SINGLE ACTIVITY ACCIDENTS

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Traditionally, tort law has been viewed as having two functions—deterrence and compensation. Taxes and fines also serve the first purpose while private and social insurance join in the second (and naturally affect the first). Accidents fit neatly into the economists' framework of externalities, and the role of taxes and insurance has been examined in an equilibrium framework in this context. The purpose of this essay is to begin the extension of equilibrium models to include tort liability for accidents. Thus, the models developed represent an attempt to examine some of the elements of the way tort law affects resource allocation. This is not an analysis of the development of tort law nor a serious putting together of all relevant questions in a way appropriate for policy analysis.

Any work in this area must be greatly influenced by the work of Guido Calabresi,1 and I started this project as an attempt to set Calabresi to mathematics, although the logic of my approach has drawn me away from that definition of the task. While the paper concentrates on developing successively more complicated mathematical models, I have attempted to make it readable by someone who omits the mathematical derivations, although he must follow the setting up of the models. The paper analyzes equilibrium behavior of all the participants in an activity, where participation exposes one to the possibility of accidents involving two (and only two) persons. For a world of risk-neutral expected-utility maximizers who do not engage in side transactions, equilibrium in the activity is related to the parameters (particularly the standard of due care) determining the outcomes of the tort law system. The focus is on the nature of equilibrium rather than the complexities of judicial decision-making. Although much of the paper is devoted to simple cases where equilibrium can be made

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1 Particularly The Costs of Accidents (1970), and, more recently, Guido Calabresi & Jon T. Hirschoff, Toward a Test for Strict Liability in Torts, 81 Yale L.J. 1055 (1972). See section 14 of this article, infra, for a discussion of some differences between my approach and Calabresi's.
efficient, the main thrust of the paper is the development of models where full efficiency is not attainable at any level of the judicially controlled variables.

The analysis begins with the situation where the decisions which determine accident probabilities and costs are measured (costlessly and accurately) by courts applying a law of negligence. Then three different models are considered where individual decision variables generate probability distributions of behavior over time. This behavior affects expected accidents and is monitored by courts which are unable to measure decision variables directly. A similar analysis is then done for comparative negligence. The negligence models are then complicated to allow additional decision variables (such as time devoted to an activity) which affect expected accident costs but are not measured by the legal system. The models to this point assume that all individuals are identical. The simplest negligence model is then reexamined for the case where individuals differ in the utility cost of taking care. In section 14, some of the differences between my approach and that of Calabresi are presented.

1. **INDIVIDUAL DECISIONS**

We shall distinguish four types of decisions that affect expected accident costs. The distinctions are somewhat arbitrary in that some decisions can be modeled as several of these types, and many decisions involve components of several types at once. The typology, however, serves as an introduction to the formal modeling. The four types are choice of activity and three types of decisions affecting care. Activity choice is exemplified by the decision to walk, drive, or bicycle, or to run a railroad rather than an airline. The key elements of a decision of this type are that the choice be discrete and that the activity engaged in at the time of an accident be nearly indisputable.

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2 The consideration of accidents between strangers by Richard A. Posner, in his *A Theory of Negligence*, 1 J. Leg. Studies 29 (1972), is similar in approach to that here, in that particular standards of due care are considered relative to alternatives. John Prather Brown, in *Toward an Economic Theory of Liability*, 2 J. Leg. Studies 323 (1973), presents a model similar to this part of my analysis. However, he considers a two-activity setting, where the legal positions and relationships of accidents to behavior are not necessarily symmetric, and the questions on which he focuses are different from mine. I examine the impact of different due care standards defined in physical units, for example speed limits. He examines different definitions of negligence in terms of behavior relative to the situation, including interpretations of the Learned Hand formula. His analysis seems most closely related to the application of the tort liability system to a new activity and models behavior both of the participants in the activity and of the legal system (in terms of the rule being applied to the particular case). Mine focuses on a long run situation where the law has become settled in terms of behavior which will be found negligent and then asks about the differences arising from different due care standards without examining a judicial process which determines which long run situation holds.
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The decisions about care will be distinguished according to whether the decision variable is directly measured at the time of an accident, is stochastically related to a variable measured at accident time, or is a variable normally not measured at accident time. The variable measured at the time of an accident will be called care and will be the basis of negligence evaluations under negligence, contributory negligence, or comparative negligence standards. Examples of care decisions are the quality of spark control devices on locomotives, the presence of radios on tugboats, the number of ropes tying a boat to a dock, and the speed driven. If the actual decision is stochastically related to a care variable we shall call it a precaution variable. Examples are the general safety policy of a firm, which affects the frequency with which its employees are careless, or a driver’s habit of turning around to talk to passengers, which affects the likelihood of his drifting into the wrong lane. The care variables here are not the control variables of the firm or automobile driver, but they are the elements contributing to the causation of particular accidents. Variables of the third type affect expected accident numbers or costs but are not themselves viewed by courts as accident causes. Examples are the number of miles driven per year, the weight of the automobile, or the amount of planting near a railroad. A more basic analysis would attempt to analyze the reasons for and effects of treating these different variables differently. We shall take the distinctions as given to examine the role of each type of variable in the interplay of the legal system and accident-related behavior. While the distinctions among the three care variables are fairly clear in terms of what individuals should reasonably be viewed as controlling and what courts can or choose to measure, the distinction of activities is less well based. In particular, I will argue that the legal system must have symmetric liability rules for two persons engaged in the same activity at the time of their accident. It is this restriction which distinguishes single-activity accidents (analyzed in this paper) from two-activity accidents (which I will discuss in a separate paper). To pursue the basis of this restriction let us digress to analyze individual decisions in more detail.

An individual realizes that engaging in any activity in a particular way exposes him to a risk of accident. The occurrence of an accident would involve him in the legal process, which might require him to give funds to the other party in the accident (we assume that all accidents involve precisely two persons), or might enable him to collect from the other party. For this analysis we assume that the legal system is costless, so that payments and receipts are equal, and that there is no insurance. It does not seem appropriate to select each accident or potential accident as the basis for separate decisions. Rather we shall model individual behavior as the choice of care and activity levels that affect both the probabilities of accidents with everyone else and the costs of accidents that do occur. For example, the purchase
of spongy bumpers, the decision to go on a long drive, and the habit of rapid driving are decisions that potentially affect all other cars (and pedestrians) on the road. In choosing the value for each variable that affects the care and level of engagement in an activity the individual is trading off the pleasure or cost of marginal adjustments in these variables against their impact on his expected accident and liability costs. The decisions of others enter his decision calculus by affecting the probability or severity of accidents given his behavior in the activity. The legal system enters his decision calculus by relating expected liability payments to his accident involvement and the care decisions of himself and the parties with whom he may have accidents.

The legal system predicates liability on behavior at the time of an accident. (We ignore the elements of damage measurement depending on mitigation before or after an accident and bases for liability arising from personal differences, such as superior knowledge, rather than behavioral differences.) The liability basis seems separable into two types—what activity was engaged in at the time of the accident (e.g., blasting, crop dusting, driving, walking) and what degree of care was shown in the activity at the time of (and proximately causing) the accident. The first aspect sometimes distinguishes potential plaintiffs from potential defendants while the second determines liability or the ability to collect (in a negligence/contributory negligence setting) or the amount of damages (under comparative negligence). The distinction is somewhat artificial in that we could define negligent driving as a different activity from nonnegligent driving (and reckless driving as a third activity), for a negligence system, and ignore the distinction between activities for comparative negligence. We might also try to distinguish activities by the care decision that was the proximate cause of a particular accident. However, the distinction between activities and care shown in the activity seems useful for analysis and reflective of the fact that activity definition is probably rarely in dispute, while the level of care often is. Thus a legal system determining only activities is presumably less expensive and more accurate than one which measures care. If activity definition were complicated this presumption would not be valid and the distinction between activity and care would not be worth maintaining. For analysis, the distinction between activities permits asymmetric rules, like strict liability, and plays a key role for the concept of the cheapest cost avoider.\(^3\)

However, when the distinction between behavior of the two parties to an accident is not easily drawn, the legal system is restricted to symmetric rules, which can still depend on the degree of care, and the analyst must

\(^3\) Guido Calabresi, The Costs of Accidents, supra note 1, at 136. Differences between persons rather than between their actions could also be a basis for asymmetric rules.
use symmetric concepts. The single-activity accident (i.e., when both parties are engaged in the same activity at the time of an accident) is a simpler case with which to begin because of these restrictions.

Given the assumption that activity definition presents no problems, we need next to model the measurement of care and the standard for due care for systems using this concept. (If there is no liability—each person bears his own costs—or if each person bears the costs of the other party, we have symmetric rules not requiring a measurement of care.) There are two starting places for modeling a due care standard, depending on whether quantities or shadow prices are viewed as the description of individual perception of judicial decisions. The approach followed here uses a distinct, measurable physical definition of taking care that is independent of the circumstances of the particular individual. Thus the standard is the speed driven at the time of the accident, the quality of the spark control device, or the depth of the water pipes. This approach seems particularly appropriate where legislated safety standards serve to define negligence. Obviously the quantity approach is only reasonable for an ongoing (long-run equilibrium) activity where people have learned the behavior patterns judged negligent by the courts. For a new activity or an extension of due care to a new dimension of behavior, it is necessary to view the individual's problem as possibly requiring prediction of legal outcomes, which in turn might be based in part on an analysis of benefits and costs. For ongoing activities people are presumed to know what to do to avoid negligence, but not necessarily why.

2. Proximate Cause

Very many elements stretching back in time can be viewed as contributing causes to any particular accident. Some contributing causes are ignored by the legal system. Those that are recognized as relevant for a decision about liability (subject to the evaluation of the degree of care) are called "proximate causes." Obviously the definition and application of the proximate cause standard to particular accident situations may be an important element in legal disputes. The relationship between the accident probability structure of a simple static model and the recognition of causes by the application of a particular proximate cause rule to a complicated dynamic reality is a difficult one to visualize fully. Following the approach in this essay of considering equilibrium where legal issues are fully settled, I will not enquire into the difficulties of the edges of application of the standard. After a brief discussion of the relationship between the structure of accident

4 The definition of new activities is a serious complication which we will not consider, since the analysis will be confined to long-run equilibria.
probabilities and a clear-cut proximate cause definition, I shall proceed in
the analysis under the assumption that proximate cause issues do not raise
any problems.

Let us assume that the only proximate causes of any accident are the
decisions of the two parties to the accident. Let us also assume that the only
determinants of the probability distributions of individual accidents are the
decisions of all parties engaged in the activity. The assumption that will be
made for the analysis is that the determinants of the expected number of
accidents between any two particular persons are only their own decisions.
Thus the only way that a decision by A, say, affects the expected utilities
of others is by affecting their expectation about accidents with A.\(^5\) With
this assumption, the legal system is in the position of examining all of the
possible consequences to others of a decision by any individual.

The assumption is not strictly valid in many situations, such as auto acci-
dents. It is an open empirical question how far from accurate it really is.\(^6\)
The presence on the highway of other drivers going at various speeds leads
to decisions about lane selection, for example, which may affect the prob-
ability of accident, or the distribution of that probability across other
drivers.\(^7\) In the other direction, having an accident with a bad driver (or
more basically, making a care decision which increases the probability of
an accident with a particular bad driver) may be saving some other good
driver from an accident with the same bad driver.

Although these difficulties will be ignored for the analysis to follow (being
left for possible future examination), I want to argue here that the deter-
minants of accident probabilities over some time period are likely to diverge
in some degree from the simple structure which would be additive in prob-
abilities relating to pairs of individuals. For example, when this condition
is satisfied, increasing the number of persons engaged in the activity while
holding accident-determining behavior of the individuals constant increases
the aggregate expected number of accidents roughly as the square of the
number of people in the activity. This relationship does not appear to be a
reasonable fundamental constant of nature. It is natural at this point to

\(^5\) We are assuming that expected accident costs are a sum across all other people of
the expected costs from accidents with each of them, with each of the latter expectations
depending solely on the behavior of the two parties to the accident. This makes sense
for very short time periods or moderately long ones. Otherwise we might need to consider
separately accident probabilities shortly after an accident to recognize the non-indepen-
dence of the possibilities of accidents over time.

\(^6\) These additional externalities not identified by the legal system provide a further
limitation on the ability of the legal system to affect efficiency in some contexts, in
addition to the limitations discussed in the paper.

\(^7\) If the presence of additional cars is viewed as “causing” the lane switch rather than
a change in accident probabilities, there is an accident-unrelated externality from the
additional car to the lane switcher, so the problem is merely shifted rather than eliminated.
attempt to argue that the difficulty with the argument is a failure to define
decisions affecting accident probabilities correctly (i.e., that the behavior
held constant when numbers increased was not the appropriate behavior).
Perhaps (although it seems to me implausible), theory can argue its way
out of this problem along these lines. It is unlikely that the legal system,
with the limitations on the decision variables it can measure, could follow.

3. Equilibrium Without Liability

If we assume that there is no legal system, no possibility of collecting for
accident costs or paying that of others, we can view the analysis of this
activity with its accident probabilities as a standard problem of economic
equilibrium with externalities. To clarify the definition of equilibrium we
shall briefly consider a model of this situation. Then we shall examine the
change in equilibrium brought about by the presence of a liability system,
as well as the response of equilibrium to changes in the parameters describ-
ing the legal system. This parallels the standard analysis of externalities
which introduces additional markets or taxes to alter the equilibrium position.

We assume that there are a large number of people engaged in this activity,
with accident possibilities present for any pair of persons. This large-numbers
assumption justifies the further assumption that (due to transaction costs)
no one attempts to directly alter the behavior of others. A second assumption
justified by the presence of large numbers is that each person assumes that
his own decisions do not induce changes in the decisions of others in response.

Given these assumptions, an individual takes the behavior of others (as
perceived by him) as given and selects his level of care to maximize expected
utility, at the margin trading off the disutility of taking more care against
the reduction in expected accident costs. We shall make the somewhat doubt-
ful assumption that the perceptions of the behavior of others on which care
decisions are based are correct. We shall then have a long-run equilibrium
when we have a simultaneous selection of care levels by each person, with
each person’s selection based on assumed behavior of others which correctly
describes the selection of care levels simultaneously being made by the others.
For the present we assume that everyone is the same.

Let us denote by x and y the levels of care chosen by the person being
considered and perceived by him to be chosen by each other person. We
assume that choosing care level x yields a utility V(x), apart from any acci-
dent involvement.\(^8\) V may have an increasing region before it starts to
decrease. Thus some accident-preventing behavior may be present in the

\(^8\) V is assumed to be twice continuously differentiable, strictly concave, and in units
comparable to income. We also make the assumption that expected utility, V minus
expected costs, is strictly concave for each of the cost allocation configurations we
consider below.
absence of accident-related incentives to take care. Since we shall assume that taking more care decreases expected accident costs, at their expected utility-maximizing position individuals will select a level of care in the range where \( V \) is nonincreasing. Let us denote by \( C(x,y) \) the cost to a person taking care level \( x \) from being in an accident with someone who was taking care level \( y \). Since these people are engaged in the same activity the cost of this accident to the other person is described by the same function, \( C(y,x) \). We shall denote the partial derivatives of \( C \) with respect to its first and second arguments as \( C_1 \) and \( C_2 \). Let us denote the expected number of accidents (per unit time) between two persons taking care levels \( x \) and \( y \) by \( \pi(x,y) \). Naturally we assume that \( \pi \) is symmetric since any accident to the two of them occurs to each. \( C(x,y) \), however, will generally not be symmetric.

