Abstract:
This paper analyzes the effects of evidentiary uncertainty on people's incentives to abide by rules in the context of negligence rules in tort law. It demonstrates that i) the comparative negligence rule is not necessarily superior to the simple or the contributory negligence rule, ii) an application of lenient standards of due care under the contributory negligence rule than in comparative negligence rule would not necessarily restore social efficiency, and iii) a partial reduction of legal uncertainty would not necessarily improve social efficiency. These results contrast previous theoretical literature.

JEL classification: K13
Key words: tort law, negligence rule, legal uncertainty

1 P.O. Box 184, Chongnyang, Seoul, Korea. Phone: 82-2-3299-1013, Fax: 82-968-5072, Email: yhy@kdischool.ac.kr.
Uncertainty and Negligence Rules

1. Introduction

It is well known in tort literature that under perfect information, all three negligence rules -- simple, contributory, and comparative negligence -- generate socially efficient levels of care by the injurer and the victim. It is also well known that once uncertainty, caused by measurement error or vagueness of a statute, is introduced into this ideal world of perfect information, the efficiency proposition breaks down. (Haddock and Curran, 1985; Calfee and Craswell, 1984; Craswell and Calfee, 1986; Cooter and Ullen, 1986; Shavell 1987).

Since uncertainty is unavoidable in life, the following set of questions naturally arise:

1) whether one negligence rule has a smaller efficiency loss than the remaining two,
2) whether one can restore social efficiency by altering the legal standard of due care, and,
3) whether one can improve social efficiency by reducing the degree of uncertainty.

Regarding the first question, Haddock and Curran (1985) conjectured that the comparative-negligence rule might be better than the remaining two, and Cooter and Ullen (1986) developed this idea into a full-blown proposition that the comparative-negligence rule is superior to the other rules.

As to the second question, Calfee and Craswell (1984) suggested that, in order to correct any incentives to overcomply or undercomply induced by uncertainty, courts should make corresponding adjustments in legal standards or damages awarded. Following this line of thought, Edlin (1994) argued that the jury's tendency to be more lenient toward the plaintiff under the contributory than the comparative-negligence rule does in fact accomplishes the required adjustment, whether wittingly or unwittingly, thereby playing an instrumental role in promoting efficiency.

Concerning the third question, calls for reduced uncertainty are too pervasive to list -- many legal arrangements such as the "bright-line principle", the "void for vagueness" doctrine, the provision of a collegiate judgment system purport to improve the legal accuracy, despite the caveat (Craswell and Calfee, 1986) that reduced
uncertainty may backfire by inducing the injurer to take excessive precaution.

This paper reexamines these three issues in a general game-theoretic setting, and shows that those earlier writers' conclusions hold true only in limited, special cases. In particular, this paper demonstrates that:

1) the comparative-negligence rule is not necessarily superior to the other rules,

2) jury leniency does not always improve the social efficiency under the contributory-negligence rule, and

3) in general, it is impossible to improve social efficiency by merely reducing the degree of legal uncertainty.

The key driving force behind these conclusions is that both the direction and the size of the deviations from the social optimum induced by uncertainty in each negligence regime are generally indeterminate. And the change in equilibrium care to be brought about by the suggested remedial measures is also indeterminate. Therefore, unless one imposes a strong restriction on the way people behave, it is not, in general, possible to 1) rank the different negligence rules by their efficiency properties, 2) make a monotonic adjustment in legal standards to the different negligence rules, nor 3) reduce uncertainty in such a way that would effect an improvement of social efficiency across the board.

This paper is organized as follows. In Section 2, a model is set up to derive equilibrium solutions under different negligence regimes. In this model, the potential injurer and victim are likened to players in a liability shifting (or buck-passing) game. The equilibrium arises as a non-cooperative solution to the game, and the social optimum as the cooperative solution. As usual, the non-cooperative solution diverges from the cooperative one, creating suboptimality. In Section 3, it is demonstrated that both the magnitude and the direction of deviation of the noncooperative solution from the cooperative optimum cannot be predicted in advance, because of the many intervening factors at work in equilibrium. This implies that the efficiency loss induced by uncertainty is much harder to cure than is suggested by earlier writers. In Section 4, earlier literature is reviewed. Section 5 offers the conclusion.
2. The Model

Let $x_1$ and $x_2$ denote the care level taken by a potential injurer and a victim, respectively. Care taking is costly, and the cost of care is represented by $c^1(x_1)$ and $c^2(x_2)$, $c^i(x_i) > 0$ (i=1,2). Greater care reduces the expected accident loss, $A(x_1,x_2)$, $A_i < 0$. A social planner wants to minimize the sum of the cost of care and the cost of expected accident loss,

$$\min_{x_1,x_2} Z(x_1,x_2) = c^1(x_1) + c^2(x_2) + A(x_1,x_2).$$  \hfill (1)

The first order conditions (FOC) are

$$Z_1(x_1^*,x_2^*) = c^1_1(x_1^*) + A_1(x_1^*,x_2^*) = 0, \quad \text{and}$$
$$Z_2(x_1^*,x_2^*) = c^2_2(x_2^*) + A_2(x_1^*,x_2^*) = 0, \quad \text{(2a)}$$

meaning that the marginal cost of precaution must be equated with the marginal reduction of expected accident loss at equilibrium. Let the optimum solution be denoted as $x_i^*$ (i=1,2).

The second order conditions (SOC) are

$$Z_{11} > 0, \quad Z_{22} > 0 \quad \text{and} \quad \begin{vmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{vmatrix} > 0, \quad \text{(3a)}$$

or equivalently

$$c_{11}^1 + A_{11} > 0, \quad c_{22}^2 + A_{22} > 0 \quad \text{and} \quad \det H_Z = \begin{vmatrix} c_{11}^1 + A_{11} & A_{12} \\ A_{21} & c_{22}^2 + A_{22} \end{vmatrix} > 0. \quad \text{(3b)}$$

Note that a negative $A_{ij}$ implies that both the injurer's care and the victim's care are complements in reducing the expected accident loss, while a positive $A_{ij}$ implies that they are substitutes. If they are complements, $x_1^*$ and $x_2^*$ will move to the same direction whenever there is an exogenous parametric change, whereas if they are
substitutes, each will move to the opposite direction. If $A_{ij}=0$, both are independent of each other, and $x_1^*$ can be determined without reference to $x_2^*$, and vice versa.

Various Negligence Rules and Equilibrium Care Under Uncertainty

In considering various negligence rules, I first assume that the court sets the standard of due care, $\bar{x}_i$, at the socially efficient level, $x_i^*$, and the damages at the level of actual loss. The party whose care level falls short of the legal standard, i.e., $x_i < \bar{x}_i = x_i^*$, will be deemed negligent or at fault.

