF(m) = -c_2 \int_0^{m_1} m dF(m) + \int_{m_1}^1 P_x(x^*)dF(m) \tag{25}$$

while the right side of (11) can be written

$$P_x(x^*, y^*(\hat{m})) = P_y(x^*, y^*(\hat{m})) = -c_2 \hat{m}\,. \tag{26}$$

From (25) and (26), if $m_1 = 1$ then $\hat{m} = \overline{m}$. However, if $m_1 < 1$ (and some potential victims have costs $m > m_1$) then $\hat{m} < \overline{m}$ since, from (24), $-P_x(x^*) < c_2 m$ for $m > m_1$. Thus, for the perfect substitutes case, the “reasonably careful person” has a cost of care less than or equal to the average cost of care and would take more care than a person with the average cost of care.

If $P(x,y)$ depends on the *product* of the care levels, the first order conditions (12) for $y^*(m)$ imply

$$P'(x^*y^*(m)) = -\frac{c_2 m}{x^*} \tag{27}$$

so that

$$P_x(x^*y^*(m)) = y^*(m)P'(x^*y^*(m)) = -\frac{y^*(m)c_2 m}{x^*}\,. \tag{28}$$

Substituting (28) into the first order condition for the choice of care by the injurer (10) we obtain

$$\int_0^1 P_x(x^*y^*(m))dF(m) = -\frac{c_2}{x^*}\int_0^1 y^*(m)mdF(m) = -c\,. \tag{29}$$

But (29) implies

$$c_2\int_0^1 y^*(m)mdF(m) = cx^* \tag{30}$$

so that, in this case, the optimal rule is for the injurer and the victims to pay an *equal share* of the cost of care. Also, (28) and (11) imply:

$$P_x(x^*y^*(\hat{m})) = -\frac{y^*(\hat{m})c_2\hat{m}}{x^*} = \int_0^1 P_x(x^*y^*(m))dF(m) = -\frac{c_2}{x^*}\int_0^1 y^*(m)mdF(m) \tag{31}$$

so that the “reasonably careful victim” $\hat{m}$ is the individual whose expenditure on care equals the *average* expenditure by the group of victims as a whole.

Finally consider the case where care levels are perfect complements:

$$P(x,y) = P(\min(x,y)) \tag{32}$$

with $P' < 0$, $P'' > 0$. Since care is always costly, optimization implies $y^*(m) = x^* = \min(x^*, y^*(m))$ for all $y^*(m) > 0$. Victims with high costs will supply either x^* or zero care depending on which care level produces the lower overall cost. When victim care is zero, the accident probability will be $P(0)$. Define m_1 as the cost level of the victim (if any) where zero care and x^* care yield the same costs. Then m_1 satisfies the self-selection constraint

$$P(x^*) + c_2 m_1 x^* \leq P(0)\,. \tag{33}$$

The first best problem can be written as choosing x^* to minimize expected costs

$$V = \int_0^{m_1} P(x^*)dF(m) + \int_{m_1}^{1} P(0)dF(m) + cx^* + c_2 \int_0^{m_1} mx^*dF(m) \tag{34}$$

subject to (33). If (33) is not binding for any $m_1 < 1$, then all individuals use the same care and $\hat{m} = \overline{m}$. If (33) is binding for some $0 < m_1 < 1$, then x^* must satisfy

$$P'(x^*)F(m_1) + c + c_2 \int_0^{m_1} mdF(m) = 0 \tag{35}$$

where

$$m_1 = \frac{P(0) - P(x^*)}{c_2 x^*}. \tag{36}$$

From (34) and (35), the minimized value of V would then equal

$$V = P(0) + F(m_1)[P(x^*) - P(0) - x^*P'(x^*)] \tag{37}$$

and, since $P'' > 0$, this will indeed be less than the value of V when $m_1 = x^* = 0$, which is $P(0)$. In this case, the left side of (11) equals

$$P'(x^*)F(m_1) + P'(0)[1 - F(m_1)]. \tag{38}$$

For $P'' > 0$, (38) is less than $P'(x^*)$ and greater than $P'(0)$. There is no solution to (11) for $\hat{m}$. Since the right side of (11) switches from the value $P'(x^*)$ to the value $P'(0)$ at m_1, however, it makes sense in this case to identify $\hat{m}$ with m_1. From (36), this person spends on care an amount equal to the *average benefit* to a victim or the injurer of taking a non-zero amount of care.

