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Discontinuities, Causation, and Grady's Uncertainty Theorem

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DISCONTINUITIES, CAUSATION, AND GRADY'S UNCERTAINTY THEOREM

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I. Introduction

In a series of articles,[1] Mark Grady considers the problem of discontinuity under a tort negligence regime. The discontinuity can be described as follows. A potential injurer who adopts the optimal level of precaution is completely shielded from liability under the negligence system even though accidents occur. A very small decrease in the level of precaution below the optimal level suddenly exposes the potential injurer to liability for these accidents. This discontinuity makes the expected cost of underinvestment in precaution greater than the expected cost of overinvestment. In a world where there is uncertainty about the optimal level of precaution to be used by the court, such an asymmetry could lead to an overinvestment in precaution. Grady has investigated the role of causation in mitigating, and even eliminating, the problem caused by asymmetries of this sort. More specifically, Grady considers three liability rules that differ in their conception of causation.

Full Liability. The injurer is liable for all accidents if negligent.

Cutoff. The injurer is liable if negligent and if the socially optimal level of precaution would have prevented the accident.

Cost Benefit. The injurer is liable if negligent and if some socially superior level of precaution would have prevented the accident. (By socially superior, he means a level of precaution that has lower expected

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[1] Mark F. Grady, A New Positive Economic Theory of Negligence, 92 Yale L. J. 799 (1983); Mark F. Grady, Discontinuities and Information Burdens: A Review of The Economic Structure of Tort Law by William M. Landes and Richard A. Posner, 56 Geo. Wash. L. Rev. 659 (1987); and Mark F. Grady, Punitive Damages and Subjective States of Mind: A Positive Economic Theory, 40 Ala. L. Rev. 1197 (1989).

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social costs than that of the precaution taken. This is explained more fully below.)

Grady makes two claims which I will refer to in the remainder of the article as Grady's uncertainty theorem and Grady's observation.

GRADY'S UNCERTAINTY THEOREM. Where the injurer is uncertain as to the optimal level of precaution to be applied by the court, the cost-benefit rule is optimal in the following sense. The cost-benefit rule results in symmetric costs for over- and underinvestment in precaution and thus provides no systematic incentives for either over- or underinvestment in the face of uncertainty about the optimal level of precaution. (Grady also claims that the full liability rule is biased toward overprecaution and the cutoff rule is biased toward underprecaution.)

GRADY'S OBSERVATION. Courts actually apply the cost-benefit rule in practice.

The theorem is based on several explicit assumptions, none of which will be disputed here.[2] Rather I will focus on a nonobvious assumption. I make the following claims:

1. Grady's theorem depends on an unstated assumption concerning the way precaution and accidents are ordered. The proof of Grady's theorem implicitly assumes that all accidents that occur at higher levels of precaution must also occur at lower levels of precaution. In practice, this will almost never be true, as will be demonstrated below. Increasing the precaution level not only lowers the expected cost of accidents but also changes the types of accidents that occur and changes the identities of those at risk.

2. One can replace Grady's implicit assumption with a more reasonable assumption without affecting the tractability of the model or changing its explicit assumptions. When one does so, the outcome of the model is radically different. The cost-benefit rule systematically leads to overinvestment in precaution. The cutoff rule, on the other hand, can lead to either over- or underinvestment in precaution. Where both rules lead to

[2] The most important of these assumptions are: (1) Expected social costs are symmetric around the optimal level of precaution. (That is, the expected social cost curve is symmetric and U-shaped.) (2) Injurers will be liable for injuries according to the legal rule. (That is, there is no significant problem of detection or enforcement.) (3) Injurers are risk neutral. (That is, injurers are expected value maximizers.) (4) The court is perfectly capable of resolving causation issues. (That is, it knows whether an accident would or would not have occurred with alternative precaution levels.) (5) Uncertainty is symmetric. (That is, there is an equal likelihood of positive and negative errors of the same magnitude.) It is possible to criticize these assumptions. For example, see John E. Calfee & Richard Craswell, Some Effects of Uncertainty on Compliance with Legal Standards, 70 Va. L. Rev. 965 n.36 (1988), for a critique of assumption 2. For my purposes, however, I will accept these explicit assumptions arguendo.

overinvestment in precaution, as is likely to be the case in practice, there will always be a greater (or as great) bias toward overprecaution under the cost-benefit rule than under the cutoff rule. The result is that in most cases we would expect the cutoff rule to be superior.