If there are \( n + 1 \) persons engaged in the activity (and so \( n \) others with whom he might have an accident) a person who believes that each of the other \( n \) are choosing care level \( y \) will choose \( x \) to maximize utility of care less expected accident costs. We can express this as

\[
\max \ V(x) - n\pi(x,y)C(x,y).
\]

(1)

The first order condition for expected utility maximization is obtained by differentiating expected utility with respect to care level \( x \)

\[
V'(x) - n\pi_1(x,y)C(x,y) - n\pi(x,y)C_1(x,y) = 0.
\]

(2)

This equation expresses implicitly the care level, \( x \), chosen by an individual who believes that everyone else is choosing care level \( y \). Despite the assumption that everyone is the same, it is possible, in some models, to consider equilibria where different people select different care levels. However, we will confine attention to equilibria where everyone selects the same care level. These equilibria will be referred to as uniform. We will have a uniform equilibrium at care level \( x^\circ \) when belief that others are choosing \( x^\circ \) leads the individual also to choose \( x^\circ \). Thus \( x^\circ \), the no-liability equilibrium care level, must satisfy (2) with both \( x \) and \( y \) equal to \( x^\circ \).

\[
V'(x^\circ) = n\pi_1(x^\circ,x^\circ)C(x^\circ,x^\circ) + n\pi(x^\circ,x^\circ)C_1(x^\circ,x^\circ).
\]

(3)

We stated above that we assumed that care could be measured so that increased care decreased expected accident costs. Stated formally we assume for all \( x,y \)

\[
\pi_1(x,y)C(x,y) + \pi(x,y)C_1(x,y) < 0.
\]

(4)

To give structure to the analysis we shall assume that each person would like to see others take more care. Formally we are assuming for all \( x,y \)
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\[ \pi_2(x,y)C(x,y) + \pi(x,y)C_2(x,y) \leq 0. \] \hfill (5)

Obviously there are many decisions which decrease costs per accident for the decision maker but increase costs per accident for others, like automobile weight. By assumption (5) we are ignoring this type of decision for now.9

Even with these assumptions, an increased care level by all others does not necessarily decrease the taking of care. To see the relationship, let us examine (2) which defines \( x \) implicitly as a function of \( y \). Differentiating implicitly we have

\[ \frac{dx}{dy} \]

\[ = \frac{\pi_{12}(x,y)C(x,y) + \pi(x,y)C_{12}(x,y) + \pi_1(x,y)C_2(x,y) + \pi_2(x,y)C_1(x,y)}{n^{-1}V''(x) - \pi_{11}(x,y)C(x,y) - \pi(x,y)C_{11}(x,y) - 2\pi_1(x,y)C_1(x,y)}. \]

For individual choice to be well behaved the denominator must be negative by the second-order condition. The assumptions (4) and (5) above are not sufficient to guarantee that the numerator is positive, so we now make that assumption explicitly. Thus we are assuming that when others take more care an individual feels less need to take care. This relationship depends on the impact of the care of others on the expected cost savings from taking more care oneself. The assumption that care of others is liked is merely an assumption that expected costs (not expected cost savings) are decreased by increased care of others.

The care decision that, if taken by everyone, maximizes the expected utility position of each person in equilibrium we call the efficient level of care and denote by \( x^* \). Thus \( x^* \) is the level of care which maximizes expected utility

\[ \text{Max } V(x) - n\pi(x,x)C(x,x). \] \hfill (7)

The first-order condition for this maximization gives us the equation for the efficient level of care

\[ V'(x^*) = n\pi(x^*,x^*) \left( C_1(x^*,x^*) + C_2(x^*,x^*) \right) + nC(x^*,x^*) \left( \pi_1(x^*,x^*) + \pi_2(x^*,x^*) \right). \] \hfill (8)

Under the sort of regularity assumptions we have been making the efficient level of care exceeds the equilibrium level of care in the absence of any liability system.10

9 See section 11 for a brief discussion of such variables when the court does not monitor them at all.

10 To pursue efficiency further one would want to evaluate the cost of inefficient
\[ x^* > x^\circ. \]  

The difference in the two positions can be characterized by the changed accident costs perceived when choosing a care level. When individuals choose a care level for themselves they examine the change in their own expected accident costs for a marginal change in care level. For efficiency, the decision should reflect the change in total expected accident costs—those of the person making the decision plus the sum of the changes in expected accident costs for everyone else with whom he might have an accident. If the cost function, \( C \), were symmetric we could say that the no-liability equilibrium reflected half the elements of social cost which appear in the condition for efficiency. We say half the elements rather than half the costs since in equilibrium the marginal expected individual costs are \( \pi_1(x^\circ,x^\circ)C(x^\circ,x^\circ) + \pi(x^\circ,x^\circ)C_1(x^\circ,x^\circ) \) while for efficiency (with \( C \) symmetric) the marginal expected social costs are \( 2\pi_1(x^*,x^*)C(x^*,x^*) + 2\pi(x^*,x^*)C_1(x^*,x^*) \). Thus the same functions (elements of cost) are being evaluated at different levels of care.

The introduction of a tort liability system in this no-liability setting alters the incentives for taking care. The alteration comes from the possible liability implications of actually having an accident. There are other general modes of affecting incentives such as checking care taken during the activity (perhaps on a sampling basis) or affecting actions, like purchases, that are related to care decisions. Examples of these alternatives would be radar checks on speeding and subsidization of spongy bumper purchases (or regulations on automobile manufacture requiring them). With different sorts of care decisions, the different types of incentives may have very different administrative costs. Where purchases are the key element of care decisions, taxes and subsidies may be a very inexpensive way of altering incentives. However, many care decisions, like driving speed, are only tenuously connected with purchases. Checking performance in the activity, independent of accidents, will be inexpensive, relative to simply monitoring accidents, when accidents are frequent relative to activity levels, when care is easy to monitor (speeding relative to driving when tired), when the location of the activity of different persons is concentrated and public, and when accidents themselves are difficult to monitor because of the incentives and opportunities for concealment. A more general theory of externality correction would explore information structures and the choice of incentive-altering mechanism. We continue the discussion with the tort liability system as the only social alteration in the incentive to take care.

4. **INDIVIDUAL CHOICE WITH A NEGLIGENCE SYSTEM**

Let us assume that each person engaged in the activity chooses the level of a single variable that affects his expected accident costs and that is

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private decisions relative to the cost of setting up any mechanism to achieve the efficient point.
directly (and costlessly) measured at the time of any accident. If everyone is alike, the equilibrium in the absence of a liability system will occur at a care level, \( x^0 \), which is below the efficient care level, \( x^* \). A strict liability system (without contributory negligence) in this context would result in each party to an accident bearing the costs of the other party. To the extent that actual costs of an accident are not symmetric, the equilibrium would diverge from \( x^0 \). It does not seem worthwhile to pursue this alternative seriously. One might consider a negligence system without contributory negligence, but this would have the same unsatisfactory nature—where both are negligent each bears the costs of the other. Thus we shall consider a negligence-contributory negligence system. Both to avoid the solution where each bears the costs of the other and to reflect current legal theory,\(^ {11} \) we shall consider a system where the same standard of care is employed in the measurement of negligence and of contributory negligence.

The question we shall pursue is the relationship between the judicially set standard of due care, which we denote by \( d \), and the level of care chosen by the individuals in equilibrium. Since we are considering only uniform equilibria, either everyone will be negligent (and contributorily negligent) or everyone will satisfy the due care standard. Thus there will never be successful lawsuits. Nevertheless, over some range, variations in the due care standard will lead to changes in the equilibrium level of care.

It is convenient for the general formulation to assume that there is a distribution \( n(y) \) of other individuals choosing care level \( y \). In the next section we will reduce this general function to the uniform case. Also, we assume that \( x \) and \( y \) lie in the unit interval. Let us denote by \( U_1 \) the level of expected utility if an individual only bears his own accident costs when he has an accident with someone who is not negligent (and never bears anyone else’s accident costs).

\[
U_1(x) = V(x) - \int_d^1 \pi(x,y)C(x,y)n(y)dy. \tag{10}
\]

Let us denote by \( x_1 \) the level of care that maximizes\(^ {12} \) \( U_1 \). Similarly we shall denote by \( U_2 \) the level of expected utility for an individual who bears all of his own accident costs and also those of the other party when he has an accident with someone who is not negligent.

\[
U_2(x) = V(x) - \int_0^1 \pi(x,y)C(x,y)n(y)dy - \int_d^1 \pi(x,y)C(y,x)n(y)dy. \tag{11}
\]

\(^{11} \) See William L. Prosser, Handbook of the Law of Torts 418-19 (4th ed. 1971).

\(^{12} \) \( x_1 \) satisfies \( V'(x_1) = \int_d^1 (\pi_1(x_1,y)C(x_1,y) + \pi(x_1,y)C_1(x_1,y))n(y)dy. \)
(Note that \(C(x,y)\) appears in the first integral and \(C(y,x)\) in the second.) Let us denote by \(x_2\) the level of care that maximizes\(^{13}\) \(U_2\).

The relevant utility function for an individual is \(U_1(x)\) when he chooses not to be negligent and \(U_2(x)\) when he chooses a care level such that he is negligent.

\[
U(x) = \begin{cases} 
U_1(x) & x \geq d \\
U_2(x) & x < d. 
\end{cases}
\]

Since accidents result in nonnegative costs it is clear that \(U_1(x) \geq U_2(x)\). From the assumptions we have made on the way care affects each person (4) and (5), it is also true that \(x_1 \leq x_2\), i.e., if an individual bore more accident costs he would take more care. Thus, we are assuming that utilities are as shown in Figure 1.

![Figure 1](image-url)

To describe individual choice, we must locate \(d\) relative to \(x_1\) and \(x_2\) since \(U_2\) is the relevant utility function for \(x < d\) and \(U_1\) for \(x \geq d\). Examining Figure 2, one confirms that a value of \(d\) less than \(x_1\) leads to choice of \(x_1\). The dotted curve represents the relevant portions of utility (i.e., represents \(U\)). Similarly it is clear that a level of due care between \(x_1\) and \(x_2\) leads to a choice of care level precisely equal to the due care level (Figure 3).

For due care levels in excess of \(x_2\), we must compare the value of \(U_2\) at its maximum, \(x_2\), with the value of \(U_1\) at \(d\). Let us define \(\hat{d}\) by the equality of these two levels

\[
U_1(\hat{d}) = U_2(x_2).
\]

The value of \(\hat{d}\) is shown in Figure 4. For due care levels above \(x_2\), values

\[
x_2 \text{ satisfies } V'(x_2) = \int_0^1 (\pi_1(x_2,y)C(x_2,y) + \pi(x_2,y)C_1(x_2,y))n(y)dy + \int_d^1 (\pi_1(x_2,y)C(y,x_2) + \pi(x_2,y)C_2(y,x_2))n(y)dy.
\]

\(^{13}\)
below $\hat{d}$ lead to a choice of $d$ but those above $\hat{d}$ lead to a choice of $x_2$, i.e., lead to a decision to be negligent. Summarizing these conclusions we have

$$d \leq x_1 \quad x_1 \leq d \leq \hat{d} \quad \hat{d} \leq d,$$

chosen level of care

Since expected costs depend on $d$ (see (10) and (11)), $x_1$, $x_2$, and $\hat{d}$ are all functions of $d$ for the individual. In addition, in determining equilibrium, the behavior of others ($n(y)$) will also vary with the due care level.

5. **Uniform Equilibrium**

We now wish to examine the possible uniform equilibria (i.e., with everyone selecting the same care level) that may arise with different judicially selected levels of due care. We shall conclude that there are only two candi-
dates for equilibrium—the no-liability care level \((x^0)\) and the due care level \((d)\)—and shall examine the conditions which determine the equilibrium level as a function of due care.

If we have an equilibrium at \(x^0\) without any liability system, the introduction of a negligence system with a due care standard below the equilibrium level \((i.e., \text{below } x^0)\) clearly has no effect on the system. No one has any reason to alter his behavior, since everyone is showing due care, although paying attention only to his personal costs. This corresponds to Figure 2 above with \(x^0\) coinciding with \(x_1\) and everyone being nonnegligent.

If the due care level is set slightly above the no-liability equilibrium, everyone will find it worthwhile to increase his care level precisely to the due care standard to avoid potential liability. This will be true despite the fact that the increased care taken by others reduces the incentive to take care for self-protection. Thus over some range the equilibrium care level rises with the due care standard. The next step is to determine the range for \(d\) such that equilibrium occurs at \(d\). To ask when the due care level is a uniform equilibrium we must ask when each person chooses his care level at the due care level given that he assumes that everyone else is selecting precisely the due care level.

For sufficiently high due care levels everyone will choose to be negligent and the legal system will have no effect, equilibrium returning to the no-liability equilibrium care level. To determine the levels of \(d\) which give rise to this equilibrium we must examine when an individual will choose \(x^0\) given that everyone else has chosen \(x^0\) and given that the due care level is \(d\). Note that the analysis for this question assumes that everyone else has chosen \(x^0\), while examination of the conditions where equilibrium occurs at \(d\) assumes that everyone else has chosen the care level \(d\). Thus these two examinations involve evaluations of the utility functions at different values for the behavior of others. Therefore it is not generally true that there will be one and only one uniform equilibrium for each level of due care. (Setting the due care standard at the efficient care level \(x^*\) does lead to a unique uniform equilibrium at \(x^*\).) The possibilities are summarized in Figure 5.

**Appendix to Section 5**

We return to the structure with \(n + 1\) persons. Let us first examine the case of equilibrium at \(d\). If everyone else chooses the due care level \((y = d)\) the utility function takes the form

\[
U(x) = \begin{cases} 
U_1(x) = V(x) - n\pi(x,d)C(x,d) & \text{if } x \geq d \\
U_2(x) = V(x) - n\pi(x,d)(C(x,d) + C(d,x)) & \text{if } x < d.
\end{cases}
\]  

From the discussion above (14) we know that \(d\) will be chosen provided \(x_1 \leq d \leq \hat{d}\) for this utility function. To make clear the functional relation we state this formally. A due care level \(d\) results in a uniform equilibrium at \(d\) provided
SINGLE ACTIVITY ACCIDENTS

\[ x_1(d) \leq d \leq \hat{d}(d), \]  

where the limits are defined by

\[ x_1(d) \text{ maximizes } V(x) - n\pi(x,d)C(x,d), \]
\[ \hat{d}(d) \text{ satisfies } V(\hat{d}) - n\pi(\hat{d},d)C(\hat{d},d) \]
\[ = \max_x V(x) - n\pi(x,d)(C(x,d) + C(d,x)). \]  

Let us consider the lower-bound constraint. At \( d = x^* \), \( x_1(d) \) is also equal to \( x^* \), so the constraint is satisfied. From the assumption made above, (6), that care taken decreases with the care of others, we know that \( x_1(d) \) decreases with \( d \) and thus the lower bound constraint is satisfied for any \( d \) above \( x^* \).

Now let us consider the upper-bound constraint. From Figure 4, \( V(\hat{d}) - n\pi(\hat{d},d)C(\hat{d},d) \) is decreasing in \( \hat{d} \). Thus from (17)

\[ \hat{d}(d) \overset{>}{\underset{<}{\approx}} d \text{ as } f(d) = \max_x V(x) - n\pi(x,d)(C(x,d) + C(d,x)) \]
\[ - V(d) + n\pi(d,d)C(d,d) \overset{<}{\underset{>}{\approx}} 0, \]  

**Figure 5**

**Uniform Equilibrium as a Function of the Due Care Standard**

\[ \hat{d}(d) \overset{>}{\underset{<}{\approx}} d \text{ as } f(d) = \max_x V(x) - n\pi(x,d)(C(x,d) + C(d,x)) \]
\[ - V(d) + n\pi(d,d)C(d,d) \overset{<}{\underset{>}{\approx}} 0, \]
where \( f \) is defined in (18). Note that \( f(x^*) \) is negative (since the maximizing \( x \) is \( x^* \)). Thus setting \( d \) equal to \( x^* \) gives an equilibrium at \( x^* \). Since increased care decreases accident costs for both parties, (4) and (5), \( \pi(x,d)(C(x,d) + C(d,x)) \) is decreasing in \( x \). By one of the many concavity assumptions \( V(d) - n\pi(d,d) \) \( C(d,d) \) is decreasing in \( d \) for \( d > x^* \). Thus \( f \) increases with \( d \) for \( d > x^* \), giving a unique value, \( \hat{d}_2 \) dividing this range of solutions from higher values of \( d \) which do not give equilibrium at \( d \). To check the region between \( x^o \) and \( x^* \), let us make the further assumption\(^\text{14}\) (for this section) that \( x_2 \) is decreasing with \( d \), i.e., care decreases with the care of others for someone who is bearing all costs. As can be seen in Figure 4, \( \hat{d}(d) > x_2(d) \). Thus when \( x_2(d) > d \) the upper bound constraint is satisfied. If the due care level is set at the efficient care level, i.e., \( d = x^* \), then \( x_2(d) \) is equal to \( x^* \). Hence the upper bound constraint is satisfied for all \( d \) below \( x^* \). Thus we have shown that for all \( d \) between \( x^o \) and \( \hat{d}_2 \) (with \( \hat{d}_2 > x^* \)) there exists a uniform equilibrium with everyone just choosing the due care level.