The damages are apportioned differently depending on which negligence rule is applied. Under the simple negligence rule, the injurer is liable if she is negligent. If the injurer is not negligent, the entire loss must be borne by the victim. Under the contributory negligence rule, the injurer is liable only when she is negligent and the victim is not negligent. Negligence on the part of the victim, no matter how minor, will result in a complete bar of damage compensation. The comparative negligence rule is identical to the contributory negligence rule except when both are negligent. In the latter case, the damages will be shared in some pre-stipulated manner.

It is now well known that in an ideal world of complete information, all three negligence rules generate an efficient outcome in which both the injurer and the victim exercise care at the socially optimal level. So there is no apparent reason to choose one negligence rule over the others as long as efficiency is concerned. This equivalence among different rules of negligence, however, breaks down when uncertainty is brought into the picture.

In order to see this, let's assume that $x_i$ is observed with an error, $e$, which has a density function $f(e)$ and a cumulative distribution function $F(e)$. The party whose observed care level is less than the legal standard, $x_i + e < x_i^*$, will now be deemed negligent. The probability that one will be found negligent is

$$\text{prob}(x_i + e < x_i^*) = \text{prob}(e < x_i^* - x_i) = F(x_i^* - x_i).$$

2 I will arbitrarily call the injurer "she" and the victim "he".
For distinction, let $F(x_1^*-x_1)$ denote the probability of the injurer's being found negligent, and $G(x_2^*-x_2)$, the probability of the victim's being found negligent.

Each party's cost minimization problem under different negligence rules can now be summarized as follows.

1) Simple Negligence

\[ Z^{1s} = c^1(x_1) + A(x_1,x_2)F(x_1^*-x_1) \] (5a)
\[ Z^{2s} = c^2(x_2) + A(x_1,x_2)[1-F(x_1^*-x_1)] \] (5b)

2) Contributory Negligence

\[ Z^{1n} = c^1(x_1) + A(x_1,x_2)F(x_1^*-x_1)[1-G(x_2^*-x_2)] \] (6a)
\[ Z^{2n} = c^2(x_2) + A(x_1,x_2){1-F(x_1^*-x_1)[1-G(x_2^*-x_2)]} \] (6b)

3) Comparative Negligence

\[ Z^{1m} = c^1(x_1) + A(x_1,x_2)F(x_1^*-x_1)[1-G(x_2^*-x_2)r] \] (7a)
\[ Z^{2m} = c^2(x_2) + A(x_1,x_2){1-F(x_1^*-x_1)[1-G(x_2^*-x_2)r]} \] (7b)

where the superscripts 1 and 2 represent the injurer and the victim, respectively, and s, n, and m, for the simple, contributory and comparative negligence rules, respectively. The parameter r represents the proportion of the damages that the victim has to bear when both parties are found to be negligent. In the following, I will assume that r is fixed, such that $0 \leq r \leq 1$.

Note first that all the objective functions under each negligence rule can be obtained by assigning different values to r: if r=0, it will give rise to the simple negligence rule; if r=1, the contributory negligence rule; if $0<r<1$, the comparative negligence rule. Thus, we can use the comparative negligence rule as an all-encompassing representative model, and generalize the result by alternating the value of r.

3 Different versions of the comparative negligence rule have different damage-sharing rules. For example, the traditional version of the US maritime rule has the damages be split equally when both the plaintiff and the defendant are found negligent. In this case, $r=0.5$ and is fixed. More commonly, however, sharing rules divide the liability in proportion to fault. In this regard, the assumption of constancy of r is a serious oversimplification of reality. Nonetheless, I adopt this assumption for the following two reasons: first, it makes the analysis much simpler, and second, it is the very assumption adopted by most of the aforementioned researchers (Cooter and Ullen, 1986; Orr, …), and a direct comparison necessitates the same assumption.
r. Rewrite the objective functions as

\[ Z_1^1 = c_1^1(x_1) + A(x_1,x_2)F(x_1^*-x_1) \phi(x_2, r) \]  
\[ Z_2^2 = c_2^2(x_2) + A(x_1,x_2) [1-F(x_1^*-x_1)\phi(x_2, r)] \]  

where \( \phi(x_2,r)=1-G(x_2^*-x_2)r, 0 \leq r \leq 1. \) Here, we have \( \phi=1, \phi'=0 \) under the simple negligence rule and \( \phi=1-G, \phi'=g \) under the contributory negligence rule. Given these, \( F\phi \) now stands for the probability that the injurer is held liable, weighted by the sharing parameter \( r \), and \( 1-F\phi \) the probability that the victim is held liable. Since \( \phi \leq 1 \), and \( \phi'<0 \), a higher \( r \) is equivalent to lowering the injurer's (adjusted) probability and raising the victim's (adjusted) probability.

Second, note that \( Z=Z_1^k+Z_2^k \) for all \( k=\{s, n, m\} \) in (5)-(8). Under any negligence rule, the social planner's objective function is simply the sum of the injurer's and the victim's objective functions. In this sense, the social planner tries to minimize the joint cost, whereas the injurer and the victim each try to minimize his/her own individual cost, with no regard to the other party's cost. In other words, the social planner's solution to the problem can be regarded as a cooperative solution to the game while the individual party's solution the noncooperative solution to the same game.

The FOCs for the noncooperative solution are

\[ \text{Injurer: } Z_1^1 = c_1^1 + A_1F\phi-A\phi = 0 \]  
\[ \text{Victim: } Z_2^2 = c_2^2 + A_2(1-F\phi)-A\phi' = 0. \]  

The marginal cost of precaution is again equated with the marginal savings of expected liability. Unlike the cooperative solution, however, the marginal savings here are composed of two terms (the second and the third term), with the second term capturing the accident loss curtailed by the increased precaution, and the third term, the liability passed onto the other party. In the noncooperative game, whenever one player increases his/her level of precaution, it always generates these two mutually reinforcing effects. In

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4 Since functions in (8) subsumes all three different negligence rules, the superscripts, \( s, n, m \) are spared.
the following, I will call the former as the loss curtailing (LC) effect of one party's precaution and the latter as the liability shifting (LS) effect.

Equations (9a) and (9b) are the reaction functions of the injurer and the victim, respectively. The Nash equilibrium is obtained by solving these two reaction functions simultaneously. Let this noncooperative solution be denoted as \((x_1^k, x_2^k)\), \(k=s, m, n\).

The following table, which is obtained through implicit differentiation of the FOCs in (9), provides the overall direction of shifts of reaction functions induced by some parameter changes.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Shifts of Reaction Functions Due to Some Parametric Changes</th>
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<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>(x_1)</td>
<td>(f\phi &gt; 0)</td>
</tr>
<tr>
<td>(x_2)</td>
<td>(F\phi &gt; 0)</td>
</tr>
</tbody>
</table>

The first column shows that, as the size of the accident loss increases (the vertical shift of the \(A(x_1, x_2)\) function), both the injurer's and the victim's reaction curves shift outward (along its own axis), except for the victim's reaction curve under the simple negligence rule, which stays put. An increase in \(A\) makes either party's LS effects bigger, thus creating incentives to take greater care. The second column concerns the effect of negligence-regime changes. As the value of \(r\) increases (as the negligence regime evolves from the simple negligence to the contributory negligence), the injurer's reaction curve shifts inward, and the victim's reaction curve outward. This is because an increase in the value of \(r\) reduces the injurer's share of burden, thus weakening the marginal productivity of the injurer's care. The opposite holds with the victim's care.

