Causality and causation in tort law

Robert Young\textsuperscript{a,}\textsuperscript{*}, Michael Faure\textsuperscript{b}, Paul Fenn\textsuperscript{a}

\textsuperscript{a} University of Nottingham Business School, Jubilee Campus, Nottingham NG8 1BB, UK
\textsuperscript{b} METRO, University of Maastricht, Maastricht, The Netherlands

Abstract

This paper considers alternative approaches to dealing with causal uncertainty in strict liability tort regimes. Beginning from the philosophical literature on causing, a distinction is made between the scientific idea of causality and the legal idea of causation. This distinction is generalized to a context of causal uncertainty and associated probabilities are constructed. It is shown that a rule of proportional liability whereby the tortfeasor pays damages in proportion to the probability in causation of them having caused the damage would be socially efficient. This contrasts with the implied use of the probability in causality by the courts and in the law and economics literature on causal uncertainty. © 2005 Elsevier Inc. All rights reserved.

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1. Introduction

The impact of causal uncertainty on case law is receiving increasing attention in the law and economics literature.\textsuperscript{1} In cases where there is scientific uncertainty concerning the causal relationship between, for example, a specific industrial activity and damage to health, responsibility is normally determined by the courts on the “balance of probabilities”, which can mean that victims go uncompensated and injurers escape liability. As a reaction to this

\textsuperscript{*} Corresponding author.

\texttt{E-mail address: Robert.Young@nottingham.ac.uk (R. Young).}

\textsuperscript{1} A topic which has also been addressed by the legal literature. See the various contributions in J. Spier (Ed.), \textit{Unification of tort law: Causation} (2000).

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there has been an increasing tendency in tort law for courts to hold injurers responsible. In some cases full scientific proof of a causal relationship is simply not required of the victim; in other cases the doubt concerning the causal relationship will result in a reversal of the burden of proof onto the injurer.

Suppose for example that in the neighbourhood of a certain factory the number of cancer cases is demonstrably higher than the national average, and suppose also that this increased risk of getting cancer is due to the presence of the factory, but that it cannot be established with certainty which of the many cancers in the neighbourhood are caused by the factory (the excess risk), and which are due to other causes (the background risk). A reversal of the burden of proof would mean that the factory owner would have to pay for the consequences of all the cancers in the neighbourhood unless he could establish that none of the cancers were caused by his actions.

This simple example shows that reversing the burden of proof in order to secure compensation for victims may mean that enterprises engaged in certain risky activities will have to take these additional liabilities into account when deciding which activities to undertake—an inefficient outcome leading to over-deterrence. However, it remains the case that these enterprises have by their actions potentially increased the risk of harmful events, and should therefore, for efficiency be made to bear the cost of the increase in risk. The way the law should deal with causal uncertainty has been addressed extensively in the economic literature, for instance by Rosenberg, Kaye and Shavell. Shavell argued that there is an economic justification for limiting the liability of the injurer to the damage that he has actually caused. Damages should, therefore, be allocated across potential tortfeasors in proportion to the probability that they caused the harmful event. Shavell argued that a proportional liability rule had particular appeal on grounds of efficiency “where the chance of uncertainty over causation is significant”, and pointed to health-related and environmental risks as examples of where this may be the case.

This paper is concerned with the way in which liability is apportioned across tortfeasors in cases where their contribution to the harmful event is subject to uncertainty. We argue that there is an inherent ambiguity in the concept of “cause”, which is fundamental and has relevance to the efficiency of alternative rules for allocating liability under causal uncertainty. Because causal uncertainty is a particular feature of environmental torts, we restrict our analysis to a comparison of alternative allocation rules under strict liability, given that this is now the basis of liability for environmental damage in most jurisdictions. Section 2 of the paper outlines the source of the conceptual ambiguity, in terms of the distinction between probabilities of causation and causality. Section 3 discusses the importance of the distinction to the efficiency of liability rules under causal uncertainty. Section 4 concludes.

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2. Causality and causation

2.1. Causality and causation without causal uncertainty

When we consider scientific evidence relating to a question of law we juxtapose two meanings of the verb to cause. First we have the scientist’s concept of causality. In the absence of uncertainty, to say that A caused D is to say that the occurrence of A implied the occurrence of D: A \rightarrow D. Secondly, we have the lawyer’s concept of causation in the sense of the ‘but for’ test. A caused D if, but for A, D would not have happened: \sim A \rightarrow \sim D. Of course, A \rightarrow D and \sim A \rightarrow \sim D are two different propositions and either may be true where the other is false.