6. Appendix 2 - Numerical analysis of the case where both groups are heterogeneous

Theorem 9: For $P(x,y)$ given by (22), the interior[23] solution to minimizing (1) is given by[24]

$$e^{-x(n)} = Ln \quad \text{and} \quad e^{-y(m)} = Km \tag{39}$$

where the positive constants K and L satisfy (for $\overline{m}$ and $\overline{n}$ denoting the means of m and n):

$$L = \frac{(2-\gamma)c_1}{1-\gamma K\overline{m}} \quad \text{and} \quad K = \frac{(2-\gamma)c_2}{1-\gamma L\overline{n}} \tag{40}$$

Proof: Functions (39) solve the first order conditions (2) and (3) when K and L satisfy (40).

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23. If c_1 and c_2 are too large, the optimal x or y will be zero for high cost individuals.

24. Equations (40) lead to a quadratic in K or L. Since e^{-x}, e^{-y}, m and $n \in [0,1]$, K and $L \in [0,1]$. If c_1 and c_2 are low enough to ensure an interior solution, only the negative roots of the quadratics are relevant and the first best levels of care are unique.

Theorem 10: For $P(x,y)$ given by (22), injurer costs $c_1 n$ with n distributed according to $G(n)$, and victim costs $c_2 m$ with m distributed according to $F(m)$, the maximizing care levels under contributory negligence with legal standards $\hat{x}$ and $\hat{y}$ are:

$$\tilde{x}(n) = \begin{cases} \hat{x} & \text{for } n \le n_1 \\ -\log(\Gamma n) & \text{for } n_1 < n \end{cases} \tag{41}$$

$$\tilde{y}(m) = \begin{cases} -\log\left[\dfrac{(2-\gamma)c_2}{G(n_1)(1-\gamma e^{-\hat{x}})}m\right] & \text{for } m \le m_2 \\ \hat{y} & \text{for } m_2 \le m \le m_1 \\ -\log\left[\dfrac{(2-\gamma)c_2}{\Phi}m\right] & \text{for } m_1 < m \end{cases} \tag{42}$$

where the critical cost levels n_1, m_1 and m_2 and the terms Γ and Φ solve the equations[25]

$$c_1 n_1[\hat{x} + \log(\Gamma n_1) - 1] + \frac{c_1}{\gamma\Gamma} - \frac{F(m_1)}{\gamma(2-\gamma)} = 0 \tag{43}$$

$$c_2(m_2 - m_1) + c_2 m_1\left[\hat{y} + \log\frac{(2-\gamma)c_2 m_1}{\Phi}\right] - \frac{\Gamma}{2-\gamma}\mathrm{E}[n|n > n_1] = 0 \tag{44}$$

$$m_2 = \frac{G(n_1)(1-\gamma e^{-\hat{x}})e^{-\hat{y}}}{(2-\gamma)c_2} \tag{45}$$

$$\Phi = 1 - G(n_1)\gamma e^{-\hat{x}} - \gamma\Gamma\mathrm{E}[n|n > n_1] \tag{46}$$

$$\frac{c_1(2-\gamma)}{\Gamma} = F(m_1)(1-\gamma e^{-\hat{y}}) + \gamma F(m_2)e^{-\hat{y}} - \frac{c_2\gamma(2-\gamma)\mathrm{E}[m|m < m_2]}{G(n_1)(1-\gamma e^{-\hat{x}})} \quad . \tag{47}$$

Proof: For $P(x,y)$ given by (22), the first order condition (16) for victims choosing $y(m) > \hat{y}$ is:

$$e^{-y} = \frac{(2-\gamma)c_2}{G(n_1)(1-\gamma e^{-\hat{x}})}m \quad . \tag{48}$$