The third and the fourth column show the effects of changes in the legal standards of due care. Surprisingly, raising the legal standard for the injurer's care does not necessarily shift the injurer's reaction function outward; it depends on the curvature of the distribution function, \(f'\). The effects on the victim's reaction function is also

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5 If the distribution function is uniform \((f' = 0)\), the injurer's reaction function shifts out.
ambiguous. But under the simple negligence rule where \( \phi' = 0 \), it causes the victim's curve to shift inward. The fourth column must all be zero under the simple negligence rule where the victim's standard is not applicable. Under the comparative or the contributory negligence rules, the signs are indeterminate.\(^6\)

Given these shifts, changes in the final equilibrium will be determined by the slope of the other party's reaction curve. As will be shown later, however, the slope of reaction curves are also affected by these shift factors, making it difficult to discern the possible direction of the equilibrium changes.

3. Properties of Equilibrium

In this section, I present some of properties of equilibrium under evidentiary uncertainty.

**Proposition 1:** In every negligence rule, the level of care taken by each party under the legal uncertainty is sub-optimal, i.e., \( x_i^k \neq x_i^* \).

**Proof:** Given the nature of the non-cooperative solution, this result is already expected. More precisely, the FOCs for the cooperative solution given in (2) can be rewritten as

\[
\begin{align*}
Z_1^* &= Z_1^* + Z_2^* = 0 \quad (10a) \\
Z_2^* &= Z_2^* + Z_2^* = 0, \quad (10b)
\end{align*}
\]

where \( ^* \) attached to each expression implies that the function is evaluated at the point of social optimum point. Comparing it with the FOCs for the non-cooperative solutions in (9), it is evident that in the non-cooperative game, the injurer fails to take into account \( Z_2^* \), the effect of her action on the victim's cost, when she chooses her precaution level to minimize her own expected cost. Alternatively, the victim does not take into account \( Z_1^* \), the effect of his precaution on the injurer's cost. Therefore, unless it happens that \( Z_2^* = Z_1^* = 0 \), the equilibrium levels of care under uncertainty, \((x_1^k, x_2^k)\), deviate from \((x_1^*, x_2^*)\).

\(^6\) If the distribution is uniform, the victim's reaction curve shifts upward.
In short, Proposition 1 states that as long as certain externality elements fail to be internalized, suboptimal levels of equilibrium care will ensue. Below, it will be shown that, $Z_1^* \neq 0$ and $Z_2^* \neq 0$, unless each player's LC effect of precaution exactly cancels out the LS effect, which is rather unlikely.

Now let's investigate the possible directions of the deviation from the social optimum. In particular, we are interested in examining whether overcompliance or undercompliance will take place as a result of uncertainty in the legal process. This is interesting because some researchers claim that there would be a general tendency that uncertainty induces parties to overcomply (Cooter and Ullen, 1986; Shavell, 2004).

Taking a Taylor series expansion around $(x_1^*, x_2^*)$ and evaluating at the other party's non-cooperative solution, we can rewrite the FOCs in (9) as

\[
Z_1^1(x_1^*, x_2^k) = Z_1^1 + Z_1^{12'}(x_2^k - x_2^*) = -Z_2^2 + Z_1^{12'}(x_2^k - x_2^*) \quad (11a)
\]
\[
Z_2^2(x_1^k, x_2^*) = Z_2^2 + Z_2^{21'}(x_1^k - x_1^*) = -Z_1^1 + Z_2^{21'}(x_1^k - x_1^*) \quad (11b)
\]

where $Z_{ij} = Z_{ij}(x_1^*, x_2^k)$, $Z_{ij}' = Z_{ij}(x_1^*, x_2^k)$ where $x_i^* = \alpha x_i^k + (1-\alpha)x_i^*$, $0 < \alpha < 1$. The second equalities are obtained using (10).

Here, a positive $Z_1^1(x_1^*, x_2^k)$ implies the injurer's undercompliance, and a negative $Z_1^1(x_1^*, x_2^k)$ her overcompliance. The same relationship holds with regard to the victim's precaution.

Note that in each equation of (11), the right hand side of the first equality has two terms: the first terms representing the deviation from the optimum at the socially optimal point, $Z_1^1$ and $Z_2^2$, and the second terms representing one party's reaction to the other party's deviation from the optimum. This implies that the deviation from the optimum caused by the introduction of uncertainty can be decomposed into two parts: the pure uncertainty effect, captured by the first terms, and the feedback effect, captured by the second terms. By inspecting the terms following the second equalities, we can see that the pure uncertainty effect is none other than the negative of the externality effects mentioned above. In the following, I will first examine the pure uncertainty effect and then the feedback effect, and show that neither are determinate.
1) The Pure Uncertainty Effect

Differentiating one party's objective function with respect to the other party's control variable and evaluating at \((x_1^*, x_2^*)\) gives

\[
Z_{1j}^* = A_1^*(1 - F^*\phi^*) + A_1^*\phi^* = (1 - F^*\phi^*) \frac{A_1^*}{x_1} [\eta_{1-F, x_1} - \eta_{A, x_1}], 
\]

\[
Z_{2j}^* = A_2^*F^*\phi^* + A_2^*\phi^* = F^*\phi^* \frac{A_2^*}{x_2} [\eta_{F, x_2} - \eta_{A, x_2}], 
\]

where \(\eta_{y, x_i}\) is the elasticity of \(y\) with respect to \(x_i\).

In each equation, the first term on the right hand side of the first equality is negative; each party's additional precaution reduces the expected liability that the other party has to bear by cutting the accident loss size itself. This is the LC effect. The second term is positive and represents the LS effect. One party's incremental precaution reduces his/her own probability of being held liable, and thereby increases the other party's probability of liability. In short, one party's increased precaution exerts two opposing forces upon the other party: the LC effect, which creates positive externalities by reducing the size of burden that the other party has to bear, and the LS effect, which creates negative externalities by increasing the other party's probability of being held liable.\(^7\) The net effect is then determined by the relative size of these two opposing effects.

Transformed into a succinct elasticity form, the expressions following the second equality are more revealing. Note that \(\eta_{1-F, x_1}\) measures the elasticity that the injurer can increase the victim's probability of being held liable by increasing her own precaution. So it is the LS effect of the injurer's precaution. Similarly \(\eta_{F, x_2}\) represents the LS effect of the victim's precaution. The remaining two elasticities, \(\eta_{A, x_i}\) \((i=1,2)\), measure each player's LC effect. Consequently, the expressions following the second equality simply say that the gap between the LS and LC elasticity determines the sign of \(Z_{1j}^*\): if the LS elasticity is greater than the LC elasticity, \(Z_{1j}^*\) is positive, and vice versa.