One problem with the proof of Grady's theorem as it is presented in the literature is that the critical assumption is never stated. Rather it is unintentionally[3] buried in the graphical analysis. However, it is easy to construct simple fact situations that satisfy all of the explicit assumptions and yet refute the result predicted by Grady's theorem. This indicates that there is a significant hidden assumption somewhere in the proof of Grady's theorem that is being violated by the example. It is then a matter of identifying the assumption and testing it for reasonableness. This article will follow this general outline. Grady's theorem is presented and explored. A counterexample is identified. The hidden assumption is uncovered. The assumption is tested for reasonableness.

We will find that Grady's theorem represents a limiting case. The model used in the proof of Grady's theorem could be used (and probably should be used) to show that the cost-benefit rule systematically leads to an incentive for overinvestment in precaution. Although this new theorem is diametrically opposed to Grady's theorem in terms of its efficiency implications, it is of interest and leads to some speculation, at the end of the article, about the *relative* efficiency of the cost-benefit rule and the cutoff rule.

I have chosen to discuss Grady's work for three reasons. First, he is the most forceful proponent of this approach. Second, his work remains important and insightful notwithstanding this critique. Third, his work has been influential. For example, Marcel Kahan has used a substantially similar approach to study causation in tort law.[4] The critique thus applies with equal force to Kahan's model. Let us now turn to a demonstration of Grady's theorem.

II. Grady's Uncertainty Theorem

We will begin with a simple demonstration of Grady's theorem.[5] Suppose that there are three distinct levels of precaution: \$0, \$15, and \$30.

[3] It is quite easy to use the graphical analysis in this manner without realizing that one is making the critical assumption.

[4] Marcel Kahan, Causation and Incentives to Take Care under the Negligence Rule, 18 J. Legal Stud. 427 (1989).

[5] Here a simple example is used to demonstrate the operation of the theorem rather than to prove it. Although a simple example cannot prove a theorem, a simple example (or rather a counterexample) can be used to disprove a theorem. (That, however, comes later.)

TABLE 1

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	etc.
$0	A	B	C	D				
$15			C	D				
$30				D				

Each level of precaution can lead to various accidents. Let us call these accidents A, B, C, and D. Whether an accident occurs depends on the level of precaution chosen and random occurrences in the environment. Let us label these random occurrences (often called "states of nature") by s_1, s_2, s_3, and so on. Let us suppose that each state of nature has a .01 probability of occurring. Table 1 can be interpreted as follows.

If the potential injurer adopts a $0 level of precaution and the state of nature s_4 occurs, then accident D happens. If the potential injurer adopts a $0 level of precaution and the state of nature s_5 occurs, then no accident happens. Suppose that no accidents occur for states of nature not shown in Table 1. Suppose also that accidents cost $1,000. I now have the basics of the simple example.

A. *The Optimal Level of Precaution*

The optimal level of precaution is found ex ante by aggregating the cost of precaution with expected accident costs. For example, let us calculate the social cost of adopting a $15 level of precaution. The cost of precaution is just $15. The expected cost of accidents is the probability that each accident will occur times the cost of the accident. The probability that accident C will occur is .01, and its cost is $1,000. This makes an expected cost of $10. Likewise, the expected cost of D is $10. However, A and B will not occur if the potential injurer adopts a level of precaution of $15. The social cost is thus $35. Using this logic, I calculate the following social costs: *SC*($0) = $40, *SC*($15) = $35, and *SC*($30) = $40. If only these three levels of precaution are possible, then a level of precaution of $15 is socially optimal. The numbers are consistent with Grady's assumptions.[6]

[6] These assumptions are listed in note 2 *supra*. Note, in particular, that social cost is symmetric around the minimum. The symmetric cost function is an important one. (See note 9 *infra*.) The justification for the symmetry assumption is that there is no reason to believe that social costs will be systematically higher for overprecaution than they are for underprecaution or vice versa.

B. Negligence and Causation Rules

The potential injurer is negligent whenever adopting a suboptimal level of precaution. In my example, the potential injurer is negligent if he or she adopts a level of precaution of $0. To be liable, the accident must actually occur and, under some rules, must be caused by the negligence. Grady considers three liability rules, presented again.

Full Liability. The injurer is liable for all accidents if negligent.

Cutoff. The injurer is liable if negligent and if the accident would not have occurred had the socially optimal level of precaution been used.