The solution for $y(m)$ from (48) equals $\hat{y}$ where $m = m_2$ given by (45). When (41) describes the cost minimizing behavior for injurers, and for $P(x,y)$ given by (22), the solution to the first order condition (17) for the level of care $Y(m) < \hat{y}$ of a high cost victim, will be

[25] We use $\mathrm{E}[N(n)|n_1 \le n \le n_2]$ to denote the conditional expectation of a function $N(n)$ of n *given that* $n \in [n_1, n_2]$.

$$e^{-Y} = \frac{(2-\gamma)c_2}{\Phi}m \tag{49}$$

where Φ solves (46). Using (41), (49), (45), and (22), the value (18) of m_1 reduces to (44). A high cost injurer will choose $x < \hat{x}$ to solve the first order condition (13), which, using (42), becomes

$$\int_0^{m_2} P_x(x,y(m))dF(m) + \int_{m_2}^{m_1} P_x(x,\hat{y})dF(m) = -c_1 n\,. \tag{50}$$

Using the solution (48) for $y(m)$ and (22) for $P(x,y)$, (50) can be shown to have a solution for x:

$$e^{-x(n)} = \Gamma n \tag{51}$$

where Γ solves (47). Using (48), (51) and (47), equation (14) can be reduced to (43).

Social cost. Substituting (41) for $\tilde{x}(n)$ and (42) for $\tilde{y}(m)$ into the expected social cost (8) yields

$$c_2\left\{\mathrm{E}[m|m>m_1] + \frac{\mathrm{E}[m|m<m_2]\Phi}{G(n_1)(1-\gamma e^{-\hat{x}})}\right\} + \frac{\Phi e^{-\hat{y}}[F(m_1)-F(m_2)]}{2-\gamma} + \frac{G(n_1)e^{-\hat{x}}}{2-\gamma} + \frac{\Gamma \mathrm{E}[n|n>n_1]}{2-\gamma} \tag{52}$$

$$+ c_1\{\hat{x}\mathrm{E}[n|n<n_1] - \mathrm{E}[n|n>n_1]\log\Gamma - \mathrm{E}[n\log n|n>n_1]\} +$$

$$c_2\left\{\hat{y}\mathrm{E}[m|m_2<m<m_1] - \log\left[\frac{c_2(2-\gamma)}{G(n_1)(1-\gamma e^{-\hat{x}})}\right]\mathrm{E}[m|m<m_2] - \mathrm{E}[m\log m|m<m_2]\right\}$$

$$-c_2\left\{\log\left[\frac{c_2(2-\gamma)}{\Phi}\right]\mathrm{E}[m|m>m_1] + \mathrm{E}[m\log m|m>m_1]\right\}$$

Corollary: The choice of the optimal legal standards under contributory negligence for $P(x,y)$ given by (22) is equivalent to choosing $\hat{x}$, $\hat{y}$, n_1, m_1, m_2, Γ and Φ to minimize (52) *subject to* (43)–(47) that determine n_1, m_1, m_2, Γ and Φ in terms of c_1, c_2, γ, F, G, $\hat{x}$ and $\hat{y}$.

Uniform distributions of costs. We obtained solutions for c_1, c_2 ranging from 0.015 to 0.175 and γ ranging from -10 to 1. Optimal care when m and n are uniformly distributed on [0,1] is given from (39) and (40) with $\overline{m} = \overline{n} = 0.5$. Using these expressions, it can be shown that optimal care is higher, and less sensitive to costs, when care is complementary rather than substitutable.

The effects of γ, c_1 and c_2 on the optimal contributory negligence standards $\hat{x}$ and $\hat{y}$ are similar to their effects on the first best $x(n)$ and $y(m)$. The party with relatively lower costs faces a higher standard. When care is complementary, both parties need to take care, and standards $\hat{x}$ and $\hat{y}$ are higher, less responsive to changes in the costs of care for the other party, and the difference in $\hat{x}$ and $\hat{y}$ for the same cost *asymmetry* is lower.