Ignoring the feedback effect temporarily, a positive value of \(Z_{1j}^*\) (negative

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\(^7\) Even though the numerical signs are positive, I call it negative externalities because one party's action hurts the other party.
externalities by player j on player i) implies that player j will overcomply. In this case, player j takes more care than is optimal because he can enjoy a greater gain by passing the buck to the other player. On the other hand, if \(Z_{ij}^*<0\), player j takes less care than is socially optimal, because his/her positive externalities (the LC effect) outweighs the negative externalities (the LC effect). This concurs with the general economic principle that the net negative externalities entail excessive activity, and the positive externalities insufficient activity.

The fact that the sign of \(Z_{ij}^*\) depends on the elasticities implies that without knowing the exact shapes of the functions that are involved in a particular case, --the cost function \(c'(x_i)\), the expected loss function \(A(x_1, x_2)\), the measurement error function \(F(x_i^*-x_i)\), and the particular negligence regime -- there is no way of knowing a priori whether there will be net positive externalities or negative externalities. This establishes the following:

**Proposition 2:** The pure uncertainty effects are indeterminate. That is, the net externalities that one party exerts on the other party can be positive, negative, or zero.

Despite this overall indeterminacy, we can still observer a few important factors that determine the direction of externality effects by examining Table 1. Evaluating the numerator of each cell in Table 1 at the socially optimal point, we have:

(i) In every negligence regime, the net (negative) externalities that one party inflicts upon the other party (except the victim under the simple negligence rule) are increasing in \(A^*\), the size of the socially unavoidable minimum accident loss.

ii) The net (negative) externalities that the injurer inflicts upon the victim are decreasing in \(r\), and the net (negative) externalities that the victim inflicts upon the injurer is increasing in \(r\).

Other things being equal, a large accident loss makes the negative externalities (the LS effect) bigger, and therefore induces both the injurer and the victim to compete more actively to pass the burden to the other party. Note, however, that greater care does not necessarily mean overcompliance. A larger value of \(A^*\) makes \(Z_{ij}^*\) numerically larger,
but not necessarily positive.

An exception to this general rule is the victim under the simple negligence rule. In this case, the victim does not have the leverage to exercise his LS effect \((\phi^l=0)\) because his level of care does not matter as long as the liability decision is concerned. Constrained to create only the beneficial LC effect, the victim is likely to take inadequate amount of care unless the feedback effect more than countervails the pure uncertainty effects.

The fact that the net externality effects are monotonic in \(r\) implies the following:

a) if \(Z_{11}^*|_{r=1}>0\), then \(Z_{21}^* > 0\) for all \(r\). That is, if the injurer exerts negative externalities under the contributory negligence regime, she exerts negative externalities in every regime,

b) if \(Z_{11}^*|_{r=0} < 0\), then \(Z_{21}^* < 0\) for all \(r\). That is, if the injurer exerts positive externalities under the simple negligence regime, she exerts positive externalities in every negligence regime.

c) if \(Z_{21}^*|_{r=1}<0\), then \(Z_{12}^* < 0\) for all \(r\). That is, if the victim confers positive externalities under the contributory negligence regime, he confers positive externalities under every negligence regime. \(^8\)

Assuming normal distribution with a zero mean and a standard deviation \(\sigma\) \(^9\) and perfect symmetry of the injurer and the victim in the sense that \(A_1^*=A_2^*\) and \(c_1^*=c_2^*\), we can have the following three cases. Let \(\rho=A^*/(c_i^*/\sqrt{2\pi})\). Note that \(\rho\) is increasing in \(A^*\) and decreasing in \(c_i^*\).

Case 1) \(\sigma > 2\rho\)
Both the injurer and the victim confer only net positive externalities under every negligence regime.

Case 2) \(2\rho/3 < \sigma < 2\rho\)
Under the simple negligence rule, the injurer exerts net negative externalities and the victim generates net positive externalities. Under the contributory negligence rule, the

\(^8\) We don't need to check \(Z_{21}^*\) when \(r=0\), because it is always negative.

\(^9\) This implies that the distribution is symmetric; the court has no upward or downward bias in measuring the care levels. As a result, \(F(0)=G(0)=1/2\).
other extreme, the injurer confers net positive externalities, and the victim gives net negative externalities.

**Case 3) \( \sigma < 2\rho/3 \)**

The injurer exerts net negative externalities under every negligence regime. The victim starts with positive externalities but ends up with negative externalities as the value of \( r \) increases.

Loosely speaking, the larger the measurement variance, the smaller the minimum accident loss \( A^* \), and/or the greater the marginal cost of care, the more likely that each party exerts net positive externalities, and, therefore, undercomplies, and vice versa.\(^{10}\)

2) **The Feedback Effects**

The feedback effect concerns how one party responds to the other party's deflection from the social optimum, and the direction of this response is determined by the signs of the cross derivatives, \( Z_{12}^1 \) and \( Z_{21}^2 \), or equivalently by whether \( x_1 \) and \( x_2 \) are viewed as strategic substitutes or complements.\(^{11}\) Note that these cross derivatives measure the effect of one party's precaution on the marginal productivity of the other party's precaution, or, by Young theorem, one party's capacity to cope with the externalities created by the other party.

By differentiating the FOCs in (9) with respect to the other party’s precaution, we have

\[
Z_{12}^1 = A_{12}F\phi - A_2f\phi + (A_1F - Af)\phi' \\
Z_{21}^2 = A_{21}(1-F\phi) + A_2f\phi - (A_1F - Af)\phi'.
\]

\(^{10}\) This is exactly the reason why Craswell and Calfee (1986) concluded that reduced uncertainty will result in excessive care. But as has been demonstrated in Yoo (2003b), this conclusion holds only at \( x_i^* \) or in its close neighborhood, and cannot be extended to other points.

\(^{11}\) For the definition of strategic complements and substitutes, see Bulow et al. (1985) and Fudenberg and Tirole (1984).
The sign of the first term of (13a) is indeterminate (depends on the sign of $A_{12}$), the second term is positive, and the third term is negative or zero. Similarly, the terms in (13b) are, respectively, indeterminate, negative and positive. Hence, it is apparent that we cannot pin down the sign of each equation, and therefore, or, the slope of each player's reaction curve.\footnote{All these terms can again be regrouped and transformed into elasticity terms, suggesting that the sign will vary along the point at which the elasticity is evaluated.} The reaction functions can take either positive or negative slope, and may even have multiple sign changes.