Cost Benefit. The injurer is liable if negligent and if the accident would not have occurred had some socially superior (to the precaution actually used) level of precaution been used.

Under the cutoff rule, a negligent defendant will escape liability if the accident would still have occurred had the socially optimal level of care been used. Thus, in my example, if the defendant used $0 of care (which is negligent) and if accident C occurred, the defendant would escape liability since C would still have occurred had the defendant used the socially optimal level of care of $15. Likewise, if the defendant used $0 of care and if accident D occurred, the defendant would escape liability since D would still have occurred had the defendant used the socially optimal level of care of $15.

Under the cost-benefit approach, if the plaintiff demonstrates that some socially superior level of care would have prevented the accident, then the defendant is liable. In Grady's formulation, there is no liability if the accident would have occurred at $30 of care. Note that $30 of care is not socially superior to $0 of care. However, virtually the same accidents would occur with $29.99 worth of care. Using $29.99 of care is socially superior to using $0 units of care since, assuming the same accidents occur, the total social costs of using $29.99 of care are $39.99. To remind us of this reasoning, I present Table 2.[7]

[7] Technically, the assumption underlying Grady's theorem is that expected liability under the cost-benefit rule is

$$EL(c^* - d) = \lim\{EA(c^* - d) - EA(c^* + d - e)\} \quad \text{as } e \text{ approaches zero,}$$
$$= EA(c^* - d) - EA(c^* + d),$$

where d is a positive number representing how much the level of care taken is below the optimum, $c^* - d$ is the amount of care taken, EL is expected liability, EA is expected accident cost, and e is some small positive number. Because social costs are assumed to be symmetric around the minimum (and U-shaped) the level of care $c^* + d - e$ is always socially superior to $c^* - d$ for any positive e. (To see this, draw a U-shaped symmetric

TABLE 2

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	etc.
\$0	A	B	C	D				
\$15			C	D				
\$30 (or \$29.99)				D				

We are assuming that \$29.99 of care produces the same result as \$30 of care. Adopting \$29.99 worth of care is thus socially superior to adopting \$0 of care. Thus, in my example, if the defendant used \$0 of care (which is negligent) and if accident C occurred, the defendant would be liable since C would *not* have occurred had the defendant used the socially superior level of care of \$29.99. This is true even though the socially optimal level of care would not have prevented the accident. However, if the defendant used \$0 of care and if accident D occurred, the defendant would escape liability since D would still have occurred had the defendant used any socially superior level of care.

To summarize, given the assumptions above, a negligent injurer would be liable for accidents A, B, C, and D under the full liability rule; for accidents A and B under the cutoff rule; and for accidents A, B, and C under the cost-benefit rule. Given this, one can construct a table of payoffs to the potential injurer for the three levels of precaution and the three liability rules (see Table 3).

We can now see the thrust of Grady's theorem. The cost-benefit rule yields a symmetric result.[8] Thus, a potential injurer who faces (symmetric) uncertainty as to the level of precaution will have no incentive to shade his or her choice either higher or lower. The full liability rule

social cost curve.) As e becomes very small, $EA(c^* + d - e)$ converges to $EA(c^* + d)$. In my numerical example, e is just one penny and the expected accident costs of \$29.99 of care are assumed to be virtually identical to the social costs of \$30 of care.

[8] Technically, the symmetric U-shaped social cost curve implies that

$$c^* - d + EA(c^* - d) = c^* + d + EA(c^* + d)$$

or

$$EA(c^* - d) - EA(c^* + d) = 2d.$$

(See note 7 *supra* for notation.) This implies that the expected liability under the cost-benefit rule is $2d$. (Again, see note 7 *supra*.) This means that if the potential injurer adopts a level of care of $c^* - d$ (where d is positive) the total expected private costs will be $c^* - d + 2d = c^* + d$. If the potential injurer adopts a level of care of $c^* + d$ (where d is positive), then the total expected private costs are $c^* + d$, since there is no liability. However, the following sections will show that the assumption that expected liability costs are $EA(c^* - d) - EA(c^* + d)$ under the cost-benefit rule is not generally a good one.