TABLE 2. Maximum cost parameter (n_1) where injurers meet the standards

		γ = -5			γ = 1		
			c_2			c_2	
		0.015	**0.055**	**0.095**	**0.015**	**0.055**	**0.095**
	0.015	0.9990	1	1	1.0000[a]	1	1
c_1	**0.055**	0.9957	0.9986	1	0.9968	0.9992	1
	0.095	0.9966	0.9955	0.9982	0.9974	0.9976	0.9992

a. This value is slightly less than 1.0 and thus some injurers choose $x < \hat{x}$.

Only injurers with $n \le n_1$ will meet the legal standard of care $\hat{x}$. The values of n_1 for a range of costs and two values of γ are given in Table 2. When c_2 is substantially greater than c_1, the optimal contributory negligence standards $\hat{x}$ and $\hat{y}$ lead *all* injurers to meet the legal standard $\hat{x}$. Even where $n_1 < 1$, far fewer than one percent of injurers fail to meet their standard.

When all injurers meet their standard $\hat{x}$, victims will choose care optimally:

Theorem 11: Under contributory negligence with $P(x,y)$ given by (22) and $F(m)$ and $G(n)$ uniform, if all injurers choose $x = \hat{x}$ then victims will choose the first best level of care.

Proof: With $n_1 = 1$, (46) implies $\Phi = 1-\gamma e^{-\hat{x}}$ so (48) and (49) have the same solution

$$e^{-y} = \frac{(2-\gamma)c_2}{1-\gamma e^{-\hat{x}}}m \tag{53}$$

Also, from (44) and (45),

$$m_1 = m_2 = \frac{(1-\gamma e^{-\hat{x}})e^{-\hat{y}}}{(2-\gamma)c_2}$$

and (52) can be simplified to

$$c_2\overline{m} + \frac{e^{-\hat{x}}}{2-\gamma} + c_1\hat{x}\overline{n} - c_2\overline{m}\log\left[\frac{(2-\gamma)c_2}{1-\gamma e^{-\hat{x}}}\right] - c_2E[m\log m] \ . \tag{54}$$

Choosing $\hat{x}$ to minimize (54) then implies

$$e^{-\hat{x}} = \frac{(2-\gamma)c_1\overline{n}}{1-\gamma\left[\frac{(2-\gamma)c_2}{1-\gamma e^{-\hat{x}}}\right]\overline{m}} \ . \tag{55}$$

Comparing (55) with (39) and (40) we see that the solution (53) for $y(m)$ will be first best.

When $n_1 < 1$, victims with $m < m_2$ choose $y(m) > \hat{y}$ while those with $m > m_1$ choose $y(m) < \hat{y}$. The values of m_1 and m_2 in Table 3 show that m_1 increases as n_1 falls below 1.0. The marginal gain to victims from meeting their legal standard $\hat{y}$ increases when some injurers choose $x(n) < \hat{x}$. Also, as $n_1 < 1$ decreases, the jump at $\hat{y}$ in the marginal benefits of additional victim care increases, $m_1 - m_2$ increases, and more victims choose $y(m) = \hat{y}$.

TABLE 3. Critical values of the cost parameter *m* for victims

		c_2					
		0.015		**0.055**		**0.095**	
		m_1	m_2	m_1	m_2	m_1	m_2
		Substitutes case γ = -5					
	0.015	0.6573	0.6051	0.5586	0.5586	0.5047	0.5047
c_1	**0.055**	0.7381	0.5611	0.7088	0.6434	0.6768	0.6768
	0.095	0.7471	0.5493	0.7485	0.6098	0.7329	0.6587
		Complements case γ = 1					
	0.015	0.6087	0.6086	0.4765	0.4765	0.4138	0.4138
c_1	**0.055**	0.6902	0.5400	0.6038	0.5584	0.5497	0.5497
	0.075	0.7009	0.5365	0.6280	0.5529	0.5779	0.5556

Table 4 gives the excess costs under optimal contributory negligence relative to first best costs.