We now wish to ask which values of \( d \) (above \( x^o \)) will lead to a choice of \( x^o \) by someone who thinks that everyone else is choosing \( x^o \). Given that everyone else has chosen \( x^o \), expected utility is now

\[
U(x) = \begin{cases} 
U_1(x) = V(x) & : x \geq d \\
U_2(x) = V(x) - n\pi(x,x^o)C(x,x^o) & : x < d.
\end{cases}
\]

(19)

Thus \( U_2 \) coincides with utility in the absence of liability when everyone else chooses \( x^o \). Thus we know that \( x_2 \) coincides with \( x^o \). From (14) above, we know that \( x_2 \) will be chosen for \( d \) above a critical value \( \hat{d}_1 \) defined (from (13)) by

\[
V(\hat{d}_1) = V(x^o) - n\pi(x^o,x^o)C(x^o,x^o).
\]

(20)

Let us note first that \( \hat{d}_1 \) is strictly greater than \( x^* \) since \( V \) is decreasing in \( x \) in this region and

\[
V(x^*) > V(x^o) - n\pi(x^*,x^*)C(x^*,x^*)
\]

\[
\geq V(x^o) - n\pi(x^o,x^o)C(x^o,x^o) = V(\hat{d}_1).
\]

(21)

The remaining question is the relationship between \( \hat{d}_1 \) and \( d_2 \). That is, whether there are ranges of \( d \) that give rise to no equilibria (\( \hat{d}_1 > d_2 \)) or two equilibria (\( \hat{d}_1 < d_2 \)). Both of these situations seem possible without further restrictions.\(^\text{15}\)

(15) It also seems possible to have non-uniform equilibria in this range.\(^\text{16}\) We will have

\(^\text{14}\) That is, we assume that \( \pi_1(x_2,d)(C(x_2,d) + C(d,x_2)) + \pi_1(x_2,d)C_2(x_2,d) + C_1(d,x_2) + \pi_2(x_2,d)(C_1(x_2,d) + C_2(d,x_2)) + \pi_2(x_2,d)(C_1 + C_2)d_2(d_2,d_2) + C_2(d_2,d_2) \geq 0.

\(^\text{15}\) From (18) and (20),

\[
f(\hat{d}_1) = \max_x V(x) - n\pi(x,d_1) + C(x,\hat{d}_1) + C(\hat{d}_1, x) - V(x^o) - n\pi(x^*,x^*)C(x^o,x^o)
\]

\[
+ n\pi(\hat{d}_1, \hat{d}_1)C(\hat{d}_1, \hat{d}_1)
\]

\[
\geq n\pi(x^o,x^o)C(x^o,x^o) - n\pi(x^*,x^*)C(x^*,x^*) + C(\hat{d}_1,x^o)
\]

\[
+ n\pi(\hat{d}_1, \hat{d}_1)C(\hat{d}_1, \hat{d}_1).
\]

If \( C(x,y) \) and \( \pi(x,y) \) take the form \( g(x)g(y) \), this expression is positive and there is a range without equilibria. I have not found any examples with two equilibria.

\(^\text{16}\) A second possible equilibrium configuration has some of the people, say \( n_1 \), at a nonnegligent point and \( n + 1 - n_1 \) people at a negligent point. For this to be an equi-
no uniform equilibria for a value of $d$ when the assumption that everyone else chooses a care level $d$ leads to a choice below $d$ while the assumption that everyone else chooses a care level $x^*$ leads to a choice of a level of care equal to $d$. The change in the care level of others between these two calculations leads to the possibility of different outcomes for the comparison of the best negligent and nonnegligent points (best points along the parts of $U_1$ and $U_2$ which represent $U$).

We have examined the situations under which $x^*$ and $d$ can be uniform equilibria. It remains to argue that these are the only uniform equilibria. A formal argument would check that possible demanded points, $x_1$, $x_2$, and $d$, coincide with either $x^*$ or $d$ when they represent uniform equilibria. An informal argument will suffice for our purposes. In a uniform equilibrium there are no successful lawsuits. Examining expected utility around the equilibrium value there are two possibilities. Either equilibrium is at $d$ (where expected utility is discontinuous) or (away from $d$) locally expected utility coincides with that of the no-liability equilibrium since there are no successful lawsuits. For the latter situation $x^*$ is the only possible equilibrium.

Let us summarize the situation described above. For $d \leq x^*$ there exists an equilibrium at $x^*$ with no one negligent. For $d \geq x^*$ there exists an equilibrium at $d$ with no one negligent. For $d \leq x^* \leq d$ there exists an equilibrium at $x^*$ with everyone negligent. For $d$ equal to $x^*$ there is a unique uniform equilibrium at $x^*$. Thus the possibilities are as shown in Figure 5 above.

6. Stochastic Control of Care

Many accident situations arise in circumstances where it would not be reasonable to model individual decisions as deliberately selecting a negligent course of action. Rather the control variables of individuals (or firms) result in different distributions of actual behavior over time. Let us call the actual control variable “precaution,” and assume that a greater expenditure on precaution leads to a higher average level of care, but does not eliminate the variations. We assume that care affects accident probabilities but not costs.

There are two aspects of the precaution-care pattern which complicate the discussion of the previous section and which seem worth discussing separately. First, people are often careful independently of any particular expenditures of money or effort on being careful. To model this phenomenon, we shall consider the case of care uniformly distributed between the pre-
caution level and some upper bound; \textit{i.e.}, we shall assume that precaution is a lower bound for care.\textsuperscript{17} Alternatively, in some circumstances people will be careless some of the time no matter how much effort they invest in trying to be careful. Greater efforts can only reduce the probability of being careless, not eliminate it. To model this aspect of behavior we shall consider precaution as an upper bound for care and assume that care is uniformly distributed between some lower bound and the precaution level. We shall also examine the case of a triangular distribution of care with its peak at the precaution level.

With precaution as a lower bound for care, there is no effect from the introduction of a negligence system with a due care level below the equilibrium level of precaution in the absence of liability. This situation is the same as in the determinate case. With increases in the due care standard over some range, the precaution levels rise exactly with the due care standard, so that each person is making sufficient effort never to be negligent. Thus over this range too the pattern from the determinate case is repeated. However, as the due care level rises out of this range, the equilibrium level of precaution decreases continuously with the due care level, approaching the no-liability equilibrium as the due care standard approaches the upper bound in the distribution of care. The situation is as shown in Figure 6. As before, it is possible to achieve the efficient equilibrium by setting the due care level at the efficient point.

\textbf{Figure 6}

\textit{Equilibrium with Precaution as a Lower Bound for Care}

To see how increases in the due care level can decrease the equilibrium level of precaution, let us examine the response of individual choice to a rise in the due care level, holding constant the behavior of others. If the individual wants to decrease his precaution, the equilibrium level will also

\textsuperscript{17} We assume that precaution and care are measured in the same units.
fall. Where the precaution level is below the due care level, each individual is negligent some of the time. The accident costs borne are therefore his own when the other party is not negligent and an additional cost when negligent himself (his own when the other party is negligent and that of the other party when he is not). Individual choice reflects a balancing of the increased utility cost of more precaution and the decrease in accident costs borne as a result of the upward shift in the distribution of care taken. This decrease in costs represents both a decrease in accidents when the other party is not negligent and a decrease in accidents when the person choosing is negligent. An increase in the due care level decreases the number of accidents when the other party is not negligent and thus decreases this part of the gain from higher precaution. Given the structure of the probability distribution of care, an increase in the due care level increases the fraction of accidents when an individual is negligent but it decreases the change in the number of negligent accidents from an increase in precaution. Thus the response to precaution of both elements of accident costs borne is decreased by a rise in the due care level. The individual responds to this decreased incentive by a decrease in precaution.

**Appendix to Section 6**

Here we derive the results in this section explicitly. We continue to denote the control variable, now precaution, by $x$ and the level of precaution chosen by everyone else by $y$. The choice of $x$ results in a uniform distribution of actual care, $a$, between $x$ and 1. The probability of an accident, given the level of care, depends only on the care being taken by the two parties $a$ and $b$. For simplicity we take a particular form $(1 - a)(1 - b)$ and also assume that all accidents cost the same amount per person, $C$. In the absence of a liability system, expected utility can be expressed as

$$U(x) = V(x) - nC \int_{x}^{1} \int_{y}^{1} \left( \frac{1 - a}{1 - x} \right) \left( \frac{1 - b}{1 - y} \right) db \, da$$

$$= V(x) - anC(1 - x)(1 - y).$$

(22)

As above we can find the no-liability uniform equilibrium by maximizing $U(x)$, given $y$, and finding a $y$ so that the chosen $x$ and $y$ coincide.

$$V'(x^*) = -anC(1 - x^*).$$

(23)

Also, as before, we can find the level of care which if chosen by everyone will lead to the highest uniform level of expected utility. For this we set $x$ equal to $y$ in (22) and maximize

$$V'(x^*) = -anC(1 - x^*).$$

(24)

The particular forms chosen here show more clearly the distinction made above between the elements of marginal accident cost and the actual marginal accident cost.
In functional terms, efficiency calls for examining twice the elements of cost examined for no-liability equilibrium. At their actual values, however, \( \lnC(1 - x^*) \) is less than twice \( \lnC(1 - x^e) \).

Let us start by examining equilibria where no one is ever negligent. Thus we begin by examining expected utility under the assumption that \( y \geq d \) and look for those values of \( d \) which lead to a selection of \( x \) which coincides with \( y \). As before we must distinguish expected utilities according to whether the person is never negligent, \( x \geq d \), or may be negligent, \( x < d \). Thus we write expected utility as

\[
U(x) = \begin{cases} 
U_1(x) = V(x) - \lnC \int_x^1 \int_y^1 \frac{(1-a)}{1-x} \frac{(1-b)}{1-y} \, db \, da & : x \geq d \\
U_2(x) = V(x) - \lnC \int_x^1 \int_y^1 \frac{(1-a)}{1-x} \frac{(1-b)}{1-y} \, db \, da \\
- \lnC \int_x^d \int_y^1 \frac{(1-a)}{1-x} \frac{(1-b)}{1-y} \, db \, da & : x < d.
\end{cases}
\]

Thus, from the utility of taking care we subtract expected accident costs and also, when negligent, the expected costs of others. Performing the integrations we have

\[
U_1(x) = V(x) - \lnC(1 - x)(1 - y) 
\]

\[
U_2(x) = V(x) - \lnC(1 - x)(1 - y) - \lnC(1 - y) \frac{d - x - \frac{1}{3}(d^2 - x^2)}{1 - x}.
\]

Let us denote by \( x_1 \) and \( x_2 \) the maximizing arguments for these two functions (ignoring the values of \( x \) for which the functions are relevant). Inspecting the utility functions we see that there is no longer a discontinuity at \( d \); rather \( U \) has a kink at that point. From the equations, we have \( U_1(x) > U_2(x) \) as \( x \leq d \). In addition, we can compare derivatives

\[
U_2'(x) = U_1'(x) + \lnC \frac{1-y}{(1-x)^2} (1 - d - x + \frac{1}{3}d^2 + \frac{1}{3}x^2).
\]

Thus \( U_2'(x) > U_1'(x) \) and the utilities appear as in the diagram for different relative values of \( d \), \( x_1 \), and \( x_2 \), with \( U \) as the dotted line—\( U \) coincides with \( U_2 \) below \( d \) and with \( U_1 \) above \( d \). It is clear from the diagrams that the care level chosen satisfies

\[
d \leq x_1 \quad x_1 \leq d \leq x_2 \quad d \geq x_2.
\]

Comparing this with the certainty case, (14), we have the same pattern except that \( x_2 \) replaces \( \bar{d} \). Since \( U_1 \) coincides with utility in the absence of liability (and so \( x_1 \) coincides with \( x^e \) when \( y = x^e \)) we have two possible uniform equilibria with everyone nonnegligent at all times, \( x^e \) for \( d \leq x^e \) and \( d \) for \( x_1 \leq d \leq x_2 \) when \( y \) equals \( d \). When \( d > x_2 \), we do not have a uniform equilibrium since we are con-
sidering the case where \( y \geq d \). We have the definitions of \( x_1(d) \) and \( x_2(d) \) for these limits by maximizing \( U_1 \) and \( U_2 \) in (26) and (27) evaluated at \( y = d \).

\[
V'(x_1) + \frac{1}{2} nC(1 - d) = 0
\]

\[
V'(x_2) + \frac{1}{2} nC(1 - d) + \frac{1}{2} nC \frac{1 - d}{(1 - x_2)^2} \left(1 - d - x_2 + \frac{1}{2} d^2 + \frac{1}{2} x_2^2\right) = 0.
\]

Since \( x_1 \) is decreasing\(^{18} \) in \( d \), the lower bound constraint is not binding for \( d \) above \( x^* \). Since \( x_2 \) is decreasing\(^{19} \) in \( d \) when \( x_2 \) equals \( d \), there is a unique due care level \( d \)

\(^{18}\) By implicit differentiation \( \frac{dx_1}{dd} = \frac{1}{2} nC/V'' \).

\(^{19}\) Differentiating, the denominator of \( \frac{dx_2}{dd} \) is the second order condition and is negative.

The numerator is \( \frac{1}{2} nC(1 + 2(1 - d - x_2 + \frac{1}{2} d^2 + \frac{1}{2} x_2^2)/(1 - x_2)^2 + 2(1 - d)^2/(1 - x_2)^2) \).
separating the values of \( d \) giving equilibria at \( d \) from higher values of \( d \) that do not give equilibria at \( d \). Equating \( x_2 \) and \( d \) in (31) we have the equation for \( \hat{d} \):

\[
V'(\hat{d}) + \frac{2nC}{(1 - \hat{d})} = 0. \tag{32}
\]

Since \( V' \) is decreasing in \( x \), comparing (24) and (32) we see that \( d \) is greater than \( x^* \). For greater values of \( d \) equilibria involve some negligence. Thus we have demonstrated the first two sections of the locus of equilibria in Figure 6.