However, in the philosophical approach to establishing “cause” there is the further ingredient of necessity. For example, to say that A causes D further involves the notion that:

\text{D necessarily follows from A; or}
\text{in every instance D always follows A.}

The former view, deriving from Kant, is to the effect that there is some a priori reason (not deriving from empirical experience) why D necessarily follows from A—a universal but synthetic truth. The alternative view, deriving from Hume, is that as a matter of fact whenever A has happened D has followed and this will always be the case.

For our purposes, we can conflate these alternative philosophical approaches and observe that they have in common the following two features. First, it is a human trait (perhaps a necessary one) to understand events in terms of cause, even if going from a series of observed regularities to a causal belief involves a leap that is both “unwarranted and indispensable”.\(^5\)

Secondly, from the perspective of the philosophical literature, if A causes D then when A occurs D necessarily follows in the sense that D always follows (whether by some a priori necessity or otherwise).

Consider now applying this most fundamental view of causing to the instance of a tort. If A is a wrongful act and D is a harm then it is typically not the case that every instance of A is followed by the occurrence of D. It follows that, in the strict (i.e. philosophical) sense we cannot say that A causes D. This is the problem of “causal uncertainty”. However, in this context a connection to the strict meaning of cause can be effected as in the following section.

2.2. Causality and causation with causal uncertainty

Causal uncertainty implies that there are some instances in which A is followed by D and some in which it is not. Assuming that there is a cause of D, let us denote this cause A\(^*\). If A in any way contributes to the occurrence of D, then it follows that A must be part of A\(^*\).

Mackie (1974) updates Hume’s perspective on cause by redefining a cause as an “insufficient but necessary part of a sufficient but unnecessary condition”. This corresponds exactly with the type of case with which we are concerned. \( A^* \) is a sufficient (but not necessary) condition for \( D \), \( A \) is a necessary (but not sufficient) part of \( A^* \). Since \( A \) is necessary but not sufficient for \( A^* \), we can decompose \( A^* \) as

\[
A^* = A \cap X
\]

for some compound event \( X \). Since \( A^* \) is a strict cause of \( D \), it follows that

\[
D \iff A \cap X
\]

In this, there is nothing to the effect that \( A \cap X \iff D \): to say that \( A^* \) causes \( D \) is not to exclude the possibility of other causes of \( D \).

From this analysis two conclusions emerge. First, it is possible to attach a fundamental concept of causing (free from scientific or legal presumptions as to what we mean by causing) to such situations. Secondly, in doing this we must admit at least three events into our analysis: the wrongful act \( A \), the harm \( D \) and an event such as \( X \) which combines with \( A \) in causing \( D \). We formalise this analysis in Theorem 1 below. Starting from a consideration of the events \( A \) and \( D \), it is necessary that there be some event such as \( X \) but, in any instance, it may not be immediately obvious what \( X \) is, nor is it necessarily the case that \( X \) could be discovered. For convenience of exposition, we shall refer to events such as \( X \) as ‘implicit’ events.\(^6\)

2.3. A general definition of causing

In the philosophy literature, a general and practical definition of causing as provided by Mackie (1974) is to the effect that \( A \) is a cause of \( D \) if and only if \( A \) is a necessary but not sufficient part of a sufficient but not necessary antecedent to \( D \). This is illustrated in the following digraph.

In Fig. 1, the points \( A, A', B, C \) and \( D \) represent events. The directed lines indicate possible successions of events. \( O \) is the origin of the events with which we are concerned—a state of the world prior to all the pertinent possible events from which one or more of them may flow. In line with Mackie’s definition, \( A \) is a cause of \( D \). Algebraically, Fig. 1 is equivalent

\(^6\) Shavell’s “events of ambiguous origin” (Shavell, 1985) are examples of such events.
to

\[ D \Leftrightarrow [(A \cap A') \cup B] \cap C \]

There are two sufficient conditions for \( D \):

\[ D \Leftarrow A \cap A' \cap C \]

\[ D \Leftarrow B \cap C \]

\( A \) is a necessary part of the sufficient condition \( A \cap A' \cap C \) but it is not sufficient for \( A \cap A' \cap C \) (because \( A' \) and \( C \) must also occur). So \( A \) is a necessary but not sufficient part of a sufficient condition for \( D \). The sufficient condition \( A \cap A' \cap C \) is not a necessary condition for \( D \) because there is the alternative sufficient condition \( B \cap C \).

This general definition of causing encompasses the type of uncertainty with which we are concerned. Let \( A \) be the act (or omission) of the defendant (\( T \)) and let \( D \) be the damage suffered by the claimant (\( V \)). The defendant’s act is, in itself, neither sufficient nor necessary for the damage. If \( T \) does \( A \), \( D \) will result only if \( A' \) and \( C \) occur and not otherwise. In the absence of \( A \), \( D \) will nevertheless arise if \( B \) and \( C \) occur.