TABLE 3

	Full Liability	Cutoff	Cost Benefit
$0	40	20	30
$15	15	15	15
$30	30	30	30

TABLE 3a

	Full Liability	Cutoff	Cost Benefit
$0	50	30	40 or 50*
$15	15	15	15
$30	30	30	30

* The payoff is $40 if accident D still occurs with $49.99 of care and $50 if accident D does not occur with $49.99 of care.

pushes injurers toward a too high level of precaution in the face of uncertainty since the cost of being too low is greater than the cost of being too high. The cutoff rule pushes injurers to a too low level of precaution in the face of uncertainty.[9]

III. The Counterexample

In this section, an example is presented that satisfies all of the explicit assumptions on which Grady's theorem is based and yet produces a result that contradicts Grady's theorem. Let us change the facts slightly to those represented in Table 4.

Again, I assume that accident D occurs with either $29.99 or $30 of care. Table 4 does not represent much of a change from Table 3. The social costs are the same. However, under the cutoff rule the potential injurer no longer escapes liability if accident D occurs since it would

[9] Here we can see the importance of the assumption that social costs are symmetric around the minimum. Suppose that if accident B occurs, then the cost is $2,000. (All other accidents cost $1,000.) In this case the social costs are *SC*($0) = $50, *SC*($15) = $35, and *SC*($30) = $40, and the rules compare as in Table 3a (see above). (The payoff is $40 if accident D still occurs with $49.99 of care and $50 if accident D does not occur with $49.99 of care.) In this case the cutoff rule is symmetric. However, this result depends not only on asymmetry of social costs but on a particular type of asymmetry. It is equally likely that the asymmetry could result in higher social costs on the high precaution side. The symmetry assumption makes sense because there is no reason to believe that on average that costs will be higher for overprecaution than for underprecaution or vice versa. Also, if we throw out the symmetry assumption, it is unlikely that any of the rules will produce predictable results. (I thank William Landes for this example.)

TABLE 4

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	etc.
$0	A	B	C	D				
$15			C		E			
$30 (or $29.99)				D				

TABLE 5

	Full Liability	Cutoff	Cost Benefit
$0	40	30	40
$15	15	15	15
$30	30	30	30

not have occurred under the optimal level of precaution. Likewise, the potential injurer does not escape liability for D under the cost-benefit rule since there is some socially superior level of care at which the accident does not occur. Thus, under the cutoff rule, the injurer must pay for accidents A, B, and D. Under the cost-benefit rule the injurer must pay for A, B, C, and D. The resulting private payoff table is Table 5.

As can be seen, the cost-benefit rule is no longer symmetric. There is an incentive for an overinvestment in precaution. The cutoff rule is actually better in this example.

IV. The Hidden Assumption

The fact that it is possible to create an example that satisfies all of the explicit assumptions of the theorem and yet contradicts the theorem indicates that there must be an unstated assumption on which the theorem depends. Observing the differences between Tables 1 and 4 reveals that Grady's theorem depends on the inverted pyramid structure of causation evident in Table 1. That is, if an accident occurs at some level of precaution, it also occurs at all lower levels of precaution. As the level of precaution decreases, new accidents are added but old ones are never subtracted. There are no "holes." Let us call this the *assumption of complete ordering of accidents by precaution level* or, for ease of reference, the *complete ordering assumption.*

By contrast, in Table 4, accidents D and E have the property of not occurring at some lower level of precaution while occurring at a higher level of precaution. This phenomenon is almost universal. As the level of precaution increases, some accidents will cease to occur while others will become more likely. On net, the expected accident costs drop as more money is invested in precaution, but the types of accidents change. Let us call this the *assumption of incomplete ordering of accidents by precaution level* or the *incomplete ordering assumption.*

Grady has shown that with complete ordering, the incentives for over- and underinvestment in precaution are symmetric if the court employs the cost-benefit rule. This is an important result, but it should be acknowledged that it represents a special case.

GRADY'S UNCERTAINTY THEOREM (RESTATED). Where the injurer is uncertain as to the optimal level of precaution to be applied by the court *and where there is a complete ordering of accidents by level of precaution,* the cost-benefit rule is optimal in the following sense. The cost-benefit rule results in symmetric costs for over- and underinvestment in precaution and thus provides no systematic incentives for either over- or underinvestment.

Complete ordering is a highly counterfactual assumption, as will be demonstrated in the next section. Thus, Grady's theorem is important not for its result but because it leads directly to the proof of another theorem whose assumptions are much more realistic. Liability is always greater with incomplete ordering than with complete ordering.[10] This is easily seen in the above example.[11] Thus, it follows that with incomplete ordering there is always an incentive for *overinvestment* in precaution. This can be stated as follows:

THEOREM. Where the injurer is uncertain as to the optimal level of precaution to be applied by the court *and where ordering of accidents by level of precaution is incomplete,* the cost-benefit rule is inefficient in the following sense. The cost-benefit rule results in asymmetric costs for over- and underinvestment in precaution and provides a systematic incentive for overinvestment in precaution.