To consider the case where in equilibrium everyone may have negligent care levels, we assume that everyone else chooses a value of \( y \) less than or equal to \( d \). We can then express expected utility as

\[
U(x) = \begin{cases} 
\bar{U}_1(x) = V(x) - nC \int_x^1 \int_d^1 \frac{(1 - a)}{1 - x} \frac{(1 - b)}{1 - y} \, db \, da & : x \geq d \\
\bar{U}_2(x) = V(x) - nC \int_x^1 \int_d^1 \frac{(1 - a)}{1 - x} \frac{(1 - b)}{1 - y} \, db \, da \\
- nC \int_x^d \int_d^1 \frac{(1 - a)}{1 - x} \frac{(1 - b)}{1 - y} \, db \, da & : x < d.
\end{cases}
\tag{33}
\]

The integrals reflect bearing one's own cost when the other party is nonnegligent plus an additional cost when one is negligent (one's own when the other person is negligent and the other party's when he is not). Rewriting and integrating we have

\[
\bar{U}_1(x) = V(x) - \frac{4nC}{1 - x} (1 - d)^2 (1 - y)^{-1} \tag{34}
\]

\[
\bar{U}_2(x) = V(x) - \frac{4nC}{1 - x} (1 - d)^2 (1 - y)^{-1} - \frac{2nC}{1 - y} (d - x - \frac{1}{2} (d^2 - x^2)) (1 - x)^{-1} \tag{35}
\]

As above \( \bar{U}_1(x) \geq \bar{U}_2(x) \) as \( x \leq d \) and \( \bar{U}_2(x) > \bar{U}_1(x) \). Thus we have the same possibilities depicted in Figure 7 and described in (29). Now, however, \( y < d \) so we have a possible uniform equilibrium at \( \bar{x}_2 \). Differentiating \( \bar{U}_2(x) \) and equating \( y \) with \( x \) we have the equation for uniform equilibrium for \( d \geq \bar{x}_2 \)

\[
-V'(x) = \frac{4nC}{1 - x} (1 - d)(1 - x)^{-1} + \frac{4nC}{1 - x} (1 - d)^2 (1 - x)^{-2} - \frac{2nC}{1 - y} (d - x - \frac{1}{2} (d^2 - x^2)) (1 - x)^{-1}. \tag{36}
\]

This is then the equation for the remaining section of the locus of equilibria in Figure 6. To check its shape, let us differentiate implicitly to get the effect of increased due care on the equilibrium care level

\[
\frac{dx}{dd} = \frac{nC(1 - d)(1 - x)^{-1}}{V'' + \frac{4nC}{1 - x} (1 - d)^2 (1 - x)^{-2} - \frac{4nC}{1 - y} (d - x - \frac{1}{2} (d^2 - x^2)) (1 - x)^{-1}} < 0. \tag{37}
\]

The denominator is negative as can be seen by subtracting the second order condition. Clearly, as \( d \) approaches one, the solution to (36) approaches \( x^* \).

7. STOCHASTIC CONTROL OF CARE II

With precaution as an upper bound for care, there is some chance of being negligent at the time of an accident even with low due care standards. In
In this case the introduction of a negligence system with a due care standard below the equilibrium precaution level tends to increase the equilibrium level of precaution. This differs from the determinate case where low due care standards had no effect at all.

To see how a rise in the due care standard is an incentive for a greater level of precaution, let us express expected utility as the utility of taking precaution less one’s own expected accident costs less the expected net payment from lawsuits as a result of the excess of accidents where one is negligent over those where the other party is negligent. At the point where everyone takes the same precaution, a rise in the due care standard increases the gains in expected net payments from higher precaution by increasing equally the frequencies of negligence by both parties. If the due care standard is set very high, however, individuals may choose a low level of precaution, realizing that they will be negligent in every accident they might have, but avoiding the high cost of a precaution level above the due care standard. This situation parallels the determinate case and seems to allow the possibility of no or two uniform equilibria. One interesting change from the earlier analyses is that it is no longer true that the efficient equilibrium is necessarily achievable. The patterns of equilibria are shown in Figure 8.

Appendix to Section 7

Here we derive the pattern of results presented in this section of the text. In the absence of a tort system, with everyone else taking the same precaution level \( y \), expected utility of an individual taking precaution level \( x \) satisfies

\[
U(x) = V(x) - nC \int_0^x \int_0^y 1 - a - \frac{1 - b}{x} \frac{1 - b}{y} \, \text{d}b \, \text{d}a
\]

\[
= V(x) - nC(1 - \frac{1}{2}x)(1 - \frac{1}{2}y). \tag{38}
\]

where \( (1 - a)(1 - b) \) is the probability of an accident when care levels \( a \) and \( b \) are present and \( \frac{1}{x} \) and \( \frac{1}{y} \) are the probabilities of these care levels for precaution levels \( x \) and \( y \) (when care is less than precaution). \( C \) is assumed to be a constant.

For uniform equilibrium, \( x \) and \( y \) coincide in the first order condition for the maximization of (38), giving the equation

\[
V'(x^*) = -2nC(1 - \frac{1}{2}x^*). \tag{39}
\]

For efficiency we set \( y \) equal to \( x \) in (38) and then maximize. This gives the first order condition

\[
V'(x^*) = -nC(1 - \frac{1}{2}x^*). \tag{40}
\]

From the concavity of \( V \) we have \( x^* > x^* \), so too little care is taken.

---

20 The conditions in footnote 15 suggest that the only possible case is that with no equilibria for some values of \( d \). However I have not been able to obtain this result nor to construct examples of the different cases.

21 The upper end of the curve must be above the 45° line, as shown.
With a standard of due care, d, applicable to both negligence and contributory negligence and with uniform equilibrium, either everyone is always negligent, \( x < d \), or people may be nonnegligent some of the time. Let us start with the case \( y < d \) where everyone else is always negligent, looking for a uniform equilibrium of this sort. We must distinguish utility depending on whether \( x \) is chosen above or below \( d \)

\[
U(x) = \begin{cases} 
U_1(x) = V(x) - nC \int_0^d \int_0^y \left( \frac{1-a}{x} \right) \left( \frac{1-b}{y} \right) \text{dbda} & : x \geq d \\
U_2(x) = V(x) - nC \int_0^x \int_0^y \left( \frac{1-a}{x} \right) \left( \frac{1-b}{y} \right) \text{dbda} & : x < d.
\end{cases}
\] (41)

For \( x \) below \( d \) everyone is negligent in all accidents and each one bears his own costs. For \( x \) above \( d \), the individual only bears his own costs when his care level is below \( d \). Performing the integrations in the definition of utility, we can express utilities as

\[
U_1(x) = V(x) - nC \int_0^d \int_0^y \left( \frac{1-a}{x} \right) \left( \frac{1-b}{y} \right) \text{dbda}
\]

\[
U_2(x) = V(x) - nC \int_0^x \int_0^y \left( \frac{1-a}{x} \right) \left( \frac{1-b}{y} \right) \text{dbda}.
\] (42)

Note that \( U_2 \) coincides with utility in the absence of liability and that \( U_1(x) \gg U_2(x) \) as \( x < d \). Also \( U_1'(x) > U_2'(x) \) at \( x = d \). Let us denote the utility maxi-
mizing levels of care, ignoring the constraints on the domain, by \( x_1 \) and \( x_2 \). Note that \( x_2 \) is independent of \( d \) and coincides with \( x^* \) when it coincides with \( y \). Then, the \( x_i \) are defined by setting the derivatives of \( U_i \) equal to zero:

\[
V'(x_1) = -nCx_1^{-2}(d - \frac{1}{2}d^2)(1 - \frac{1}{2}y) \quad \text{(44)}
\]

\[
V'(x_2) = -\frac{1}{2}nC(1 - \frac{1}{2}y) \quad \text{(45)}
\]

There are four possible configurations of utilities given the constraints above. These are shown in Figure 9 with \( U \) given as the dotted curve. The four possibilities depend on the relative positions of \( d, x_1, \) and \( x_2 \). (The remaining situation, \( x_1 < d < x_2 \), is ruled out by the conditions above; with \( d < x_2 \) the relationships between \( x_1 \) and \( x_2 \) do not matter for the analysis and need not appear as shown.)

As the figures show we have the choice of care satisfying

\[
x = x_1 \quad \text{for } d < x_2
\]

\[
x = x_1 \quad \text{for } x_1 > d > x_2, \ U_1(x_1) \geq U_2(x_2)
\]

\[
x = x_2 \quad \text{for } x_1 > d > x_2, \ U_1(x_1) \leq U_2(x_2)
\]

\[
x = x_2 \quad \text{for } d > x_1.
\]

(46)

The only case which can give rise to a uniform distribution (\( x = y \)) must have \( x < d \) (since we are examining the case \( y < d \)). This corresponds to the choice of \( x_2 \) under either of its possible circumstances. Note that \( d \) does not affect \( U_2 \) so that \( x_2 \) coincides with \( x^* \) at the uniform equilibrium.

Now let us consider the range of \( d \) resulting in this equilibrium. From the four diagrams we see that \( x_2 \) is chosen if and only if \( U_1(x_1) \leq U_2(x_2) \) both evaluated at \( y = x_2 = x^* \). Since \( U_1 \) is decreasing in \( d \), there will be a single due care level \( \hat{d}_1 \) separating the due care levels giving rise to this equilibrium from those that don't.

\[
V(x^*) - nC(1 - \frac{1}{2}x^*)^2 = \max_{x} V(x) - nCx^{-1}(1 - \frac{1}{2}x^*)(\hat{d}_1 - \frac{1}{2}d_1^2). \quad \text{(47)}
\]

Now let us examine the case where others are not always negligent, \( y > d \). To calculate utility, we must distinguish the cases where the individual is sometimes negligent and where he is always negligent.

\[
U(x) = \begin{cases} 
\bar{U}_1(x) = V(x) - nCx^{-1}y^{-1} \left[ \int_0^d \int_0^x (1 - a)(1 - b)dbda 
+ 2 \int_0^d \int_y^x (1 - a)(1 - b)dbda 
+ \int_d^x \int_y^x (1 - a)(1 - b)dbda \right] & : x \geq d \\
\bar{U}_2(x) = V(x) - nCx^{-1}y^{-1} \left[ \int_0^x \int_0^y (1 - a)(1 - b)dbda 
+ 2 \int_0^x \int_y^d (1 - a)(1 - b)dbda \right] & : x < d.
\end{cases}
\]

Performing the integrations and rearranging terms we have

\[
\bar{U}_1(x) = V(x) - nCx^{-1}y^{-1} \left[ (d - \frac{1}{2}d^2)(y - \frac{1}{2}y^2) 
+ (x - \frac{1}{2}x^2)(y - d - \frac{1}{2}(y^2 - d^2)) \right] \quad \text{(49)}
\]
\begin{align*}
\text{Figure 9} & \quad U_2 \quad U_1 \\
& \quad x_2 \quad d \quad x_1 \\
& \quad d < x_1 \quad d < x_2 \\
& \quad U_1(x_1) > U_2(x_2)
\end{align*}

\begin{align*}
\text{Figure 9} & \quad U_2 \quad U_1 \\
& \quad x_2 \quad d \quad x_1 \\
& \quad x_2 < d < x_1 \\
& \quad U_1(x_2) > U_2(x_2)
\end{align*}

\begin{align*}
\text{Figure 9} & \quad U_2 \quad U_1 \\
& \quad x_2 \quad d \quad x_1 \\
& \quad x_2 < d < x_1 \\
& \quad U_2(x_2) > U_1(x_1)
\end{align*}

\begin{align*}
\text{Figure 9} & \quad U_2 \quad U_1 \\
& \quad x_2 \quad x_1 \quad d \\
& \quad x_1 < d \quad x_2 < d \\
& \quad U_2(x_2) > U_1(x_1)
\end{align*}
\[ \bar{U}_2 = V(x) - nC y^{-1}[(1 - \frac{1}{2}x)(2y - d - \frac{1}{2}(2y^2 - d^2))]. \]  

(50)

As before, we have \( \bar{U}_1(x) = \bar{U}_2(x) \) as \( x \geq d \) and \( \bar{U}_1'(x) > \bar{U}_2'(x) \) at \( x = d \). We denote the maximizing levels of care for the two functions by \( \bar{x}_1 \) and \( \bar{x}_2 \). Thus the possible configurations are the same as in Figure 9 leading to the same description of choice, (46) with \( \bar{U}_1 \) replacing \( \bar{U}_i \). Now we will have a uniform equilibrium if and only if \( \bar{U}_1(\bar{x}_1) \geq \bar{U}_2(\bar{x}_2) \) both evaluated at \( y = \bar{x}_1 \).

For the uniform equilibrium in this situation, we have the first order condition for \( \bar{x}_1 \), obtained by differentiating (49),

\[ V'(x) = -nC x^{-2} y^{-1}[(d - 2 \frac{1}{2} d^2)(y - 2 \frac{1}{2} y^2) \]
\[ + (x - 2 \frac{1}{2} x^2)(y - d - 2 \frac{1}{2}(y^2 - d^2))] \]
\[ + nC x^{-1} y^{-1}[(1 - x)(y - d - 2 \frac{1}{2}(y^2 - d^2))] \].

(51)

This needs to be satisfied at \( x = y \), giving the condition for equilibrium

\[ -V'(x) = nC x^{-1} (1 - 2 \frac{1}{2} x^2) + nC x^{-1} (1 - x)(1 - 2 \frac{1}{2} x) \]
\[ + nC x^{-2} (1 - x)(d - 2 \frac{1}{2} d^2) \]
\[ = \frac{1}{2} nC (1 - 2 \frac{1}{2} x) + nC x^{-2} (1 - x)(d - 2 \frac{1}{2} d^2). \]

(52)

Given this range of equilibria, we can calculate how \( x \) changes with \( d \). Differentiating (52) we have

\[ \frac{dx}{dd} = \frac{nC (1 - x)(1 - d)}{-x^2 V'' + \frac{1}{2} nC x^2 + nC (d - 2 \frac{1}{2} d^2)(2x^{-1} - 1)} > 0. \]

(53)

Thus the equilibrium level of precaution increases with the due care level throughout this range.

I have not shown that the set of equilibria is in fact an interval. We denote by \( \bar{d}_j \) the maximal level of \( d \) giving rise to this type of equilibrium (i.e., maximal \( d \) satisfying \( \bar{U}_1 = \bar{U}_2 \)).

Let us examine whether \( x^* \) is a possible equilibrium. First let us find the due care level \( d^* \) so that \( x^* \) is the solution to (52), i.e.,

\[ x^* = \bar{x}_1(d^*). \]

(54)

From the definitions of \( \bar{x}_1 \), (52), and of \( x^* \), (40), we see that \( x^* = \bar{x}_1 \) when

\[ (1 - \frac{1}{2} x^*) = \frac{1}{2} (1 - 2 \frac{1}{2} x^*) + x^* - 2(1 - x^*)(d - 2 \frac{1}{2} d^2). \]

(55)

Rearranging terms we have

\[ (d^* - 2 \frac{1}{2} d^2) = (x^* - 2 \frac{1}{2} x^2) \frac{x^*}{2(1 - x^*)}. \]

(56)

Now let us examine the utility comparison condition, making use of the definition of \( d^* \) to see whether \( x^* \) qualifies as an equilibrium.
\[ U_1(x^*) - U_2(\bar{x}_2) = V(x^*) - nC(1 - \frac{1}{2}x^*)^2 \]
\[ - \max_x [V(x) - nC(1 - \frac{1}{2}x)x^{*-1}(2x^* - d^* - \frac{1}{2}(2x^{*2} - d^{*2}))] \]
\[ = \min_x \left[ V(x^*) - nC(1 - \frac{1}{2}x^*)^2 \right. \]
\[ - V(x) + nC(1 - \frac{1}{2}x)(1 - \frac{1}{2}x^*) \left( 2 - \frac{x^*}{2(1 - x^*)} \right) \right]. \quad (57) \]

This minimization is strictly less than the value achieved at \( x^* \) (since the minimizing \( x \) never coincides with \( x^* \)).

\[ U_1(x^*) - U_2(\bar{x}_2) < nC(1 - \frac{1}{2}x^*)^2 \left( \frac{2 - 3x^*}{2(1 - x^*)} \right). \quad (58) \]

Since the right-hand side is nonpositive for \( x^* \geq \frac{2}{3} \) the efficient equilibrium is not achievable for \( x^* \geq \frac{2}{3} \).

8. Stochastic Control of Care III

Some of the features of the two examples above can be combined into a single model if we assume that care has a triangular distribution with its peak at the point of precaution (we continue to assume that costs per accident are constant and that accident probability is the product of one minus the care level for each party). This relationship is shown in Figure 10 for a precaution level of \( x \).

\[ \text{Figure 10} \]

Now whatever the due care standard (within the unit interval) an individual will be negligent some of the time and will show more than due care some of the time. The level of due care now affects the equilibrium at all levels. The equilibrium level of precaution is continuous in the due care level,

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22 The analysis of this section was done by Roger Gordon.
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rising up to a point and then declining with further increases in the due care standard (with a kink in the curve where it crosses the $45^\circ$ line). With the due care standard at either extreme, we have the same equilibrium as in the absence of liability since either everyone is negligent or no one is. Figure 11 depicts such a locus of equilibria.