**Proposition 3:** The directions of the feedback effects are indeterminate.

A few things are worthy of note: first, every term except the first in $Z_{12}^1$ is identical to the corresponding term in $Z_{21}^2$ in magnitude, but opposite in sign. This is again because of the zero-sum nature of the game: every additional gain enjoyed by the injurer by passing the buck becomes an additional burden to the victim, and vice versa.

Second, when we ignore the terms related to the LS effect (the second and third terms), the sign of $Z_{ij}$ is solely determined by the sign of $A_{ij}$, the technical complementarity or substitutability between $x_1$ and $x_2$. This implies that any divergence between the technical and strategic complementarity is due to the LS effect.

Third, we have $Z_{12}^1+Z_{12}^2=A_{12}$ in every negligence regime. As the LS effects are being completely netted out and the LC effects are being probabilistically divided between the two, we are left only with $A_{12}$ when we add them together. One immediate implication is that $Z_{12}^1$ and $Z_{12}^2$ are asymmetrical unlike the cooperative solution. In particular, $A_{ij}=0$ no longer guarantees the mutual independence between the injurer's precaution and the victim's precaution. Rather, $A_{ij}=0$ dictates $Z_{12}^1$ and $Z_{21}^2$ must have opposite signs, but the same magnitude: if one party considers $x_1$ and $x_2$ mutual complements, the other party should necessarily consider them substitutes.

Turning to the question of different negligence regime, the victim has no power to shift the liability ($\phi'=0$) under the simple negligence rule, but only to cut it small. This leaves only the first two terms in each equation of (13). The $A_{ij}$ term is common to both $Z_{12}^1$ and $Z_{21}^2$. The remaining term is $A_{ij}\phi$, which concerns the interaction between the injurer's LS effect and the victim's LC effect. This effect is positive to the injurer, but
negative to the victim, implying that the injurer views the victim's care as a substitute, and the victim views the injurer's care as a complement. From the injurer's viewpoint, her power to shift the liability is weakened as the victim's care increases; whatever the injurer shifts onto the victim, the victim cuts it small by his loss curtailing power. From the victim's viewpoint, however, his loss cutting effect gets the bigger, the more the injurer shifts the liability onto him, because he has more grain to grind in his mill.

The above implies that, under the simple negligence regime, it is more likely for the injurer to consider the victim's care as a substitute for her care (a downward sloping reaction curve), and for the victim to view the injurer's care as a complement to his care (a upward sloping reaction curve).\textsuperscript{13} This is definitely so when $A_{ij}=0$. Note also that under the simple negligence rule, neither $Z_{12}$ nor $Z_{21}$ depends on $A$, the vertical shift factor, but only on $A_2$, the marginal productivity of the victim.

As the negligence regime tilts toward the contributory negligence rule, the strategic position taken by either party gradually switches toward the opposite direction, with the injurer's position heading toward the strategic complements, and the victim's toward the substitutes. This comes from the fact that the third terms in (13) are negative in $Z_{12}$ but positive in $Z_{21}$.

This diametric response to the other party's precaution has its roots in the fundamental asymmetry between the injurer and the victim in every negligence rule; as a residual bearer of the accident loss, the victim can pass the burden only when the injurer also has a positive probability of being held liable, whereas the injurer can always pass the buck regardless of the victim's level of care. To see this, note that, by taking more care, the injurer can always reduce her probability of being held liable. Moreover, the gain from her additional care grows in proportion to the victim's care, because the victim's larger care increases the probability of the injurer being held liable. It makes the victim's care become more complementary to the injurer.

However, this is not the case with the victim. The victim can reduce his probability of being found liable only with condition that the injurer is negligent. Once the injurer is not negligent, the level of the victim's care does not matter at all. Consequently, a greater care by the injurer, which makes the injurer's probability smaller, destroys the

\textsuperscript{13} Putting aside the first terms, which reflects the LC effects of each party's care.
basis on which the victim can control his own or the other party's fate. It makes the injurer's care become more substitutionary to the victim.

Finally, this position switching effect is the larger, the greater the magnitude of the accident loss, A, or the injurer's marginal productivity, A_1, is. The victim's reactionary power gets the greater, the bigger the ball tossed onto his court, either directly or indirectly.

3. The Total Effect

For the total effect, the pure uncertainty effect must be combined with the feedback effects, as is shown in (11). Equations in (11), however, though giving us the directions of the changes induced by the introduction of uncertainty, do not give the exact size of the deviations from the optimum. The actual deviations must be solved simultaneously.

Rewriting the FOCs in (9) as

\[ Z_1^1(x_i^k, x_2^k) = 0 = -Z_{11}^1 + Z_{11}^{1*}(x_i^k - x_i^{*}) + Z_{12}^{1*}(x_2^k - x_2^{*}) \]  \hspace{1cm} (14a)

\[ Z_2^2(x_i^k, x_2^k) = 0 = -Z_{22}^2 + Z_{21}^{2*}(x_i^k - x_i^{*}) + Z_{22}^{2*}(x_2^k - x_2^{*}) \]  \hspace{1cm} (14b)

and rearranging, we have the following simultaneous equations system,

\[ \begin{bmatrix} Z_{11}^1 & Z_{12}^1 \\ Z_{21}^2 & Z_{22}^2 \end{bmatrix} \begin{bmatrix} x_i^k - x_i^{*} \\ x_2^k - x_2^{*} \end{bmatrix} = \begin{bmatrix} Z_{11}^{1*} \\ Z_{22}^{2*} \end{bmatrix} \]  \hspace{1cm} (15)

Note that if \( Z_{11}^{1*} = Z_{22}^{2*} = 0 \), \( x_i^k - x_i^{*} = x_2^k - x_2^{*} \). This implies that the ultimate sources of the deviation from the optimum is the pure uncertainty effect.\(^{14}\) If the pure uncertainty effects become non-zero, then the feedback effects start to propagate the initial deviations to each player. The overall signs and magnitudes of \((x_i^k - x_i^{*}, x_2^k - x_2^{*})\) are indeterminate for the following two reasons: first, \( Z_{11}^{1*} \) and \( Z_{22}^{2*} \) are indeterminate, and

\(^{14}\) The coefficient matrix is positive definite, and therefore non-singular from the stability condition, Dixit(1986). A homogenous simultaneous equation system with non-singular coefficient matrix will generate a null solution.
second, the signs of the $Z_{12}^1$ and $Z_{21}^2$ are indeterminate.¹⁵ This implies that there is no way of knowing whether uncertainty will lead to over- or under-compliance, contrary to the earlier writers' claim.¹⁶ The indeterminacy of $Z_{12}^1$ and $Z_{21}^2$ also implies that the standard comparative static analysis will always generate ambiguous outcomes, whether the external shock to the system comes from a change in the legal standard of due care or a reduction of legal uncertainty.¹⁷

**Graphical Illustration**

In this subsection, I provide a few graphical illustrations to check some of the results thus far. I assume that $A(x_1,x_2) = \tilde{A} - 4x_1 - 4x_2$, $c(x_i) = x_i^2$, and a uniform distribution with the support $[-e, e]$.¹⁸ This implies that $A_{ij} = 0$ and $F(x_i^* - x_i) = (x_i^* - x_i)/2e + 1/2$. In particular, I first set $\tilde{A} = 20$, $e = 1/2$ and then allow small changes in $\tilde{A}$ and $e$ later. Apparently these assumptions are highly restrictive; the cost of care function, the expected loss function and the error distribution function take a particular functional shape, and therefore, some of the results obtained below cannot be generalized to other cases. Despite this limitation, it still provides us with a variety of rich implications. Trivially, the social optimum solution is attained at $x_1^* = x_2^* = 2$.