Other claims must be modified as well. With incomplete ordering, the

[10] This is true of the cost-benefit rule but only half true of the cutoff rule. With the cost-benefit rule any "hole" in the table is relevant since any hole will create additional liability. (The exception to this are "holes" at extremely high precaution levels.) To find such a "hole," I simply ask if there are any accidents that would occur at some level of precaution but will not occur at a lower level of precaution. For the cutoff rule, only "holes" below the optimal level of precaution are relevant. That is, I ask whether there are accidents that would occur at the optimal level of precaution that would not occur at a lower level of precaution. Of course, "holes" are completely irrelevant to the full liability rule.

[11] Another way to state this is that Grady's theorem works as long as the expected cost of marginal accidents equals the marginal expected accident cost. (Marginal accidents are any accidents that do not occur at some socially superior level of precaution.) For example, consider the move from a precaution level of \$30 to a precaution level of \$0. In Table 1, the marginal accidents are A, B, and C. The expected cost of these accidents is \$30. The marginal expected accident cost is also \$30 since the expected cost of accidents at a precaution level of \$30 is \$40 and the expected accident cost at a precaution level of \$0 is \$10.

cutoff rule no longer provides a systematic incentive for underinvestment in precaution. Rather, the presence of "holes" will push the cutoff rule toward overprecaution. As a result, the cutoff rule can result in an incentive for either underprecaution or overprecaution. I will speculate about the comparative merits of the "cutoff" rule and the "cost-benefit" rule later in this article.

V. How Reasonable Is Complete Ordering?

Given the above theorems, it is important to test the complete and incomplete ordering assumptions. If we conclude that complete ordering is a poor assumption, then we must reject the claim that the cost-benefit rule is efficient in the sense described by the theorems.

As a first pass, let us take an example used by Grady (although I will modify it for my own purposes); that is, the case of someone injured by swimming in a flooded rock strip mine.[12] Consider Table 4 once again.

Suppose $0 is a sign saying "keep out." Precaution level $15 is having lifeguards in the summer and signs the rest of the year. Precaution level $30 is erecting a fence. It is useful to think of A, B, C, D, and E as people.[13] Suppose that the $0 level of precaution were adopted and that A drowned during the summer months. In-court evidence shows that either lifeguards or a fence would have worked. Thus, A collects under either rule. I could make the identical argument for B if instead B had drowned. Suppose alternatively that C drowned in the winter. Obviously, summer lifeguards would not have saved C. However, a fence would have. Suppose instead that D drowned in the summer. Lifeguards would have saved D. (D would not have been deterred, however, by either signs or fences.) E would not have gone swimming with signs or fences. With a lifeguard, however, E would go swimming. Unfortunately, people can drown even with lifeguards.

In the above example, increasing the level of precaution not only decreases the expected accident costs, it also changes the mix of accident types. This is common to just about every tort scenario imaginable. And the effect can be quite dramatic. Suppose a car is driving along a road with no speed marking. Suppose the driver is trying to decide among three speeds. High speed costs $0 because of the benefits of arriving at

[12] This example is roughly based on facts in Hendricks v. Peabody Coal Co., 115 Ill. App. 2d 35, 253 N.E.2d 56 (1969); see Grady, Discontinuities and Information Burdens, *supra* note 1, at 667.

[13] We think of A, B, C, D, and E as people only for purposes of illustration. In fact, A, B, C, D, and E are accident types and in this sense may be distinguished even if the accidents occur to the same people, as we will see in a later example.

the destination early. Moderate speed costs $15 in terms of delay. Low speed costs $30 in terms of delay. A possible result is presented in Table 6.

Again I think of the accidents as people. Driving fast ($0) puts A, B, C, and D at risk. Driving more slowly ($15) puts E and F at risk, since A, B, C, and D are no longer on the scene and G has not yet arrived. Driving even more slowly ($30) puts only G at risk. The social optimum is still $15. The private payoffs are now presented in Table 7.