![Figure 11](image)

The ability to achieve the efficient equilibrium (i.e., whether $x^*$ is below the maximal level of $x$ in Figure 11) depends on the parameters of the utility function. As in the previous section it is sometimes achievable and sometimes not.

**APPENDIX TO SECTION 8**

Here we derive the results of this section of the text. With a triangular distribution the density function $f(a,x)$ for care is $\frac{2a}{x}$ for $a \leq x$ and $\frac{2(1-a)}{(1-x)}$ for $a \geq x$. The expected value of $(1-a)$ is thus $\frac{y}{2}(1-\frac{x}{2})$. Thus expected utility in the absence of a liability system, assuming that everyone else has chosen care level $y$ is

$$U(x) = V(x) - \frac{4nC}{9} (1 - \frac{x}{2})(1 - \frac{y}{2}).$$

(59)

In the same way as above we can derive the no-liability equilibrium level as the solution to

$$V'(x^*) = -\frac{2nC}{9} (1 - \frac{x^*}{2})$$

(60)

and the efficient care level as the solution to

$$V'(x^*) = -\frac{4nC}{9} (1 - \frac{x^*}{2}).$$

(61)

It is now the case that negligence and due care are possible for each individual for any level of the due care standard. However, we will consider the cases with
$x \equiv d$ separately for convenience since the expressions for the density of care when negligent differ in these two cases. Let us first write expected utility in terms of the density function covering both cases. One bears one's own costs whenever negligent and when nonnegligent and the other party is also nonnegligent. One bears the other's costs when negligent when he is not. Thus

$$U(x) = V(x) - nC \left[ \int_0^d (1 - a)f(a,x)da \int_0^1 (1 - b)f(b,y)db \right. $$
$$+ \left. \int_d^1 (1 - a)f(a,x)da \int_d^1 (1 - b)f(b,y)db \right]$$

$$= V(x) - nC \left[ \int_0^d (1 - a)f(a,x)da \int_0^1 (1 - b)f(b,y)db \right. $$
$$+ \left. \int_0^1 (1 - a)f(a,x)da \int_0^d (1 - b)f(b,y)db \right].$$

(62)

Now let us consider the case $y < d$. Performing the integrations we have

$$U_1(x) = V(x) - \frac{4nC}{3} \left[ (1 - \frac{x}{2})x^{-1} \left( -\frac{d^2}{2} - \frac{d^3}{3} \right) \right.$$
$$+ \left. (1 - \frac{d}{x}) \frac{(1 - d)^3}{3(1 - y)} \right] : x \geq d$$

$$U_2(x) = V(x) - \frac{4nC}{9} \left[ (1 - \frac{y}{2}) \left( 1 - \frac{x}{2} - \frac{(1 - d)^3}{x} \right) \right.$$
$$+ \left. (1 - \frac{d}{x}) \frac{(1 - d)^3}{(1 - y)} \right] : x < d.$$ (63)

To see the relationship between the functions let us calculate the derivative of the difference between them

$$U_1(x) - U_2(x) = \frac{4nC}{9} \left( 1 - \frac{x}{2} \right) \left( 1 - \frac{x}{2} - \frac{(1 - d)^3}{x} \right)$$
$$\left( -\frac{d^2}{2} - \frac{d^3}{3} \right) - \frac{2nC}{9} (1 - \frac{x}{2})x^{-1}(1 - x^{-1}) \left( -3x^2 + x^3 + 6dx - 3xd^2 - 3d^2 + 2d^3 \right).$$ (64)

$$U'_1(x) - U'_2(x) = \frac{4nC}{9} \left( 1 - \frac{x}{2} \right) \left( -\frac{3}{2} - \frac{(1 - d)^3}{(1 - x)^2} + \frac{3d^2}{2x^2} - \frac{d^3}{x^2} \right)$$
$$= \frac{2nC}{9} (1 - \frac{x}{2})(1 - x)^{-2}x^{-2}(-3x^2 + 2x^3 - x^4 + 6dx^2 - 3d^2x^2 - 6d^3x + 4d^3x + 3d^2 - 2d^3).$$ (65)
Thus $U_1 - U_2$ and $U'_1 - U'_2$ are both zero when $x = d$. To see the relationship over the rest of the range of $x$ we note that

$$\text{sign}(U_1(x) - U_2(x)) = \text{sign}(-3x^2 + x^3 + 6xd - 3xd^2 - 3d^2 + 2d^3).$$ \hspace{1cm} (66)

The expression on the right is zero when $x = d$ and positive everywhere else in the unit interval since the sign of its derivative with respect to $x$ is the same as that of $(d - x)$.

Given these facts we see that $U_2$ is at least as large as $U_1$, with the two functions tangent at $d$. $U$ coincides with $U_2$ below $d$ and $U_1$ above it. Thus the situation coincides with one of the two positions in Figure 12, with $U$ dotted in the figure.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure12}
\caption{Figure 12}
\end{figure}

Thus the level of care chosen maximizes $U_1$ or $U_2$, whichever maximum is part of $U$. This depends on whether $d$ is less than or greater than $x_1$ and $x_2$, the values which maximize $U_1$ and $U_2$. For $d \geq x_2$, $x_2$ is chosen, for $d < x_2$, $x_1$ is chosen. Since the calculation is done for $y < d$, we get a uniform equilibrium at $x_2$. Since $x_2$ maximizes $U_2$ we obtain its equation by setting the derivative of $U_2$ equal to zero.

$$V'(x) + \frac{4nC}{9} \left[ \frac{1}{3} \frac{(1 - d)^3}{(1 - y)} + (1 - \frac{4}{3}y) \left( \frac{4}{3} + \frac{(1 - d)^3}{(1 - x)^2} \right) \right] = 0. \hspace{1cm} (67)$$

The equation for equilibrium is obtained by substituting $y = x_2$ in the first order condition. Thus for $x_2 < d$ we have equilibrium where

$$V'(x_2) + \frac{2nC}{9} \left[ \frac{(1 - d)^3}{(1 - x_2)} + (1 - \frac{4}{3}x_2) \left( 1 + \frac{2(1 - d)^3}{(1 - x_2)^2} \right) \right] = 0. \hspace{1cm} (68)$$
Note first that $x_2$ coincides with $x^*$ at $d = 1$. Differentiating (68) implicitly we get the slope of this part of the locus of equilibria

$$
\frac{dx_2}{dd} = \frac{2nC}{3} \left( \frac{(1 - d^2)}{(1 - x_2)} + 2(1 - \frac{1}{2}x_2) \frac{(1 - d^2)}{(1 - x_2)^2} \right) = 0. \quad (69)
$$

The numerator is clearly positive, while the denominator is less than the second order condition. At $d = 1$, $\frac{dx_2}{dd} = 0$.

We can examine the other part of the locus of equilibria in the same fashion. We now assume $y \geq d$. Performing the integrations in (62) we have

$$
U(x) = \begin{cases} 
\bar{U}_1(x) = V(x) - \frac{2nC}{9} (x^{-1}(1 - \frac{1}{2}y)(3d^2 - 2d^3)) \\
\quad + (1 - \frac{1}{2}x)[2 - y - y^{-1}(3d^2 - 2d^3)] \\
\bar{U}_2(x) = V(x) - \frac{2nC}{9} \left( 2 - x - \frac{2(1 - d)^3}{(1 - x)} \right)(1 - \frac{1}{2}y) \\
\quad + (1 - \frac{1}{2}x) \left[ 2 - y - y^{-1}(3d^2 - 2d^3) \right]. 
\end{cases} \quad (70)
$$

Since

$$
\bar{U}_2(x) - \bar{U}_1(x) = U_2(x) - U_1(x), \quad (71)
$$

the discussion above on the relative positions of the curves carries over. Thus $\bar{x}_1$ is chosen for $d < \bar{x}_2$ and $\bar{x}_2$ is chosen for $d \geq \bar{x}_2$. For a uniform equilibrium we have $\bar{x}_1 = y \geq d$. The equation for this part of the locus is obtained by calculating the first order condition for the maximization of $\bar{U}_1$ and evaluating at $y = \bar{x}_1$

$$
V'(\bar{x}_1) + \frac{2nC}{9} \left[ (\bar{x}_1^{-2} - \bar{x}_1^{-1})(3d^2 - 2d^3) + 1 - \frac{1}{2}x_1 \right] = 0. \quad (72)
$$

Again, (72) can be differentiated to obtain the slope of this part of the locus of equilibria (also $\bar{x}_1 = x^*$ and $\frac{d\bar{x}_1}{dd} = 0$ at $d = 0$).

$$
\frac{d\bar{x}_1}{dd} = -\frac{\frac{2nC}{9} (\bar{x}_1^{-2} - \bar{x}_1^{-1})(6d - 6d^2)}{V'' - \frac{2nC}{9} \left[ (2\bar{x}_1^{-3} - \bar{x}_1^{-2})(3d^2 - 2d^3) + \frac{1}{2} \right]} > 0. \quad (73)
$$

Thus the part of the locus above the $45^\circ$ line is rising, the part below is falling. From (68) and (72) we confirm that each part hits the $45^\circ$ line at the same value.
of d. From the slope conditions there is a kink in the locus at this point. This justifies the description of the shape of the curve given at the start of this section.

It remains to check when \( x^* \) is obtainable. The greatest obtainable equilibrium value of \( x \) occurs at \( x = d \). From either (68) or (72) this value satisfies the equation

\[
V'(x) = -\frac{2nC}{9} \left( 4 - \frac{11x}{2} + 2x^2 \right).
\]  

(74)

Since \( V \) is concave, \( x^* \) is achievable when the right-hand side of (64) is less than the right-hand side of (74); that is, when

\[
\frac{2nC}{9} (2 - x) \leq \frac{2nC}{9} \left( 4 - \frac{11x}{2} + 2x^2 \right).
\]  

(75)

Solving this expression we see that the efficient solution is obtainable when

\[
x^* \leq \frac{9 - \sqrt{17}}{8} \approx .6.
\]  

(76)

Thus the efficient solution is not always attainable.

The introduction of uncontrolled elements in individual behavior alters somewhat the description of equilibrium as a function of the level of the due care standard. It introduces the realistic element of the presence of successful law suits, at least for some range of judicial selection of the due care standard. It also tends to remove discontinuities in the response of equilibrium to the due care standard. However, the general picture of the impact of different due care standards on accidents is preserved—the presence of a negligence system tends to increase the level of care above the no-liability equilibrium level; with a higher due care standard increasing care in the low range, but decreasing it when the due care standard gets very high.

9. Stochastic Measurement of Care

Underlying the models discussed above was the assumption that the legal system accurately measured the level of care at the time of an accident. The stochastic models given above can also be interpreted as describing a situation where individual decisions are determinate but stochastic elements are present in the attempt by a court to measure what occurred at the time of the accident. To carry over the analysis we need to assume that the choice of any care level by the individual gives rise to a probability distribution of possible care measurements by a court. The first two cases described correspond to possible over- and underestimation of care taken. To carry over the analysis we need two further assumptions—that the distribution of errors of measurement is independent of the due care standard and that the errors of measurement relative to the two parties to an accident are also independent. It is not clear that these are good assumptions.

From the diagrams, we see that with the tendency to overestimate care
taken, setting the due care level at the efficient care level results in an efficient equilibrium. With underestimation of care taken, the due care level must be set below the efficient care level to achieve the efficient equilibrium when it can be achieved at all.

10. Comparative Negligence

Two different forms of comparative negligence have been employed—either total accident costs, or those of the less negligent, are divided between the two parties in fractions reflecting their relative contributions toward causing the accident. By converting negligence issues to differences in degree rather than kind the legal process is considerably changed. We wish to ask, however, what the impact of comparative negligence on care decisions is. With differences across people the selection of comparative negligence (rather than negligence) will alter relative income distributions (loss-bearing) both ex ante and ex post. This selection also affects care choices, and so efficiency.

Given the symmetry that comes from assuming that everyone is the same, there are two differences between comparative negligence (sharing total costs) and an absence of liability. The first is that one expects to bear some fraction of the costs of others to match the fraction of one’s costs borne by others. Where there are decisions that affect the two parties to an accident differently, this alters incentives. Secondly, the perception that increased care decreases the fraction of total costs borne serves to induce more care. The more sharply the cost-sharing fractions change with the care decisions, the greater the inducement to increased care, and the greater the care taken in equilibrium (under suitable assumptions). As the shares become less responsive to care differences between the two parties—as, in other words, the system tends toward simply dividing accident costs between the parties—the ex ante equilibrium tends toward a position that differs from the no-liability equilibrium only because of the different impact of care decisions on the two parties to the accident. When care affects accident probabilities but not costs, the equilibrium tends to the no-liability equilibrium as care differences decrease in importance in cost allocation. These points are brought out clearly in the determinate model used above where the ability to select the cost-sharing fraction permits the choice of the efficient equilibrium. In the determinate case, however, in all accidents both parties are equally negligent so the key element is merely the change in the fraction of cost

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23 The section on comparative negligence may be omitted, without loss of continuity, by the reader who wants to proceed to the discussion of negligence in more complicated settings.

24 In addition, a negligence standard may be imposed as a preliminary hurdle to the application of comparative negligence.
bearing with increased care at this point. When we consider the stochastic model used above, a wide range of possible cost allocations have positive probabilities bringing the shape of the entire curve into the determination of equilibrium. Rather than considering all possible cost divisions, we shall consider the class of divisions \( \frac{e-a}{2e-a-b} = \frac{e-b}{2e-a-b} \) for different values of \( e \).

As \( e \) increases, this division converges to equal division and the equilibrium level of precaution decreases, converging to the no-liability equilibrium. The efficient allocation is only achievable in some cases with this class of division rules (specifically for \( x^* \leq \frac{a}{2} \)).

Let us derive this pattern of results starting with the determinate case. We follow the notation of section 5 above. Let \( x \) and \( y \) be levels of care taken by the two parties to the accident; \( \pi(x, y)C(x, y) \) and \( \pi(x, y)C(y, x) \), the expected values to each party of costs from accidents between two parties having these care levels (\( \pi \) symmetric); and \( n + 1 \) the number of identical individuals. Let \( \phi(x, y) \) be the fraction of costs borne by the person having care level \( x \) at the time of an accident (\( \phi(x, y) + \phi(y, x) = 1 \)). As in section 3 efficiency is achieved by a uniform care level \( x^* \) satisfying

\[
V'(x^*) = n\pi(x^*, x^*)(C_1(x^*, x^*) + C_2(x^*, x^*)) + nC(x^*, x^*)(\pi_1(x^*, x^*) + \pi_2(x^*, x^*))
\]

and in the absence of any liability system equilibrium occurs at \( x^o \) satisfying

\[
V'(x^o) = n\pi(x^o, x^o)C_1(x^o, x^o) + nC(x^o, x^o)\pi_1(x^o, x^o)
\]

where \( V(x) \) is the utility of taking care (\( V'' < 0 \)). Under the comparative negligence system, utility net of costs satisfies (assuming everyone else chooses care level \( y \))

\[
U(x) = V(x) - n\pi(x, y)(C(x, y) + C(y, x))\phi(x, y).
\]

The first order condition for utility maximization is

\[
V'(x) - n\pi(x, y)(C(x, y) + C(y, x))\phi_1(x, y) - n\pi(x, y)(C_1(x, y) + C_2(y, x))\phi(x, y) - n\pi_1(x, y)(C(x, y) + C(y, x))\phi(x, y) = 0.
\]

We have equilibrium at \( x \) if (80) is satisfied for \( x = y \).