Figure 1 shows the equilibrium outcomes under various negligence rules, the simple negligence ($r=0$), the comparative negligence ($r=.2$ and .6), and the contributory negligence rule ($r=1$). In each panel, the solid curve ($R_1$) represents the injurer's reaction curve, while the dashed one ($R_2$) represents the victim's. The horizontal axis measures the level of the injurer's care, and the vertical axis, the victim's care. The equilibrium values of care, which are found at the intercept of the two reaction curves, are given in the first row of Table 2 below.

Under the simple negligence rule with $A_{ij} = 0$, we have $Z_{12}^1 > 0$ and $Z_{21}^2 < 0$ which implies that the injurer has a negative-sloped reaction curve, and the victim has a positive-sloped reaction curve. At the intersection of $R_1$ and $R_2$, the equilibrium $(x_1^*, x_2^*)$

¹⁵ To be precise, $Z_{21}^2 < 0$ under the simple negligence rule.
¹⁶ This point is explained in Yoo(2003a), which examines the issue of overcompliance under the simple negligence rule.
¹⁷ These points will be elaborated later.
¹⁸ This example is from Edlin(1994).
occurs at (2.33, 1.67), that is, $x_1^* > x_1^*$ and $x_2^* < x_2^*$, implying that the injurer overcomplies and the victim undercomplies.

<Figure 1> Equilibrium Care Under Different Negligence Rules

As the value of $r$ increases, the slope of $R_1$ gets steeper and finally turns into a positive value at the equilibrium point under the contributory rule. On the other hand, the slope of $R_2$, which used to be positive, becomes negative. This confirms the predicted switch of each party's strategic position.

At the same time, the injurer's reaction curve shifts in, and the victim's curve shifts up as the value of $r$ increases. These shifts are clearly shown in Figure 2, which combines all four panels. There, the shifts and the simultaneous changes in slope make the injurer's and the victim's reaction curves rotate clockwise. The shifts create a general tendency that the care level taken by the injurer declines, from 2.33 to 2.24, 2.02, and
finally to 1.95, and the care level taken by the victim increases, from 1.67 to 1.68, 1.95 and finally to 2.19, as the value of \( r \) increases. However, this general tendency is, sometimes obtruded by the concomitant slope changes. For example, the victim's care decreases from 1.88 to 1.86 as the value of \( r \) increases from 0 to 0.2 under \( \bar{A} = 22 \) (see Table 2 below). In fact, the equilibrium path always contains an initial segment that declines southwestward before it climbs northwestward.

Figure 3 shows the effect of an increase in \( \bar{A} \), from 20 to 22. It makes the injurer's reaction function shift outward and the victim's reaction curve shift upward, except for the victim's reaction curve under the simple negligence rule. It also makes the reaction curves rotate clockwise again, although the rotation effects are smaller than in the case of \( r \).

Under the simple negligence rule, the victim's reaction curve stays put, but the injurer's reaction curve shifts out. This makes both the injurer's and the victim's care levels to increase from \((2.33, 1.67)\) to \((2.44, 1.89)\). This implies that if \( \bar{A} \) is sufficiently large, both the injurer and the victim will overcomply. Similarly, a sufficiently small \( \bar{A} \) would make both undercomply. This simple relationship between the equilibrium points and changes in \( \bar{A} \) does not, however, extend to the case of other negligence rules under which the victim's reaction curve also shifts. For example, the victim's care under the
contributory negligence rule declines from 2.25 to 2.23 as $\bar{A}$ increases from 22 to 24 (Table 2).

<table>
<thead>
<tr>
<th></th>
<th>$r=0$</th>
<th>$r=0.2$</th>
<th>$r=0.6$</th>
<th>$r=1.0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{A}=20$</td>
<td>2.33</td>
<td>1.67</td>
<td>2.24</td>
<td>1.68</td>
</tr>
<tr>
<td>$\bar{A}=22$</td>
<td>2.44</td>
<td>1.88</td>
<td>2.39</td>
<td>1.86</td>
</tr>
<tr>
<td>$\bar{A}=24$</td>
<td>2.56</td>
<td>2.12</td>
<td>2.53</td>
<td>2.04</td>
</tr>
</tbody>
</table>

<Table 2> Equilibrium Care Levels Under Different Values of $\bar{A}$.

<Figure 3> The Effect of $\bar{A}$ Changes on Equilibrium Care

Figures 4 and 5 below show the effects of altering the margin of measurement error, first from $e=0.5$ to 1.0, and then from 0.3 to 0.5. The reactions differ depending on the
initial level of uncertainty.

<Table 3> Effects of Changes in the Margin of Measurement Error

<table>
<thead>
<tr>
<th></th>
<th>r=0</th>
<th>r=0.2</th>
<th>r=0.6</th>
<th>r=1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$x_1^s$</td>
<td>$x_2^s$</td>
<td>$x_1^m$</td>
<td>$x_2^m$</td>
</tr>
<tr>
<td>$e=0.5$</td>
<td>2.33</td>
<td>1.67</td>
<td>2.24</td>
<td>1.68</td>
</tr>
<tr>
<td>$e=1.0$</td>
<td>2.25</td>
<td>1.25</td>
<td>2.08</td>
<td>1.37</td>
</tr>
<tr>
<td>$e=0.3$</td>
<td>2.30</td>
<td>2.01</td>
<td>2.28</td>
<td>1.96</td>
</tr>
</tbody>
</table>

<Figure 4> The Effect of Increased Margin of Measurement Error(I)

When the margin of error increases from 0.5 to 1.0, both the injurer's and the victim's equilibrium care decrease in every negligence regime, as shown by the arrows
all pointing southwest. This is the result predicted initially by Craswell and Calfee (1986), and analyzed more formally later by Yoo (2003b), who coined them as "discounting effects." When the initial variance of legal uncertainty is relatively large, people tend to become lax and consequently take less care as variance further increases.