Again, expected accident cost falls as the precaution level increases. Yet the accidents completely change in identity. As a result, we get a bias toward excess precaution with all three rules.[14]

As yet another example, consider the case in which making an activity safer encourages people to engage in it (see Table 8). In this example, G and H would never have engaged in the activity or bought the product if it had not been relatively safe. The social costs in this example are *SC*($0) = $60, *SC*($15) = $55, and *SC*($30) = $60. Private costs to the potential injurer under the three rules are presented in Table 9. Note also that all rules produce an incentive for overinvestment in precaution. However, the cutoff rule is superior to the cost-benefit rule.

Other examples abound.[15] Consider the dam example used by Grady in his Yale piece.[16] Building a higher dam may protect those in front of the dam from flooding but put at greater risk those behind the dam (also from flooding) even though doing so would be on net socially efficient. Alternatively, building a higher dam may protect against higher rainfall but may be more vulnerable in an earthquake. Those injured when the dam collapses in an earthquake and those injured by an overflow in a flood are likely to be different (though overlapping) groups. However, it is important to realize that we have incomplete ordering even if the *same* people or class of people are injured. Consider Table 10.

Interpret $0 as building a low dam, $10 as building a medium dam, and

[14] It is interesting that the notion of probabilistic causation can work to remove some holes. Let us consider a variation of the above problem. Consider Table 6a (p. 298). Now suppose that accidents E, F, and G can be categorized as an accident type, such as a rotten tree falling on the car as in Berry v. Borough of Sugar Notch, 191 Pa. 345 (1988). In this case, liability will be excused for accident E, even though there is but-for causation. This has the effect of removing all holes and creating symmetry under the cost-benefit rule. Of course, the notion of probabilistic causation will not necessarily remove all holes. Consider Table 6b. In this case, even if we have no liability for accident E, then the cost-benefit rule still leads to an incentive for overprecaution. (I thank an anonymous referee for this insight.)

[15] As another example of holes consider seat belts. It is clear that seat belts reduce the probability of injury but there are situations where not wearing a seat belt saved the occupant of the car.

[16] Grady, A New Positive Economic Theory of Negligence, *supra* note 1, at 807 *et seq.*

TABLE 6

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	etc.
$0	A	B	C	D				
$15					E	F		
$30 (or $29.99)							G	

TABLE 6a

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	etc.
$0	A	B	C	D	E				
$15	A	B				F			
$30 (or $29.99)	A						G		

TABLE 6b

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	etc.
$0	A	B	C	D	E				
$15	A	B				F			
$30 (or $29.99)			C				G		

TABLE 7

	Full Liability	Cutoff	Cost Benefit
$0	40	40	40
$15	15	15	15
$30	30	30	30

TABLE 8

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	etc.
$0	A	B	C	D	E	F			
$15					E	F	G	H	
$30 (or $29.99)						F	G	H	

TABLE 9

	Full Liability	Cutoff	Cost Benefit
$0	60	40	50
$15	15	15	15
$30	30	30	30

\$20 as building a high dam. Let s_1 be low rainfall, s_2 be medium rainfall, s_3 be high rainfall, and s_4 be an earthquake. Assume again that states of nature have a .01 probability of occurring, that the accidents occur to the same person, and that they cost \$1,000. Notice that a low dam will result in flooding with low, medium, or high rainfall. A medium dam will result in flooding only with high rainfall. Only a high dam is susceptible to earthquake damage and consequent flooding. A, B, C, and D all represent flooding damage to the same victim whether by rainfall or by earthquake. In this case, social costs are $SC(\$0) = \$30$, $SC(\$10) = \$20$, and $SC(\$20) = \$30$. Private costs to the potential injurer under the three rules are presented in Table 11.

"Holes" in the table can come from different types of accidents that happen to the same persons or class of persons (as in this example), from the same accidents that happen to different persons or classes of persons (as in previous examples) or different accidents that happen to different persons or classes of persons. So pervasive are the opportunities for incomplete ordering that it is difficult to conceive of an example in which incomplete ordering does not occur.[17]

VI. Some Concluding Remarks

The purpose of this article is primarily to examine Grady's theorem, that is, to consider the assertion that the cost-benefit rule leads to unbiased incentives for precaution. We can now see that the conclusion that the cost-benefit rule is efficient depends on an assumption that is highly counterfactual. One can replace this assumption with a more reasonable one without affecting the tractability of the model or changing its explicit

[17] It is important to keep in mind that under the cost-benefit rule the plaintiff can come into court and specify the type of precaution that should have been taken. The plaintiff is constrained only by the necessity of showing that this level of precaution is superior to the one taken. The plaintiff is well motivated to find and present a precaution that would indeed have prevented his or her injury. Given the range of options and the creativity of plaintiffs the likelihood of finding a socially superior precaution that would have prevented this accident is high. In the above tables, only a few of the many options possible have been presented and yet the result is quite dramatic.