Comparing the two allocation equations, (77) and (80), we have equilibrium at the efficient point if

\[
\pi(x^*, x^*)C_1(x^*, x^*) + C_2(x^*, x^*) + C(x^*, x^*)(\pi_1(x^*, x^*) + \pi_2(x^*, x^*)) = 2\pi(x^*, x^*)C(x^*, x^*)\phi_1(x^*, x^*) + \pi(x^*, x^*)(C_1(x^*, x^*) + C_2(x^*, x^*))\phi(x^*, x^*) + 2\pi_1(x^*, x^*)C(x^*, x^*)\phi(x^*, x^*).
\]
Since \( \pi \) is symmetric, \( \pi_1(x^*,x^*) = \pi_2(x^*,x^*) \). From its definition we see that \( \phi(x^*,x^*) = \frac{1}{2} \). Thus we can write this condition as

\[
\phi_1 = \frac{\pi(C_1 + C_2) + 2C\pi_1}{4\pi C}.
\] (82)

Comparing equilibrium (80) with that in the absence of liability, (78), an individual perceives different elements of gain from further care between the two equilibria of one-half the difference in expected marginal accident cost inflicted on himself and on the other party, \( \frac{1}{2}n(\pi(C_2 - C_1) + \pi_1(C(y,x) - C(x,y))) \), plus the gain arising from the marginal decrease in the share of total costs for which he is liable, \( \pi(C + C)\phi_1 \). If the cost function were symmetric, \( C(x,y) = C(y,x) \), the stimulus toward more care would be precisely the value of the shift in the liability fraction, \( \phi_1 \). (Of course this difference refers to the functional forms of the cost elements, since different levels of care give different actual values.)

Turning to the stochastic case, we follow the model used in section 7 above: the choice of a precaution level \( x \) generates a uniform probability of actual care a between 0 and \( x \) (\( x < 1 \)) and total expected accident costs from accidents between two individuals having care levels a and b at the time of the accident are \( 2(1 - a)(1 - b)C \), where \( C \) is a constant. From section 7 we know that efficiency requires a precaution level \( x^* \) satisfying

\[
V'(x^*) = -nC(1 - \frac{1}{2} x^*)
\] (83)

while in the absence of liability we have the equilibrium precaution level satisfying the equation

\[
V'(x^0) = -\frac{1}{2} nC(1 - \frac{1}{2} x^0).
\] (84)

Let us examine the equilibrium level as a function of a parameter \( e \) which reflects how importantly differences in care are reflected in the division of costs. If costs are divided in proportions \( \frac{e-a}{2e-a-b} \) and \( \frac{e-b}{2e-a-b} \) (we assume \( e > x,y \) throughout) utility net of costs for someone choosing precaution level \( x \) when everyone else has chosen precaution level \( y \) is

\[
U(x) = V(x) - 2nC x^{-1} y^{-1} \int_0^x \int_0^y (1 - a)(1 - b) \left( \frac{e-a}{2e-a-b} \right) db da.
\] (85)

The first-order condition for utility maximization is

\[
V'(x) + 2nC x^{-2} y^{-1} \int_0^x \int_0^y (1 - a)(1 - b) \left( \frac{e-a}{2e-a-b} \right) db da
- 2nC x^{-1} y^{-1} \int_0^y \frac{(1 - x)(1 - b)(e-x)}{(2e - x - b)} db = 0.
\] (86)
We have equilibrium when this condition holds for \( x = y \)

\[
V'(x) - 2nCx^3 \int_0^x \int_0^x \left( \frac{(1 - x) (1 - b) (e - x)}{2e - b - x} \right) \, db \, da = 0. \tag{87}
\]

Let us write this as

\[
V'(x) + nCF(x,e) = 0. \tag{88}
\]

From this equilibrium condition we know that equilibrium changes with respect to the parameter \( e \) satisfy

\[
\frac{dx}{de} = -\frac{\partial F/\partial e}{V''/nC + \partial F/\partial x}. \tag{89}
\]

The numerator of this expression is positive and the denominator negative so that a decreased responsiveness of the fraction to care lowers the equilibrium level of precaution. And \( F \) tends to \( \frac{1}{2} (1 - \frac{1}{2} x) \) as \( e \) increases without limit, confirming (from (84)) the convergence to the no-liability equilibrium as cost sharing converges to equal division. \( F \) takes on the value \( (1 - \frac{1}{2} x^*) \) for some value of \( e \) (above \( x^* \)) if and only if \( x^* \leq \frac{3}{2} \). Thus from (83) the efficient equilibrium is achievable only in some situations.

These propositions are derived in the appendix to this section.

**APPENDIX TO SECTION 10**

From (87) and (88) we have the definition of \( F \)

\[
F = -2x^{-3} \int_0^x \int_0^x \left( \frac{(1 - x) (1 - b) (e - x)}{2e - b - x} \right) \frac{(1 - a) (1 - b) (e - a)}{2e - b - a} \, db \, da. \tag{90}
\]

Let us examine the integrand separately. Define

\[
f(a,b,e) = \frac{(1 - a) (1 - b) (e - a)}{2e - b - a} \tag{91}
\]

so that

\[
F = -2x^{-3} \int_0^x \int_0^x (f(x,b,e) - f(a,b,e)) \, db \, da. \tag{92}
\]

First we note that by symmetry
\begin{align*}
\int_0^x \int_0^x (f(a,b,e) - f(b,a,e)) \, db \, da \\
= \int_0^x \int_0^x \frac{(1 - a)(1 - b)(b - a)}{(2e - b - a)} \, db \, da = 0. \tag{93}
\end{align*}

This implies that

\begin{align*}
\int_0^x \int_0^x \left( \frac{\partial f(a,b,e)}{\partial e} - \frac{\partial f(b,a,e)}{\partial e} \right) \, db \, da = 0. \tag{94}
\end{align*}

Since by direct calculation we also have

\[ f(a,b,e) + f(b,a,e) = (1 - a)(1 - b) \]

we see that

\[ \frac{\partial f(a,b,e)}{\partial e} + \frac{\partial f(b,a,e)}{\partial e} = 0. \tag{95} \]

Combining (94) and (96) we see that

\begin{align*}
\int_0^x \int_0^x \frac{\partial f(a,b,e)}{\partial e} \, db \, da = 0. \tag{97}
\end{align*}

Thus

\[ \frac{\partial F}{\partial e} = -2x^{-3} \int_0^x \int_0^x \frac{(1 - x)(1 - b)(x - b)}{(2e - b - x)^2} \, db \, da < 0 \tag{98} \]

where the inequality follows from \(b\) being less than or equal to \(x\) and both \(b\) and \(x\) being less than or equal to one.

Before turning to the derivative of \(F\) with respect to \(x\) let us calculate the second order condition by differentiating (86) and evaluating at \(y = x\)

\begin{align*}
V'' - 4nCx^{-4} \int_0^x \int_0^x f(a,b,c) \, db \, da + 4nCx^{-8} \int_0^x f(x,b,e) \, db \\
+ 2nCx^{-2} \int_0^x \frac{(1 - b)}{(2e - x - b)^2} ((e - x)^2 \\
+ (e - x)(e - b) + (1 - x)(e - b)) \, db < 0. \tag{99}
\end{align*}

Calculating the denominator of (89) (times \(nC\)) we have

\begin{align*}
V'' + nC \frac{\partial F}{\partial x} = V'' + 6x^{-4}nC \int_0^x \int_0^x (f(x,b,e) - f(a,b,e)) \, db \, da \\
- 2x^{-3}nC \int_0^x (f(x,x,e) - f(a,x,e)) \, da \\
+ 2x^{-3}nC \int_0^x \int_0^x \frac{(1 - b)}{(2e - x - b)^2} ((e - x)^2 \\
+ (e - x)(e - b) + (1 - x)(e - b)) \, db \, da. \tag{100}
\end{align*}
The denominator will be negative if it is less than the second order condition; \( i.e., \) if \((100) - (99)\) is negative. Calculating this difference we have

\[
-2x^{-4nC} \int_0^x \int_0^x (f(a,b,e) - f(a,x,e) - f(x,b,e) + f(x,x,e)) \, db \, da.
\]  
(101)

Let us call the integrand \(g(a,b,x,e)\). Then

\[
-2x^{-4nC} \int_0^x \int_0^x g(a,b,x,e) \, db \, da = -x^{-4nC} \int_0^x \int_0^x (g(a,b,x,e) + g(b,a,x,e)) \, db \, da
\]

\[
= -x^{-4nC} \int_0^x \int_0^x (a - x)(b - x) \, db \, da < 0.
\]  
(102)

As \(e\) rises without limit \(F\) tends to

\[
-2x^{-3} \int_0^x \int_0^x \frac{1}{2} ((1 - x)(1 - b) - (1 - a)(1 - b)) \, db \, da
\]

\[
= -x^{-3} \int_0^x (a - x)(x - \frac{x^2}{2}) \, da
\]

\[
= \frac{1}{2} (1 - \frac{x}{2}).
\]  
(103)

Thus \(x\) tends to \(x^*\) (see (84)). Since \(x\) decreases with \(e\), the maximal value of \(x\) achievable occurs at \(x = e\). At this point

\[
F = 2x^{-3} \int_0^x \int_0^x \frac{(1 - a)(1 - b)(x - a)}{(2x - b - a)} \, db \, da
\]

\[
= x^{-3} \int_0^x \int_0^x (1 - a)(1 - b) \, db \, da
\]

\[
= x^{-1}(1 - \frac{x}{2})^2
\]  
(104)

where (94) and (95) were used to simplify the integration. Thus the maximal achievable precaution level satisfies

\[
V'(x) = -nCx^{-1}(1 - \frac{x}{2})^2.
\]  
(105)

We know that the efficient level satisfies (83) and that \(V'\) is decreasing in \(x\). Equating the right-hand sides of (105) and (83) we see that the efficient point is the maximal achievable precaution level when \(x^* = \frac{3}{2}\). When \(x^*\) is higher, it is not achievable (\(i.e.,\) the solution to (105) is less that \(x^*\)) while whenever \(x^*\) is less than \(\frac{3}{2}\) it is achievable.
11. **Unmeasured Variables**

Despite the complications of the analysis thus far, the models have been extremely restricted in that everyone was assumed to be the same and each person made but one decision. In the next section we will examine a difference across individuals in the utility of taking care. In this section we shall consider the interaction of the due care standard (with the distribution of care determined by a single precaution variable) with two variables which the court does not attempt to monitor. One element that will not enter the discussion is the realistic possibility of a care variable the distribution of which is determined by several precaution decisions. Since we have considered precaution variables affecting the level of the distribution of care, with the form of the distribution given, it is natural to enquire into variables that affect the shape of the distribution function.\(^{25}\) In particular some decisions may compress the distribution, eliminating both high and low levels of care. While I have not examined any examples in detail, it seems that the presence of the due care standard imparts great significance to shifts of probability between care levels above and below the due care standard relative to the significance given shifts strictly within either category. Thus the presence of a due care standard will affect this sort of decision in ways which may vary greatly with the details of the particular situation.

In the first section we discussed the different types of individual decisions relative to the measurements which a court makes. To examine some of the interactions among these variables let us consider an activity where each individual makes three decisions that affect expected accident costs. We assume that the nature of the activity is such that given his other two decisions (and the decisions of others), the individual faces a constant rate of expected accident costs per hour engaged in the activity. (We denote the number of hours by \(x_2\) for the individual and \(y_2\) for all others.) We assume that the court, examining individual accidents, never asks about the total time devoted to the activity. Secondly, we assume that there is a safety decision that affects the costs of any given accident but has no effect on accident probabilities. (We denote the level of the safety decision by \(x_3\) and \(y_3\).) Thus this decision is never viewed, by the court, as causing an accident, and so is never part of a judgment of negligence. (We ignore the possibility of attributing incremental accident costs to particular safety decisions.) The third decision is a precaution decision (denoted by \(x_1\) and \(y_1\)) that generates a probability distribution of care that in turn affects accident probabilities but not costs per accident. We assume that accident probability given care levels \(a\) and \(b\) is \((1 - a)(1 - b)\) while care is uniformly distributed between 0 and \(x_1\).

\(^{25}\)Having several decisions which would merely combine to determine the level of the distribution does not appear to be an interesting direction for extension.
Given this structure a person expects accident costs of \((1 - a)(1 - b) x_2 y_2 C(x_3, y_3)\) for accidents he has when taking care level \(a\) with a given person taking care level \(b\). To determine total expected costs, we multiply by the number of other people, \(n\), attach probabilities to the occurrence of care levels \(a\) and \(b\), and add up across care levels.

Assuming everyone else is identical, the expected utility maximizing individual wishes to

\[
\text{Max } V(x_1, x_2, x_3) - nx_1^{-1}x_2y_1^{-1}y_2 C(x_3, y_3) \int_0^{x_1} \int_0^{y_1} (1 - a)(1 - b)dbda. \tag{106}
\]

Integrating we can express consumer choice as

\[
\text{Max } V(x_1, x_2, x_3) - n(1 - \frac{1}{2}x_1)(1 - \frac{1}{2}y_1)x_2y_2 C(x_3, y_3). \tag{107}
\]

For the maximization we have the first-order conditions

\[
V_1 = -\frac{1}{2}n(1 - \frac{1}{2}y_1)x_2y_2 C(x_3, y_3) \tag{108}
\]

\[
V_2 = n(1 - \frac{1}{2}x_1)(1 - \frac{1}{2}y_1)y_2 C(x_3, y_3) \tag{109}
\]

\[
V_3 = n(1 - \frac{1}{2}x_1)(1 - \frac{1}{2}y_1)x_2y_2 C_1(x_3, y_3). \tag{110}
\]

For uniform equilibrium these three equations are simultaneously satisfied at \(x_1 = y_1\).

Assuming for the moment that all three variables are centrally controlled, the maximization of utility of the representative individual is

\[
\text{Max } V(x_1, x_2, x_3) - n(1 - \frac{1}{2}x_1)^2x_2^2 C(x_3, x_3). \tag{111}
\]

This gives the first-order conditions

\[
V_1 = -n(1 - \frac{1}{2}x_1)x_2^2 C(x_3, x_3) \tag{112}
\]

\[
V_2 = 2n(1 - \frac{1}{2}x_1)^2x_2 C(x_3, x_3) \tag{113}
\]

\[
V_3 = n(1 - \frac{1}{2}x_1)^2x_2^2 (C_1(x_3, x_3) + C_2(x_3, x_3)). \tag{114}
\]

Thus as before, approximately half the elements of social cost are being examined by the individual in the absence of liability, since he ignores the impact of his decisions on the expected accident costs of others.

To examine equilibrium with a negligence standard let us assume that the due care level is not set so high that anyone chooses to be negligent all the time; \(i.e.,\) we assume \(y_1 > d\) and \(x_1 > d\). Thus an individual bears his own accident costs when negligent or when neither party is negligent and
bears the costs of the other person when negligent and the other party is not negligent. We can write expected utility as

\[
U(x_1, x_2, x_3) = V(x_1, x_2, x_3) - nx_1^{-1}y_1^{-1}x_2y_2 \left[ C(x_3, y_3) \left( \int_0^1 \int_0^{y_1} (1 - a)(1 - b) \, db \, da \right) + \int_0^x \int_0^{y_1} (1 - a)(1 - b) \, db \, da \right) + C(y_3, x_3) \int_0^a \int_0^{y_1} (1 - a)(1 - b) \, db \, da \right].
\]

(115)

Performing the integration we have

\[
U = V - nx_1^{-1}y_1^{-1}x_2y_2\left[ C(x_3, y_3) \left( (d - \frac{d^2}{2}) (y_1 - \frac{y_1^2}{2}) \right) + \left( x_1 - d - \frac{1}{2}(x_1^2 - d^2) \right) (y_1 - d - \frac{1}{2}(y_1^2 - d^2)) \right] + C(y_3, x_3) (d - \frac{1}{2}d^2)(y_1 - d - \frac{1}{2}(y_1^2 - d^2))].
\]

(116)

For convenience let us refer to the term in brackets as B. Note that when \(x_3 = y_3\) and \(x_1 = y_1\), B is equal to \(C(x_1 - \frac{1}{2} x_1^2)\). Calculating the first order conditions for individual choice we have

\[
V_1 = -nx_1^{-2}y_1^{-1}x_2y_2B + nx_1^{-1}y_1^{-1}x_2y_2 \left[ C(x_3, y_3) \left( (1 - x_1) \left( y_1 - d - \frac{1}{2}(y_1^2 - d^2) \right) \right) \right]
\]

(117)

\[
V_2 = nx_1^{-1}y_1^{-1}x_2y_2B
\]

(118)

\[
V_3 = nx_1^{-1}y_1^{-1}x_2y_2 \left[ C_2(x_3, y_3) \left( (d - \frac{1}{2}d^2)(y_1 - \frac{y_1^2}{2}) \right) + \left( x_1 - d - \frac{1}{2}(x_1^2 - d^2) \right) (y_1 - d - \frac{1}{2}(y_1^2 - d^2)) \right] + C_2(y_3, x_3) (d - \frac{1}{2}d^2)(y_1 - d - \frac{1}{2}(y_1^2 - d^2))].
\]

(119)

We have a uniform equilibrium when these three equations are solved simultaneously with \(x_1\) equal to \(y_1\).