TABLE 4. Percent excess of contributory negligence over first best cost

		γ = -5			**γ = 1**		
		c_2			c_2		
		0.015	**0.055**	**0.095**	**0.015**	**0.055**	**0.095**
	0.015	2.50	1.44	1.15	1.70	0.89	0.64
c_1	**0.055**	5.28	3.53	2.92	3.24	2.20	1.75
	0.095	7.28	5.03	4.19	4.07	3.03	2.52

From these we conclude that contributory negligence performs better when care is complementary or victims have higher costs of care. The first best care by injurers is higher in these cases, so encouraging them to choose $x \cong \hat{x}$ imposes fewer excess costs. Nevertheless, even in the worst case, the optimal contributory negligence rule has costs close to first best. The excess costs in Table 4 average about 3.65% of first best minimum costs when $\gamma = -5$ and 2.22% of first best minimum costs when $\gamma = 1$. Also, the excess costs under optimal contributory negligence range from a little under 0.145% to a little over 0.917% of expected damages.

An implication of the asymmetry in excess costs in Table 4 is that social costs can be reduced by reversing roles when $c_2 < c_1$. A particular injurer would then be liable for all damages *unless* $x \geq \hat{x}$ *and* $y < \hat{y}$. Brown (1973) refers to this rule as "strict liability with dual contributory negligence". Under a "symmetric contributory negligence" rule, where contributory negligence applies when $c_2 > c_1$ but strict liability with dual contributory negligence applies when $c_2 < c_1$, minimized social cost can be kept below 4.2% above first best costs. Note that under this symmetric rule, the party *likely* to have lower costs should be given the stronger incentive to meet their standard $\hat{x}$ or $\hat{y}$ by eliminating their responsibility if they do so. With almost all of the low cost group meeting their standard, the high cost group effectively is in a strict liability (or no liability) regime, but with the other party still taking positive care.

Optimal comparative negligence with a uniform distribution of costs. With $P(x,y)$ given by (22), and $F(m)$ and $G(n)$ non-degenerate, we can find the optimal comparative negligence rule only when $F(m)$ and $G(n)$ are uniform, and $\sigma(x)$ and $\tau(y)$ are also exponential:

$$\sigma(x) = \frac{e^{\hat{x}_2 - x} - 1}{e^{\hat{x}_2 - \hat{x}_1} - 1} \text{ and } \tau(y) = \frac{1 - e^{\hat{y}_1 - y}}{1 - e^{\hat{y}_1 - \hat{y}_2}} . \tag{56}$$

Theorem 12: Suppose $P(x,y)$ is given by (22), $G(n)$ and $F(m)$ are uniform on [0,1] and the comparative negligence sharing rules with legal standards $\hat{x}_1, \hat{x}_2, \hat{y}_1$ and $\hat{y}_2$ are given by (56). Then there exists a set of 12 endogenous variables n_1, n_2, m_1, m_2, m_3, Γ_1, Φ_1, Φ_2, A_1, B_1, A_2 and B_2 determined by 12 simultaneous non-linear equations such that the maximizing levels of care can be written:

$$x = \begin{cases} \hat{x}_2 & \text{for} \quad n \leq n_2 \\ -\log\left[\dfrac{-B_1 + \sqrt{B_1^2 + 4A_1 c_1 n}}{2A_1}\right] & \text{for} \quad n_2 \leq n \leq n_1 \\ -\log(\Gamma_1 n) & \text{for} \quad n_1 < n \end{cases} \tag{57}$$

and

$$y = \begin{cases} -\log(\Phi_1 m) & \text{for} \quad m \le m_3 \\ \hat{y}_2 & \text{for} \quad m_3 \le m \le m_2 \\ -\log\left[\dfrac{-B_2 + \sqrt{B_2^2 + 4A_2 c_2 m}}{2A_2}\right] & \text{for} \quad m_2 \le m \le m_1 \\ -\log(\Phi_2 m) & \text{for} \quad m_1 < m \end{cases} . \tag{58}$$

Outline of Proof: As in the contributory negligence case, one shows (57) and (58) solve the first order conditions for appropriate values of the constant terms. The variables n_1, n_2, m_1, m_2, m_3, A_1, B_1, A_2, B_2, Γ_1, Φ_1 and Φ_2 satisfy ten equations that follow from the first order conditions for choice of care in different regions, continuity restrictions on *x* and *y*, and two equations that arise from the restriction that total costs remain fixed as *x* and *y* jump discontinuously. The solutions (57) and (58) for maximizing care are graphed in Figure 8:

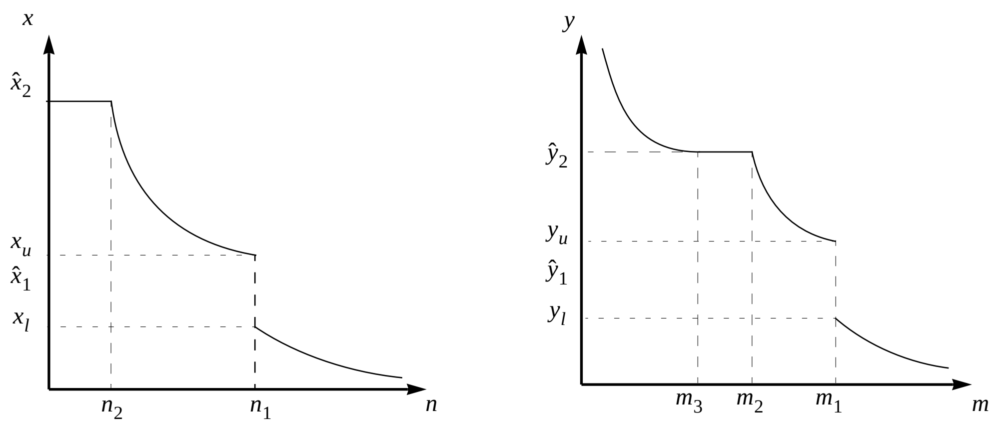

FIGURE 8. Care under comparative negligence

Corollary: The optimal legal standards of care $\hat{x}_1, \hat{x}_2, \hat{y}_1$ and $\hat{y}_2$ under comparative negligence, and for $P(x,y)$ given by (22), $G(n)$ and $F(m)$ uniform on [0,1], and sharing rules (56), are found by substituting (57) and (58) into (8) and choosing n_1, n_2, m_1, m_2, m_3, A_1, B_1, A_2, B_2, Γ_1, Φ_1, Φ_2, $\hat{x}_1, \hat{x}_2, \hat{y}_1$ and $\hat{y}_2$ to minimize the resulting expression *subject to* the twelve non-linear constraints.

In the numerical analysis, we only considered $\gamma = -5$, where contributory negligence performed less well. The effects of c_1 and c_2 on the optimal comparative negligence standards $\hat{x}_1, \hat{x}_2, \hat{y}_1$ and $\hat{y}_2$ are similar to the effects on the optimal contributory negligence standards $\hat{x}$ and $\hat{y}$. In all cases, the single legal standard for injurers or victims under the optimal contributory negligence rule lies between the two legal standards under the optimal comparative negligence rule.

For all the values of c_1 and c_2 that we examined, $n_1 = 1$, so that all the injurers meet at least the lower legal standard of care. Since $n_1 = 1$, we also found that the care of injurers is continuous. On the other hand, the care taken by victims is discontinuous when the cost of care for victims is high relative to the cost for injurers. In addition, the optimal comparative negligence legal standards, and the choices of care in response to those standards, are much less "smooth" as functions of c_1 and c_2 than in the contributory negligence case. More significantly, we also found that the fraction $(1{-}n_2)$ of injurers supplying care in the "middle" region, where liability depends on the care of both parties, ranges from 70 to 95%, and averages 89%. Also, the fraction $(m_1{-}m_3)$ of victims in the middle region ranges from 40 to 70%, and averages 62%.

TABLE 5. Relative costs when standards are optimally set

		c_2			c_2		
		0.015	**0.055**	**0.095**	**0.015**	**0.055**	**0.095**
		Comparative minus first best as % of first best			Contributory minus comparative as % of first best		
	0.015	0.77	0.45	0.36	1.73	0.99	0.79
c_1	**0.055**	3.74	1.35	1.00	1.53	2.17	1.92
	0.095	5.89	2.71	1.77	1.38	2.32	2.42
		Contributory minus comparative expected costs			Symmetric contributory minus comparative as % of first best		
	0.015	0.0010	0.0010	0.0010	1.73	0.99	0.79
c_1	**0.055**	0.0015	0.0033	0.0035	-2.30	2.17	1.92
	0.095	0.0017	0.0042	0.0053	-4.74	0.20	2.42

Table 5 gives the differences in expected costs under the first best, optimal contributory negligence, and optimal comparative negligence regimes. The top half, and bottom right corner, of Table 5 express the differentials as a percentage of the first best expected costs, as in the left half of Table 4 (whose entries equal the sum of the entries in the top half of Table 5).