<Figure 5> The Effect of Increased Margin of Measurement Error (II)

When the initial variance is relatively small, however, people may react by increasing their precaution in response to an increase in uncertainty; some people who have already secured a high-enough probability of getting exonerated by taking a sufficiently large amount of care may try to guard their expected good fortunes by expensing more care as the randomness increases. Their incentives are like those who purchase insurance against a small chance of bad outcome (thus termed the "insurance
effect" in Yoo(2003b)). 19 This is what happens to the injurer under the simple negligence rule (southeast movement) and the victim under the contributory rule (northwest movement) in Figure 5. In response to the increased margin of error, from 0.3 to 0.5, the injurer under the simple negligence rule increases her care level from 2.30 to 2.33 (insurance effect), whereas the victim decreases his care level from 2.01 to 1.67 (discounting effect). Under r=0.2 or 0.6, both the injurer and the victim decrease their care levels, from (2.28, 1.96) to (2.24, 1.68) and from (2.19, 2.02) to (2.02, 1.95). Under the contributory negligence regime (r=1), the injurer decreases her care level from 2.15 to 1.95, but the victim increases his care level from 2.17 to 2.19 as the variance increases.

Finally, Figure 6 below shows the effects of increasing the injurer's legal standard of due care. An increase in \( x_1 \) from 2.0 to 2.2 causes all R1's to shift out under the uniform distribution, as is predicted. But the effect on R2 is indeterminate. It shifts down the R2 curve when r=0, but may shift up or down when r \( \neq \) 0. (In the graph below, R2 shifts up under the contributory negligence rule.) The resulting overall effects are, in general, indeterminate. A similar experiment can be performed with regard to \( x_2 \). Again, the results are indeterminate.

\[ \begin{array}{cccccc}
\text{r=0} & \text{r=0.2} & \text{r=0.6} & \text{r=1.0} \\
- x_1 = 2.0 & \begin{array}{cc}
2.33 & 1.67 \\
2.24 & 1.68 \\
2.02 & 1.95 \\
1.95 & 2.19 \\
\end{array} \\
- x_1 = 2.2 & \begin{array}{cc}
2.47 & 1.53 \\
2.34 & 1.57 \\
2.09 & 1.92 \\
2.02 & 2.18 \\
\end{array} \\
\end{array} \]

19 People who initially exerted a relatively low level of care, and are thus facing a high probability of bad outcome, may also increase their care levels in response to the increased variance in the hope that the increased randomness may bring them a luck by chance. They "gamble" in the face of increased risk. This "gambling" behavior, which can occur under a normal distribution, however, does not arise here because the assumed distribution is uniform. See Yoo (2003b).
4. Comparison with Earlier Literature

1) Non-Superiority of the Comparative Negligence Rule

The proposition that the comparative negligence rule is superior to the other two rules (Cooter and Ullen, 1986) is founded on the following three building blocks: i) under evidentiary uncertainty, both parties are induced to overcomply in every negligence rule, ii) the magnitude of overcompliance, however, can be ranked among the three different negligence rules in such a way that $x_1^s > x_1^n > x_1^l$ and $x_2^s < x_2^n < x_2^l$, and

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20 Bargill and Ben-Shahar (2003) makes similar argument. But they show the non-superiority through a numerical simulation, not by algebraic proof as is done in the present paper.
iii) assuming that both injurer and victim are symmetrically situated, the comparative negligence rule is superior to the other two because it entails the smallest sum of deviations from the optimum. Below, it is shown that none of these claims are necessarily true.

First, Proposition 2 and the examples we examined graphically in Section 3 clearly denies the claim i): if the size of accident loss (A) is small enough, or the variance of the distribution is large enough, people would definitely undercomply under every negligence rule. Second, there exist no clear-cut ranking among \((x^k_1, x^k_2), k=\{s, n, m\}\) as is shown in Table 3. It is true that as \(r\) increases, there is a general tendency for the injurer's care to decrease and the victim's care to increase. This is because the injurer's reaction curve shifts in, and the victim's reaction curve shifts up as the value of \(r\) increases. Yet the concurrent change in slope of the reaction curves interferes this monotonic relationship between the care levels and negligence regime, and thereby makes the final results ambiguous.

More formally, by differentiating (9) with respect to \(r\), we have

\[
\frac{\partial x^k_1}{\partial r} = \frac{1}{|H_k|} \left[ Z^2_{12} (A_1 F - Af)G - Z^1_{12} (Ag - A_2 G)F \right] 
\]

\[
\frac{\partial x^k_2}{\partial r} = \frac{1}{|H_k|} \left[ Z^1_{11} (Ag - A_2 G)F - Z^2_{21} (A_1 F - Af)G \right],
\]

where \(H_k\) is the derivative matrix of (9) evaluated at \((x^k_1, x^k_2)\) and is positive by the stability condition. Note that all the terms except \(Z^i_{ij}\) \((i,j=1,2)\) are shift factors whose signs are known. Also, the signs of \(Z^2_{22}\) and \(Z^1_{11}\) are positive by the SOC. But the signs of \(Z^1_{12}\) and \(Z^2_{21}\) are indeterminate. Hence, we cannot determine the sign of equations in (16).

If we ignore the cross derivatives which capture the feedback effect, (16a) is negative and (16b) is positive, which yields the claimed ranking among different rules of negligence. This shows where the earlier researchers have erred when they make the claim; they did not consider the feedback effect.21

21 In examining whether one party has incentives to over- or undercomply, they
It is clear that "the superiority of the comparative negligence" proposition cannot hold in general, because we don't know whether the comparative negligence rule would yield smaller or larger deviation from the optimum, positive or not, than the other rules. Turning to the third building block, I show below that even if we know the size of dislocation of care levels in each negligence rule, we still cannot rank the relative efficiency of each rule simply based on the sum of deviations.

Denoting \( Z^* \) the minimized social cost at the optimum, and \( Z \) the social cost at any other levels of care, we have

\[
Z - Z^* = X'H_ZX. \quad (17)
\]

where \( X = \{ x_1 - x_1^*, x_2 - x_2^* \} \). This is positive definite by definition and the contour map of this function represents an ellipse centered at the origin. The direct implication is that there is no way of ascertaining the superiority or inferiority of any negligence rule simply by looking at the sum of the deviations. For example, point A in Figure 7 has a larger sum of deviations, but a smaller social cost than the point B. Therefore, point A is superior to point B from a social efficiency point of view.

\[\text{<Figure 7> Sum of Deviations and Social Efficiency}\]

assumed that the other party will stick to the socially optimal level of care. Haddock and Curan (1985), Cooter and Ullen (1986). By forcing \( x_{ij}^k - x_{ij}^* = 0 \) in (11), they effectively rendered the signs and magnitude of the \( Z_{12}^1 \) and \( Z_{21}^2 \) terms irrelevant.
2) Curing the Efficiency Loss by Changing the Legal Standards of Due Care