By basing the determination of negligence on the level of care, which is (stochastically) affected by the precaution decision, the court is indirectly monitoring the precaution decision and directly affecting the equilibrium level of precaution by the choice of a due care standard.\(^{26}\) The decision as to the amount of time to devote to the activity is not directly affected. However, by directly affecting the choices of precaution and safety of all participants, the legal system affects the benefits from engaging in the activity and so affects the time allocated to the activity.\(^{27}\) In the normal case we would expect the legal system to reduce the accident rate per unit time (time held constant) and so to increase time devoted to the activity.\(^{28}\) This

\(^{26}\) This exactly follows the analysis in section 7; compare (51) and (117).

\(^{27}\) In form (109) and (118) are the same when \(x_1 = y_1\), although the values solving them will be different since the first order conditions from differentiation relative to \(x_1\) and \(x_3\) are different.

\(^{28}\) That is, if V is additive, time devoted to the activity will increase if \((1 - \frac{1}{2} x_1)^2\)
response increases accidents per person in the activity by increasing time per person. Also, increased time in the activity by others increases the accident rate per hour, partially offsetting the improved precaution decision.\footnote{C(x_3,x_3) is smaller, or (provided provision for one’s own safety doesn’t raise the costs of others by too much) if x_1 and x_3 are larger.}

The safety decision is also affected by the changed precaution and time decisions. In addition, it is affected directly by the court system, in that accident costs are sometimes borne by the other party to an accident. Given the symmetry of the \textit{ex ante} positions of all individuals, this changed incentive takes a simple form. For the expected number of accidents where an individual is negligent and the other person is not, an individual pays attention to the impact of his marginal safety decision on the cost per accident of the other party to an accident \( C_2(y_3,x_3) \) rather than to its impact on his own cost per accident \( C_1(x_3,y_3) \). (The simplicity of this change arises from the equal probabilities of being either party in an accident with one party negligent and the other party not.) Whether this improves resource allocation depends on the relative magnitudes of the impacts of one person’s safety decisions on the two parties to an accident. For full efficiency, we would want individual decisions to reflect the marginal costs to both parties from a lower level of safety, so the larger impact is closer to the sum of impacts.

This system is rather complicated, making it more difficult to trace out the efficiency implications of different due care standards. The legal system focuses on the precaution decision and so cannot attempt to achieve full efficiency.\footnote{Expected accident costs per hour are \( n(1 - \frac{1}{3} x_1)(1 - \frac{1}{3} y_1)y_2 \ C(x_3,y_3) \).} In altering precaution decisions, it also has a direct impact on the safety decision, in that individuals sometimes must bear the accident costs of others, sometimes have others bear their accident costs. These two direct impacts also have indirect impacts on time and safety decisions due to the change in parameters describing the accident structure of the system and utility of engaging in the activity.

\section*{12. Different Individuals}

While some differences in the abilities of individuals to be careful are recognized by the legal system (as in separate standards for children and the blind), many others are not. Some of these, such as wealth, are not recognized because of the philosophical stance of the legal system. Other differences are beyond the competence of the court to measure readily (\textit{e.g.}, general driving skill). In these circumstances a due care standard defined in

\[ C(x_3,Y_3) \]
physical terms is a blunt\textsuperscript{31} instrument for altering behavior where different actions are desired from different people. To explore this issue let us consider a model where the accident structure is the same for everyone, as is the due care standard, but people differ in the cost to them of taking care. We shall follow the determinate model of section 5. It is impossible to achieve the efficient solution in these circumstances. The example to be considered points up the distributional implications of different due care standards since increases in the due care standard in some regions will increase some expected utilities while lowering others. In addition, the examination of efficiency will be more complicated, depending on the choice of care levels by different individuals as well as the aggregate amount of care taken.

A function giving the amount of care taken by people of different abilities to take care will represent an equilibrium when, for each utility level, it correctly describes the expected utility-maximizing care level of a man who assumes that everyone else's decisions are correctly described by the function. Under the assumption that greater ability lowers the marginal cost of taking care, the equilibrium in the absence of liability will have a shape such as the one in the diagram.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure13}
\caption{Figure 13}
\end{figure}

Let us derive this structure explicitly. We assume that the utility-of-taking-care level \( x \) for a man of type \( k \) satisfies\textsuperscript{32}

\[ V(x,k) = k^{-1}a^{-1}(1 - x)^a \quad k > 0, 0 < a < 1 \quad (120) \]

In presenting the general structure we shall ignore the constraint \( 0 \leq x \leq 1 \). In the computer simulation described below, this condition will be imposed

\textsuperscript{31} A legislated safety standard, like a speed limit, will generally be uniformly applicable, or at least uniform over wide classes (e.g., auto, truck, trailer). No attempt is made to tailor the speed limit to the reflexes or sense of the driver.

\textsuperscript{32} We are assuming that the utility of taking care decreases with \( k \) \( \frac{\partial V}{\partial k} < 0 \) but that the marginal utility of taking care increases \( \frac{\partial^2 V}{\partial x \partial k} > 0 \); i.e., the marginal dis-utility decreases.
and the nonnegativity constraint will often be binding. We denote by \( n(h) \) the number of persons of type \( h \) and by \( y(h) \) the care (perceived to be) taken by a person of type \( h \). The expected costs for accidents between two persons taking care levels \( x \) and \( y \) are \((1 - x)(1 - y)C\) for each person, with \( C \) a constant. Expected utility for a person of type \( k \) can now be written as

\[
U(x, k) = k^{-1}a^{-1}(1 - x)^a - C(1 - x) \int (1 - y(h))n(h) \, dh. \tag{121}
\]

In the absence of liability an individual of type \( k \) maximizes \( U \), taking the care of others as given. This gives a first order condition

\[
k^{-1}(1 - x(k))^{a-1} = C \int (1 - y(h))n(h) \, dh. \tag{122}
\]

For equilibrium \( x(k) \) and \( y(h) \) must be the same functions. Thus solving this for \( x^\circ(h) \), we have the distribution of care in equilibrium

\[
1 - x^\circ(h) = \left[ hCK^\circ \right]^{1 \over a - 1} \tag{123}
\]

where \( K^\circ \) must satisfy

\[
K^\circ = \int (1 - x^\circ(h))n(h) \, dh = C^{a-1} K^\circ \int h^{a-1} n(h) \, dh. \tag{124}
\]

Thus \( K^\circ \) is the aggregate of contributions by others to the accident probability of an individual. An individual need only know \( K^\circ \), not the complete pattern of care chosen by others, to select his care level. Solving we have

\[
K^\circ = C^{a-2} \left[ \int h^{a-1} n(h) \, dh \right]^{a-1 \over a - 2}. \tag{125}
\]

Thus expected accident costs for a person of type \( k \) are \( C(1 - x(k))K^\circ \).

Where everyone was the same, efficiency among uniform equilibria was suitably described by maximizing the common expected utility function. Where individuals differ, the problem of efficiency becomes more complicated. With utility defined in units commensurable with the resource units of accident costs, we shall define efficiency as maximizing the sum of expected utilities \( \int U(x, h) \, n(h) \, dh \). Finding the efficient solution is simplified where the accident structure has the simple form we are taking here: a single aggregate representing the state of the system which conveys to any individual the expected accident costs from his care decision. In this case efficiency calls for everyone to take more care than occurred in the no-liability equilibrium. (It is easy to construct hypothetical accident structures that do not have this property.) Thus the relationship between efficiency and no-liability equilibrium can be shown in a diagram.
For efficiency we seek a function \( x^*(h) \) to maximize
\[
\int a^{-1} k^{-1} (1 - x(k))^a n(k) dk - C \int \int (1 - x(h))(1 - x(k)) n(k)n(h) dh dk.
\]
(126)

This yields the first-order condition (also obtainable by maximizing \( U \) minus externality costs)
\[
k^{-1}(1 - x^*(k))^a - 1 = 2C \int (1 - x^*(h)) n(h) dh
\]
(127)
or, solving for \( x^*(h) \)
\[
1 - x^*(h) = \left[ 2hCK^* \right]^{1/a-1}
\]
(128)
where \( K^* \) must satisfy
\[
K^* = \int (1 - x^*(h)) n(h) dh
= (2CK^*)^{a-1} \int h^{a-1} n(h) dh
\]
(129)
or, solving for \( K^* \)
\[
K^* = (2C)^{1/a-2} \left[ \int h^{a-1} n(h) dh \right]^{a-2}.
\]
(130)

Thus, in the efficient solution, expected accident costs for an individual of type \( k \) are \( C(1 - x^*(k))K^* \).

Comparing the no-liability equilibrium with the efficient solution, we see first (from (125) and (130)) that
\[
K^o = 2^{2-\alpha} K^*.
\]
(131)

Thus the comparison of care levels satisfies
\[
1 - x^o(k) = 2^{2-\alpha} (1 - x^*(k))
\]
(132)
and efficiency requires every person to take more care. Expected accident costs for each person decrease both because he takes more care and because the other people take more care. Comparing expected accident costs, we have

$$C(1 - x^*(k))K^* = 2^{2-a} C(1 - x^*(k))K^*. \quad (133)$$

Thus in the no-liability equilibrium expected accident costs for each person are $2^{2/(2 - a)}$ times what they should be for an efficient solution.

Let us now consider a negligence system where the due care standard is selected within the range of care decisions. Some people may find the due care standard too difficult or expensive to maintain and will choose to be negligent. Others, to avoid the legal consequences of negligence, will choose precisely the due care level. Those with great ability (low marginal cost) to take care may choose a care level for self-protection (given the decisions of all others) that is above the due care level. Thus, the equilibrium will have the following structure, where we denote the range of abilities of individuals who select precisely the due care level by $[\bar{h}, \bar{h}]$.

![Figure 15](image)

From the shape of this curve we can see that the efficient solution is not attainable.

Let us derive the formulas for this equilibrium structure. Given that the marginal utility cost of taking care decreases with $h$, the level of care in equilibrium is nondecreasing in $h$. Thus, there will be a unique index of type $h$, such that for $h \geq \bar{h}$, type $h$ is not negligent and for $h < \bar{h}$, type $h$ is negligent. Expected utility for an individual of type $k$ is thus the utility from taking care less his expected accident costs from accidents with the nonnegligent if he is nonnegligent. If he is negligent he bears his own costs

33 There may be no members of the population in either of the two rising parts of this curve, depending on the shape of $n(h)$ and the level of due care.

34 Individuals of type $h$ will be indifferent between precisely due care and the appropriate level of negligence. We assume that they choose the due care level.
in all accidents, and the costs of others when he has an accident with someone who is not negligent.

\[
U(x,k) = \begin{cases} 
U_1(x,k) = k^{-1}a^{-1}(1 - x)^a - C \int_h^\infty (1 - x)(1 - y(h))n(h)dh & : x \geq d \\
U_2(x,k) = k^{-1}a^{-1}(1 - x)^a - 2C \int_h^\infty (1 - x)(1 - y(h))n(h)dh & : x < d.
\end{cases}
\]  

(134)

Let us denote by \(K_1\) and \(K_2\) the contributions to the probability of accident by the nonnegligent and negligent respectively

\[
K_1 = \int_h^\infty (1 - y(h))n(h)dh 
\]  

(135)

\[
K_2 = \int_0^h (1 - y(h))n(h)dh.
\]  

(136)

Then we can rewrite expected utilities as

\[
U_1(x,k) = k^{-1}a^{-1}(1 - x)^a - (1 - x)CK_1 
\]  

(137)

\[
U_2(x,k) = k^{-1}a^{-1}(1 - x)^a - 2(1 - x)CK_1 - (1 - x)CK_2.
\]  

(138)

From these expressions it is clear that \(U_1(x) > U_2(x)\) and \(U'_2(x) > U'_1(x)\) so that utilities appear as in the figure, where \(x_1\) and \(x_2\) are the maximizing levels for the two utility functions. \(U\) coincides with \(U_2\) up to \(d\) and with \(U_1\) for \(x\) greater than or equal to \(d\). This is the same situation described above in section 4.

\[x_1 < x_2 < d\]

\[U(x,k) = \begin{cases} 
U_1(x,k) = \ldots & : x \geq d \\
U_2(x,k) = \ldots & : x < d.
\end{cases}
\]

(139)

\[x_1(k) \leq d \leq x_2(k)\]

\[\text{level of due care} \quad d \leq x_1(k) \quad x_1(k) \leq d \leq \hat{d}(k) \quad \hat{d}(k) \leq d, \quad \text{chosen level of care} \quad x_1(k) \quad d \quad x_2(k)\]
where \( \hat{d} \) satisfies
\[
U_1(\hat{d},k) = U_2(x_2,k) \tag{140}
\]
and \( x_1 \) and \( x_2 \) are obtained by maximizing \( U_1 \) and \( U_2 \)
\[
k^{-1}(1 - x_1)^{a^{-1}} = CK_1 \tag{141}
\]
\[
k^{-1}(1 - x_2)^{a^{-1}} = 2CK_1 + CK_2. \tag{142}
\]
It is clear that \( x_1 \) and \( x_2 \) increase with \( k \). Implicitly differentiating the definition of \( \hat{d} \), (140), we have
\[
\frac{d\hat{d}}{dk} = -\frac{k^{-2}a^{-1}((1 - \hat{d})^a - (1 - x_2)^a)}{-k^{-1}(1 - \hat{d})^{a^{-1}} + CK_1}. \tag{143}
\]
From the diagram we see that the denominator \( \left( \frac{\partial U_1}{\partial \hat{d}} \right) \) is negative while the numerator is positive (since \( \hat{d} > x_2 \)). Thus \( \hat{d} \) also increases in \( k \). We can depict the division of the population according to (139) in the following diagram, with the dotted line showing the choice of care level.

![Figure 17](image_url)

As the diagram shows, we can partition the types of people by two values, \( \bar{h} \) and \( \bar{\bar{h}} \), with choice satisfying
\[
\begin{align*}
\text{ability} & \quad h < \bar{h} \quad \bar{h} \leq h \leq \bar{\bar{h}} \quad \bar{\bar{h}} < h, \\
\text{care} & \quad x_2(h) \quad d \quad x_1(h).
\end{align*}
\tag{144}
\]

We can determine the levels of the partitions by the equations
\[
\begin{align*}
\hat{d}(\bar{h}) &= d \tag{145} \\
x_1(\bar{\bar{h}}) &= d. \tag{146}
\end{align*}
\]
From the expression for \( x_1(h) \), (141), we can express \( \overline{h} \) implicitly in terms of \( K_1 \) by substituting in (146)

\[
(1 - d)^{a-1} = CK_1 \overline{h}.
\]  
(147)

Similarly from (140) and (145) we have

\[
U_1(d,\overline{h}) = U_2(x_2(\overline{h}),\overline{h}).
\]  
(148)

Substituting in the explicit expressions for \( U_1 \) and \( U_2 \) we have

\[
(\overline{h})^{-1}a^{-1}(1 - d)^a - (1 - d)CK_1
\]

\[= (\overline{h})^{-1} \frac{1}{a-1} (2CK_1 + CK_2)^{a-1} (a^{-1} - 1).
\]  
(149)

Now let us examine the two constants which appear in the equations for \( x_1 \) and \( x_2 \), evaluated at the equilibrium levels.

\[
K_1 = \int_{\overline{h}}^{\infty} (1 - x(h))n(h)dh
\]

\[= (1 - d)\int_{\overline{h}}^{\infty} n(h)dh + \int_{\overline{h}}^{\infty} (CK_1h) \frac{1}{a-1} n(h)dh
\]  
(150)

\[
K_2 = \int_{0}^{\overline{h}} (1 - x(h))n(h)dh = \int_{0}^{\overline{h}} ((2CK_1 + CK_2)h) \frac{1}{a-1} n(h)dh.
\]  
(151)

We thus have four equations in four unknowns, \( \overline{h} \), \( \overline{\overline{h}} \), \( K_1 \), and \( K_2 \). For further analysis we shall consider numerical solutions for particular values of \( a \), \( C \), and \( n(h) \).