TABLE 10

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	etc.
\$0	A	B	C					
\$10			C					
\$20 (or \$19.99)				D				

TABLE 11

	Full Liability	Cutoff	Cost Benefit
\$0	30	20	30
\$10	10	10	10
\$20	20	20	20

assumptions. Doing so, however, completely changes the result. That is, the cost-benefit rule now results in a bias toward overprecaution.

Although I have completed my main task, there remains an interesting question. Even though the cost-benefit rule will typically be biased toward overprecaution, might it still be preferred to the cutoff rule?

As previously noted, incomplete ordering affects the cutoff rule as well as the cost-benefit rule. Compared to the complete ordering scenario, "holes" push both rules toward inducing greater precaution. The result is that the presence of a single "hole" will create an overprecaution bias under the cost-benefit rule.[18] In many cases, a single "hole" will create an overprecaution bias under the cutoff rule as well. Given the pervasive opportunities for "holes," it is highly likely that both rules will result in an overprecaution bias. However, the amount of overprecaution that occurs under the cutoff rule is always less than (or equal to) that under the cost-benefit rule.[19]

There are two reasons for this result. First, the cost-benefit rule provides for greater liability than the cutoff rule even in the absence of "holes." Second, the only "holes" that are relevant for the cutoff rule are those below the optimal level of care. This is because, for purposes of causation, comparisons are made between the actual level of care (if suboptimal) and the optimal level of care. However, with the cost-benefit

[18] Technically, extremely high levels of precaution (those with social costs higher than the social cost at the lowest possible level of precaution) will never be implicated and thus "holes" at these extremely high levels of precaution are irrelevant.

[19] In general, the bias toward overinvestment in precaution will be less under the cutoff rule. However, it may occasionally be equal in those cases where both rules lead to identical liability. See the example in Tables 5 and 6 for such a case.

rule, all "holes" are relevant, since all levels of precaution are potentially implicated.[20]

I can summarize the above discussion as follows.

1. The existence of a single "hole" will bias the cost-benefit rule toward overprecaution. The existence of a single "hole" will often bias the cutoff rule toward overprecaution.

2. Given the pervasive opportunity for "holes," scenarios in which there are no "holes" must be extremely rare, if they exist at all. Rather, if the tables could capture the rich detail of reality, they would be riddled with "holes."

3. As a result of 1 and 2 above, both rules would have an overprecaution bias.

4. The cutoff rule has an overprecaution bias that is always less than (or equal to) the bias of the cost-benefit rule.

From this we may wish to conclude that the cutoff rule is preferred to the cost-benefit rule under the criterion of least overprecaution bias. Of course, the final determination as to the best rule will depend on a host of other factors including evaluations of other assumptions of the model and the importance of other criteria, such as fairness, administrative efficiency, and the like.

In a sense, this article is more a discussion of the complexity of reality than of the efficiency of any one particular rule. Grady's theorem, in portraying a limiting case of a more complex reality, really proves its opposite. (This in no way diminishes its value.) That is, it proves that the cost-benefit rule is *not* efficient. Indeed, it is not even the better rule under the criterion of least precaution bias.

In this light, one is led back to Grady's observation that courts actually apply the cost-benefit rule in practice. In reconciling the inefficiency of the cost-benefit rule with the use of it by the courts, one could come to several conclusions. One might be that the tort law is not efficient after all. However, another might be that ease of application of the cost-benefit rule might make it superior from an efficiency standpoint even though the incentives are not quite as good as under the cutoff rule. (The argument is that courts have more difficulty with defining the optimal level of precaution than they would defining superior levels of precaution.) These issues, however, I will leave for another day.[21]

[20] Again, "holes" at extremely high levels of precaution are irrelevant. Nevertheless, the range of relevant levels of precaution is far greater under the cost-benefit rule than under the cutoff rule.

[21] We also will leave for another day some analogous issues affecting the continuity of causation rules. These involve cases in which the severity of the accident varies with care and cases in which states of nature are not perfectly discernible ex post.