We have already seen that changing the legal standard of care yields ambiguous effects on the equilibrium care levels. More formally, by implicitly differentiating the FOC in (9), we obtain

\[
\begin{bmatrix}
Z_{11}^1 & Z_{12}^1 \\
Z_{21}^2 & Z_{22}^2
\end{bmatrix}
\begin{bmatrix}
dx_1^k \\
dx_2^k
\end{bmatrix}
= \begin{bmatrix}
\phi(Af' - Af)
\\
f(A_f \phi + A \phi')
\end{bmatrix} d_x_1 + \begin{bmatrix}
gr(A_f - Af)
\\Fr(Ag' - A_g)
\end{bmatrix} d_x_2.
\]

The terms inside the two vectors on the right hand side show the shifts of the reaction curves in response to changes in legal standards. Most of them are indeterminate in their signs as we have already seen in Table 1. These indeterminate shift factors have to be fed into the feedback process to get the final outcome. We know, however, that the feedback effects are also indeterminate. All in all, it appears hopeless to produce a socially efficient outcome by making adjustment in the legal standards. First of all, we don't know in which direction the equilibrium care level will respond to the changes in the legal standards. Combined with the earlier result that we don't know whether there will be under- or over-precaution, we are caught in a hopeless impasse. The tragic situation is that we don't know which direction we should move, upward or downward, and furthermore, we don't know whether the engine we are driving will lead us upward or downward.

The solution to this impasse, suggested by Edlin (1994), is, however, deceptively simple. You do not need to know all those shift factors or feedback effects to restore the social optimum. Just set the legal standards at the levels that would force each party to stay at the social optimum! Or, instead of trying to fine-tune the suboptimal state of affairs back to the optimum, just nail them at the optimum point. This can be done by eliminating the externality elements we have identified in Section 3, i.e., by setting the legal standards such that \(Z_{11}^* = Z_{12}^* = 0\) is assured.

Imposing this constraint on equations in (12) gives

\[
Z_{11}^* = A_1^* - [A_1^* F(x_1 - x_1^*)] - A^*[f(x_1 - x_1^*)][1 - G(x_2 - x_2^*)] = 0
\]  

(19a)
This is a rather complicated simultaneous equation system in \( x_1 \) and \( x_2 \), and cannot be solved without having a particular distribution function and an expected accident loss function. Edlin assumes a uniform distribution with \( e=1/2 \) and proposes a set of adjusted legal standards of due care for the baseline model illustrated above as follows: when \( r=1 \), set \( (\bar{x}_1, \bar{x}_2)=(1.5,1.5) \), and when \( r=6/10 \), \( (\bar{x}_1, \bar{x}_2)=(13/6, 13/6) \). Indeed, this new set of adjusted legal standards generate the desired social optimum. Based on this result, he interpreted that \( \bar{x}_i \) is decreasing in \( r \), that is, in the contributory negligence regime, the court has to impose a more lenient standard on both the injurer and the victim than in the comparative negligence regime.

Edlin's proposal, however, has several shortcomings. First, a simple solution may not exist once one assumes a non-uniform distribution. Second, even with a uniform distribution, there is no guarantee that the solution can be found within the range \( 0 \leq F, G \leq 1 \). For example, if the variance of the underlying error distribution is large enough, no adjustment of the legal standards will restore the social optimum. Third, but most critically, the solution, even under the uniform distribution and within the feasible range, may not be unique; therefore, the monolithic association of leniency with the negligence regime may not hold. For example, the adjusted standard he proposed for the contributory negligence rule, \( (\bar{x}_1, \bar{x}_2)=(1.5,1.5) \), can be equally effective for the comparative negligence rule as well. In fact, one can easily verify that there exist infinitely many solutions which yield the desired optimum; set \( \bar{x}_2 \) at 1.5, and \( \bar{x}_1 \) at any value less than or equal to 1.5, regardless of \( r \). This is because for any value \( \bar{x}_1 \leq 1.5 \), \( F \) is always zero in his example, and given \( F=0 \), \( \bar{x}_2 \) should always equal 1.5, independent of the value of \( r \).

If one dispenses with the idea of the unidirectional adjustment of leniency, however, Edlin's idea, interpreted in general terms, that one can restore the social optimum by securing \( Z_1^1 = Z_2^2 = 0 \) is still valid. Either by readjusting the legal standards of due care
or some other institutional settings, if one can eliminate the externality elements aforementioned, the social optimum will surely be reestablished. However, whether one can find a workable solution which is independent of any particular distributions or cost functions is another matter.

3) Non-curability of Efficiency Loss by Improving the Legal Accuracy

As has been already suggested, it is in general impossible to correct the situation by partially reducing the measurement error or improving the legal accuracy, either. A reduced variance of the error distribution, being just another parameter subsumed in the model, will always generate ambiguous outcomes because of the indeterminacy of both $Z_i^{*}$ and $Z_{ij}^{*}$.

As a matter of fact, there is one further complication that the authority has to face in the event of measurement error. As shown in Yoo(2003b), a reduction in the variance of the error distribution may generate three different effects -- gambling, insurance, and discounting effects -- depending on the initial size of the measurement error and the size of the damages awarded. These diverse responses to the improved accuracy in legal processes arise even under unilateral care, where strategic buck-passing incentives do not exist.

4. Conclusion

Uncertainty, which is pervasive in every legal arena, inevitably creates social inefficiency. A vague legal statute may make some people overly chilled, causing excessive precaution. Uncertain punishment of crimes may induce some to engage in more crimes, and others in defensive or protective activities.

In this paper, the effects of evidentiary uncertainty on social efficiency, and the probable effects of some of the suggested remedial measures, have been analyzed in the context of negligence rule in tort law.

Conclusions are largely dismal: no simple cure appears to exist to deal with the efficiency loss caused by the legal uncertainty. The comparative negligence rule, which has been hailed by some as deus ex machina to the evidentiary uncertainty problem,
does not appear to be capable of solving the problem. Adjustment of legal standards of due care may not work, either, unless the measurement error distribution has a particular shape and deviations from the social optimum fall within a particular range. Still worse, a partial reduction of uncertainty through a decrease in the variance of the measurement error is not likely to be helpful because there still remains the possibility to make the situation worse. Reduced uncertainty creates divergent incentives for each party, via its discounting, gambling, and insurance effects. Furthermore, the possible strategic interactions between the injurer and the victim are ambiguous.

Admittedly, these conclusions are model-based, implying that a change in the assumptions introduced may yield different results. Assumptions of some potential relevancy in this regard are, among others, the assumption of the fixed r, the liability sharing rule, and the assumption of homogenous players. If the sharing rule is determined responsively to the level of care taken, each party will have additional incentives to manipulate it. If players are heterogeneous, a change in the legal standard applied indiscriminately over the whole population will create differential effects on individual incentives, depending on the intrinsic attributes each individual has. On average, some change in legal standard may improve the overall efficiency aggregated over the population, again depending on the distribution of those attributes. A more rigorous analysis will be required to confirm these conjectures. However, at the moment, it appears that a large part of our conclusions will hold even under these new assumptions.
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