The top left corner of Table 5 shows that, as with contributory negligence, the optimal comparative negligence rules perform worse when c_1 is high relative to c_2. But we also find that comparative negligence with this particular accident reduction technology, exponential sharing rules and uniformly distributed costs can improve upon contributory negligence. In this case, the extra instruments available under comparative negligence enable lower expected costs to be achieved. The savings are, however, under 2.5% of the first best costs. Also, the figures in the bottom left corner of Table 5 show that for an accident with damages of $1 million, for example, the expected costs under optimal contributory negligence are at most $5,300 more than the expected costs under optimal comparative negligence.

The bottom right corner of Table 5 shows that a "symmetric contributory negligence" rule, where contributory negligence is replaced by "strict liability with dual contributory negligence" when $c_1 > c_2$, can outperform the optimal comparative negligence rule.

Optimal contributory negligence with other distributions of costs. We also examined the optimal contributory negligence rules when $F(m)$ and $G(n)$ have a beta distribution with parameters (1.75, 4.0), which is a skewed "humped shape" distribution defined on [0,1] with a concentration of individuals having low costs of care (so the distribution has an "upper tail").

TABLE 6. Maximum *n* where injurers meet standards (skewed distribution)[a]

		$\gamma = -5$			$\gamma = 1$		
			c_2			c_2	
		0.015	**0.055**	**0.095**	**0.015**	**0.055**	**0.095**
	0.015	0.6950	0.8007	0.8786	0.7019	0.7856	0.8399
c_1	**0.055**	0.6724	0.6844	0.7239	0.6915	0.7025	0.7288
	0.095	0.6842	0.6576	0.6779	0.7039	0.6902	0.7032

a. It can be shown that approximately 4.19% of injurers have $n \geq 0.65$, 1.18% have $n \geq 0.75$ and 0.16% have $n \geq 0.85$.

For the same c_1, c_2 and γ, the optimal legal standard was higher than in the uniform case to encourage effort by the many individuals with low costs of taking care. Nevertheless, from Table 6 we conclude that the proportion of injurers choosing care below the legal standard $\hat{x}$ remains quite low.

TABLE 7. Excess contributory negligence cost (skewed distribution)

		$\gamma = -5$			$\gamma = 1$		
			c_2			c_2	
		0.015	**0.055**	**0.095**	**0.015**	**0.055**	**0.095**
	0.015	1.99	1.11	0.82	1.38	0.75	0.49
c_1	**0.055**	3.77	2.63	2.15	2.47	1.73	1.35
	0.095	5.14	3.61	3.05	3.08	2.31	1.92

Table 7 shows the excess costs under the optimal contributory negligence rule, as a percentage of first best costs, when costs of taking care are beta distributed and skewed. As with uniformly distributed costs, there is little room to improve on the efficiency of contributory negligence. Also, the expected cost is again reduced when the parties are treated symmetrically. When victims have the higher average cost of taking care, injurers should be exempt from liability if they have met their standard. However, when injurers have the higher average cost of taking care, strict liability with dual contributory negligence is more efficient.

Finally, we allowed the costs of either injurers or victims to follow a symmetric beta distribution with parameters (4.0, 4.0) while the costs of the other party followed the asymmetric beta distribution with parameters (1.75, 4.0). We again found that total expected costs are minimized when, approximately, $r(x,y)$ applies to the party having the lower *expected* costs of care. If the contributory negligence is implemented this way, the minimized expected costs are less than 1.75% above first best. Another general result was that contributory negligence performs best when the distribution of the costs of care has a lower variance. Contributory negligence tends to encourage a low variance in care and can achieve first best if all the individuals in either have the same cost of care.

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