The particular values chosen for this example are \( a = .7 \) and \( C = .04 \), while \( h \) has a uniform distribution between 5 and 40. A nonnegativity constraint on the choice of care level was imposed and is frequently binding. Thus the general equations above require this modification.\(^{35}\) We have already examined the cross-section pattern of the chosen levels of care for a given due care standard. Now let us examine the change in care chosen by an individual as changes in the due care standard result in different equilibria. The values of the four constants, \( \overline{h} \), \( \overline{\overline{h}} \), \( K_1 \), and \( K_2 \) for several different due care levels are given in Table 1.

Let us consider an individual with a care level strictly above the due care standard. Since he bears no costs from accidents with people below the due care standard, the changes in care levels chosen by these people have no

\(^{35}\) That is, \( x(h) \) satisfies the given equation, (141) or (142), or is zero. In calculating the integrals defining \( K_1 \) and \( K_2 \), 0 must replace the expressed value of \( x \) where negative. Otherwise the equations are unchanged.
effect on his choice. Of the people formerly just at the due care level, some increase their care to remain precisely at the due care level, while others decrease their care and become negligent. Both of these responses decrease the incentive to take care for someone above the due care standard. The first response decreases the incentive by decreasing accident probabilities. The second response decreases the incentive by relieving the individual of accident costs (since the other party is now negligent). Thus there is an incentive for everyone above the due care standard to decrease his care with an increased standard. The response to this incentive by the others also above the due care standard partially offsets the decrease in incentives. The offset is only partial since the response cannot exceed the original change in incentives with this structure of interactions. (From (141) we see that care of those above the due care standard decreases as $K_1$ decreases, and Table 1 shows a steady decrease in $K_1$.) Naturally the expected utility of someone strictly above the due care standard increases with the due care standard since the probability of losses decreases.

Since the care of those above the due care standard decreases as the standard increases, the level of ability at which choice just coincides with the standard increases (up to the maximum), and thus $\bar{h}$ increases with the due care standard (see Figure 17). In the calculations in Table 1 we see that $\bar{h}$ is also nondecreasing in the due care standard. Thus both the upper and lower limits of abilities for people selecting precisely the due care level move up with the due care standard. The number of people in this position first increases and then decreases. By continuity we would expect those with abilities close to $\bar{h}$ to experience a rise in expected utility as the due care standard rises. However, those who are not close to this upper limit experience a decrease in utility as the increased utility cost of remaining non-negligent exceeds the gains from the decrease in expected accident costs. (We see in Table 2 that the expected utility of a man of type 12 decreases from .05 to .04 as he keeps in step with the due care standard as it rises from .3 to .7.) Both care and utility for three different types are shown for several equilibria.
Those below the due care standard have an increased incentive for care as a result of the decreased care by those above the due care standard. Those remaining precisely at the due care standard give a decreased incentive for care. Those dropping below the due care standard may give either an increased or a decreased incentive. While at the due care standard, they contribute $2C(1 - d)(1 - x(k))$ in expected accident costs to someone of ability $k$ who is negligent. When someone of type $h$ also becomes negligent he contributes $C(1 - x(h))(1 - x(k))$ in expected accident costs to type $k$. Thus the changed incentive depends on the relative sizes of $2(1 - d)$ and $(1 - x(h))$. In the equilibria shown in Table 1, $2K_1 + K_2$ decreases with $d$ so, by (142), care is decreasing with $d$ for those strictly above a zero care level in the calculated numbers up to .992.\(^{36}\) (Figure 18 depicts the care levels chosen, by people of different abilities, in equilibria occurring with due care standards of .3, .5, and .7. With standards of .5 and .7 those with least ability set care equal to 0.)

\(^{36}\) However, as the due care standard gets arbitrarily close to one, everyone chooses to be negligent and equilibrium is the same as with a zero due care standard. This represents a slight rise in $2K_1 + K_2$ from 16.246 to 16.26. This difference is very small given the accuracy of these numbers, and might not remain with more precise calculations.
Having considered individual choice in different equilibria, let us now consider the aggregates of expected utility (denoted \( \Sigma U \)) and expected accident costs (denoted \( \Sigma EC \)). Table 3 gives values for some chosen due care levels and Figure 19 shows the sum of utilities as a function of the due care standard.

While the calculated values of expected accident costs have the U-shape one would anticipate, aggregate utility does not have an inverse U-shape and is still increasing at levels of the due care standard above the point where accident costs have reached their minimum. There are two factors that seem to me important in determining this pattern—the nonnegativity constraint on care and the distribution of care across individuals. Since it costs different

\[
\begin{array}{ccc}
\text{d} & \Sigma U & \Sigma EC \\
.0 & 1.070 & 1.0573 \\
.3 & 1.019 & .8494 \\
.5 & 1.020 & .8070 \\
.7 & 1.044 & .7840 \\
.8 & 1.162 & .7536 \\
.85 & 1.183 & .7832 \\
.992 & 1.0856 & 1.055 \\
\end{array}
\]

**Figure 19**
amounts for different people to take care, the sum of utilities is sensitive to which individuals take care, while expected accident costs depend only on the aggregate lack of care, i.e., expected accident costs equal $C(K_1 + K_2)$. In the no-liability equilibrium, more than one quarter of the population are taking no care at all ($\bar{h} = 5$, $\bar{h} = 15.38$). As the due care level rises above zero, all of these people increase their care levels to avoid being negligent. Thus those with the greatest marginal cost of taking care are increasing their care levels while those with low marginal costs, being above the due care standard, are decreasing their care levels. In this way the sum of utilities is decreasing at the same time that expected accident costs are decreasing. As the due care standard gets higher, those with the highest marginal costs of taking care have dropped back to a zero level of care and the rise in the standard only affects those with relatively lower marginal costs. For a sufficiently high level of due care no one is above the due care standard ($\bar{h} = 40$) and more care is being induced from those with the lowest cost of taking care (although care decreases for those just becoming negligent). Even higher due care standards decrease the number of people acting non-negligently.

13. Equity and Efficiency

We have focused on the determination of the equilibrium levels of ex ante control variables which affect expected utilities and the distributions of accident costs. Since efficiency in this setting is an ex ante concept, it was natural to talk of the efficient solution relative to the different equilibrium positions occurring with different parameters for the legal system. There are a number of equity concepts which seem potentially relevant for a model in this stage of development. There are two standard ex ante equity calculations. One is the standard tax incidence question of asking who gains and loses (in terms of expected utility) with any change in the legal system. For the bulk of the models, considering only uniform equilibria for a population of identical individuals, this question is not interesting. For the model with varying abilities to take care, we saw that those naturally above the due care standard were benefited by a higher standard, while those at or below the standard sometimes were hurt. The evaluation of a changed level of the due care standard is a calculation of utility differences between the position chosen and a projection of the historically given position.

37 Since the model is essentially static (there is a before and after as accident probability distributions become actual accidents, but no development of individual knowledge or positions) the equity concepts discussed are static. Thus no mention is made of the ongoing nature of social decisions.

38 One could calculate differences relative to any hypothetical alternative, for example differences from the best equal utility allocation.
second standard \textit{ex ante} approach is to evaluate the actual position in terms of some criterion (welfare function) which is not dependent on hypothetical or real alternatives. With the usual (individualistic) assumptions that welfare can be expressed as an increasing function of individual expected utilities, we are reduced to the efficiency concept where everyone is identical (and equilibrium is uniform). Given differing individuals and alternative welfare functions one could evaluate different due care standards in terms of a social welfare function.

In \textit{ex post} terms, there are again several equity notions that seem potentially interesting. Economists have considered welfare functions of actual \textit{ex post} positions and considered \textit{ex ante} expectations of these welfare functions. In the absence of additivity of the welfare function, this notion will not coincide with that of a welfare function of expected utilities. Evaluation with such a procedure would depend on the calculation of the distribution of accident costs across the population. (A similar calculation arises using expected utilities if individuals are risk averse and insurance is not available.) In parallel fashion to the distinction in \textit{ex ante} concepts, we have \textit{ex post} concepts that depend on differences between actual positions and hypothetical alternatives. The obvious alternative to use is the absence of some particular accident. The basic question is then whether accidents have moral significance. If not (if they are viewed morally as random events) it seems unfair to have people bearing accident costs above the average. If accidents have moral significance, and particularly if there are differences in the care of the parties at the time of an accident (either because of different care decisions or a random component coming from identical precaution decisions), then the fairness notion will focus precisely on behavior in the individual accident. With uniform decisions in a model where the stochastic structure is so explicitly present, it is difficult to attribute moral significance to chance outcomes. This may be a shortcoming in the model rather than in moral intuitions from actual settings. The difficulty in pursuing moral intuitions in such an abstract setting is why I end the discussion of equity with a mere listing of some possible approaches.

14. Omissions

When I read Calabresi's \textit{Costs of Accidents},\textsuperscript{39} I was struck by the number of complicated issues that he kept simultaneously before the reader. To be able to cope mathematically (or even at all) I have followed the opposite tack of selecting a single issue and assuming away the complications from all others. It seems appropriate, then, to review some of the omissions. Before this, however, let me draw out some of the other distinctions between my

\textsuperscript{39} See note 1 supra.
analysis and that of Calabresi. The overall conception of the problem is the same for both of us—whole systems of possible accidents and costs of accident avoidance. A key element of the difference comes from our different starting places—Calabresi starts with accidents while I start from individual decisionmakers.

A typical question for Calabresi is what assignment of liability will most cheaply avoid the costs of hard rather than spongy bumpers. The typical analysis of this paper is to examine first the determinants of the full set of individual decisions and then the interaction of decisions to determine equilibrium. The outcomes of these general approaches are not necessarily different. The difference concerns the elements that one places in the foreground of the analysis and those that one drags in later. For example, with the approach here, natural questions to explore are how standards of care affect other decision variables (as in section 11), how an increase in care to comply with a higher standard induces changed behavior on the part of other participants in the activity (as in section 12), and how the due care standard can affect behavior even when there are no successful lawsuits in equilibrium (as in section 5).

One obvious difference between the two analyses is the attention here to a negligence system and the different outcomes that can result from different due care standards. Calabresi focuses on questions of the assignment of liability and uses the cheapest cost avoider as a major engine of analysis. The difference is especially striking in the highly relevant context of auto-auto accidents, which are single-activity accidents. Since I have examined none of the other aspects of accidents, within this model as formulated I cannot analyze whether the additional deterrence of a negligence system is worth the cost of having the negligence system rather than some simpler system or none at all. Only after considering this issue, which Calabresi has, does the better-known analysis of the cheapest cost avoider come into play. (I think that the selection of the cheapest cost avoider terminology may discourage awareness in some readers of Calabresi that it is generally desirable to have changes in the behavior of both parties to possible accidents relative to the no-liability equilibrium, and also that any liability system will generally induce some changes in the behavior of all parties.)

As discussed above, and as Calabresi recognizes, a distinction between activities is only useful for the assignment of liability when there are clear-cut definitions of activities, i.e., definitions that leave little scope for dispute as to what activities the parties were engaged in at the time of an accident. Only in these circumstances could strict liability avoid the complicated factual issues that make a negligence system expensive to administer. In some situations the accident that occurred resembles other accidents which might have occurred. Here, the cheapest-cost-avoider approach must lump to-
gether categories of accidents (like those caused by careless pedestrians and those caused by careless drivers in auto-pedestrian accidents) and find the cheapest cost avoider for the whole set rather than for each of the subcategories. There will be situations where this represents the best overall approach—when, given the other elements of accident costs, the failures of deterrence from this type of grouping are less important than the administrative costs and failures of deterrence of an approach measuring care as well as the activity. The same questions are approached from a different standpoint by focussing on the legal rule (and its implications) rather than the class of accidents to be modified. Presumably the two approaches are complementary in that accident situations are not all alike.

The model of individual behavior I have employed is highly simplified and excessively rational. The presence of simplifications is clear in the simplified form of the expected utility function, the small numbers of decisions (often just one), the absence of other (alternative or related) activities, and the absence of a decision to engage in the activity at all. The last decision, often involving a capital outlay (such as automobile purchase), may be one that is highly responsive to incentives, while decisions about care may be particularly subject to nonmarket forces. Knowledge of the consequences to others and of appropriate accident-preventing modes of behavior may be significant determinants of behavior (with or without direct social pressure). Thus the assumption of concern solely with one’s own expected utility is not fully accurate and the quality of the approximation will vary with the type of decision being considered. In addition, the imperfect nature of compensation (most clearly evident in case of death) limits the assumed blunting of incentives by the liability of others. The existence of defendants without sufficient means to pay damage judgments also alters incentives for both parties. It is particularly in the realm of decisions involving low probability events and involving one’s own health and safety that the accuracy and rationality of individual choice are questionable.

To an even greater extent, the model of the legal system is greatly simplified, almost to the point of extinction. The legal system was assumed to be

40 See Richard A. Posner, supra note 2.
41 In a book as meaty as The Costs of Accidents, I am obviously commenting only on the part most closely paralleling the analysis I have done.
42 In part the shape of V can correct for these misspecifications.
43 See, e.g., J. D. Tumerin & H. I. D. Resik, Risk Taking by Individual Option—Case Study—Cigarette Smoking, in Perspectives on Benefit Risk Decision Making (Natl. Academy of Engineering, 1972); P. Slovic, From Shakespeare to Simon: Speculations and Some Evidence—on Man’s Ability to Process Information (unpublished); A. Tversky & D. Kahneman, Judgment under Uncertainty: Heuristics and Biases (unpublished).

Incorrect perceptions of accident probabilities could probably be fitted into the models in a straightforward manner, as could incorrect perception of the utility of taking care.
costless, prompt, and fully determinative of legal outcomes. There were no settlements out of court, failures to initiate legal proceedings, legal fees and personal costs for litigants, or expenses to the public. Legal rules were fully worked out, so there were no problems arising from ignorance of the rules and from the lack of a rule to fit a new case. Furthermore, individuals were assumed to base decisions (and society to evaluate outcomes) on the correctly calculated expected value of costs. We ascribed this to an absence of insurance and to risk neutrality among individuals, but risk-averse individuals plus perfect insurance would produce the same situation. In practice, however, there are administrative costs in insurance and complications and disputes over collection. Price setting by private companies, depending on industry structure, may well diverge from marginal cost pricing. There are also distortions arising from imperfect perceptions by insurance companies that parallel the inability of courts to evaluate some variables. Thus, individuals with different expected costs may be charged the same because of the cost or inability of telling them apart; prices may be quoted that reflect costs on average rather than person by person. Inability to measure (or expense in measuring) behavior of the insured that affects expected costs results in charges that do not vary with such behavior, and so in a blunting of incentives relative to these variables. Similar measurement problems after accidents occur can lead to inefficient repair or treatment of damage and excessive payments, both of which affect costs and so premiums (leading again to incorrect price incentives). Attempts by insurance companies to classify people by past accident history alter incentives too, since anticipated future payments for insurance affect current decisions.

Drawing policy conclusions directly from models with so many omissions seems foolhardy. But understanding these models may help in drawing policy conclusions from less formal consideration of a more detailed view of the actual workings of accident law.