2.4. Causal chains

At the core of any analysis of the connectedness of \( T \)’s act and \( V \)’s harm is the notion of a causal chain: a conjunction of events and/or circumstances, which lead to some particular outcome. The outcome may depend upon the occurrence of a number of events, or on their being certain circumstances, or on particular events occurring in the context of particular circumstances.

To formalise the notions in which we have been dealing, let \( V \) be a proposition relating to an event or a circumstance, such that \( V \) takes the truth value \( T \) when the event occurs or the circumstance obtains. Let \( D \) be a particular event or circumstance whose occurrence or non-occurrence we are concerned with, and which we call the outcome. We define a causal chain leading to \( D \) to be a composite proposition of the form

\[ \bigcap_{i=1}^{n} \bigcup_{j=1}^{m} V_{ij} \]

such that

\[ D \Leftarrow \bigcap_{i=1}^{n} \bigcup_{j=1}^{m} V_{ij} \]

where each \( V_{ij} \) is either itself a causal chain or a proposition of the type \( V \). In other words, a causal chain is a conjunction of \( n \) events or circumstances, each of which may be (but is not necessarily) two or more events/circumstances/causal chains in the alternative, which leads to the outcome with which were concerned. In all cases of interest causal chains thus defined are synthetic propositions, i.e. their truth is a matter of fact and not of reason.

In what follows it will be convenient to refer to the union of two or more causal chains, by which we shall mean their boolean disjunction, and their intersection, by which we mean the conjunction of common elements in conjunction. For example, if \( U \cap W \cap X \) and
V ∩ W ∩ X are causal chains, their union is (U ∩ W ∩ X) ∪ (V ∩ W ∩ X) = (U ∪ V) ∩ W ∩ X. Their intersection is the ‘sub-chain’ W ∩ X.

The device of a causal chain, as we have defined it, allows us to address the factual causes of an outcome. The notion of liability arises when we consider, in addition to this, a person (T) somehow involved with one or more events or circumstances within a causal chain. Suppose that within a causal chain leading to D there is a proposition (asserting an event or a circumstance) the truth value of which is susceptible to determination by T. It will be convenient to refer to T making this proposition true as an ‘act’ of T. When T acts there is some potential consequence in terms of whether or not the outcome D comes about. It is because of this act that liability may attach to T.

Defining an act in this way, we are investing in the term a generalised meaning. In general, the sort of acts and outcomes with which we are concerned are those connected in such a way that there are two sorts of uncertainty. First, the act does not necessarily lead to the outcome. Secondly, the outcome may arise in the absence of the act. Situations in which the outcome necessarily follows from the act, or in which the outcome can arise only if the act is done, are special cases. In the following section, we devise a framework for analysing such general situations in the context of our notion of a causal chain.

To formalise the position, we adopt the following axioms pertaining to the general case:

1. If the act is done the outcome may, but does not necessarily, follow.
2. If the act is not done the outcome may, but does not necessarily, occur anyway.
3. If the act is done the outcome occurs only if there occur other events, which are not necessary for the outcome if the act is not done.

Axioms (1) and (2) express the essence of the situations in which we are interested. Axiom (3) allows for generality in the ways in which the act can connect with the rest of the causal chain, in a way which emerges below. Where these three axioms obtain, the causal chain necessarily has a particular structure, expressed in the following result (all proofs can be found in the Appendix A).

Theorem 1. Let A be an act and D be an outcome conforming to Axioms (1) to (3) then ∃ disjoint causal chains A′, B and C such that

\[ D \iff ((A \cap A') \cup B) \cap C \]

Theorem 1 is to the effect that \(((A \cap A') \cup B) \cap C\) is a causal chain leading to D and that it is the only causal chain leading to D. Where an act A has potential consequences for an outcome D in such a way that our axioms apply, there are (in general) non-empty causal chains A′, B and C involved in the relationship between A and D, and the causal chain leading to D has the particular structure given in the Theorem. So we may refer to A′, B and C as ‘implicit (compound) events’.

2.4.1. An illustration

As an illustration (somewhat simplified) consider the following. T operates a chemical factory adjacent to a river. Upstream of T there are other businesses which use similar
chemicals. Let $A$ be the act that $T$ runs the overspill from some process onto the factory grounds. Let $D$ be the outcome that some person $V$ suffers chemical burns. Suppose that when the weather is dry the chemicals soak away to no ill effect, but when it rains they are washed into the river and remain there in potentially injurious concentration for 24 h. The implicit events may be as follows:

$A' = \text{‘it rains soon after the overspill’};$

$B = \text{‘factories upstream allow a leakage of chemicals into the river’};$

$C = \text{‘$V$ goes swimming less than 24 h after the overspill’}.$

These implicit events could be seen as the actions of nature, other potential tortfeasors, and the victim, respectively. It is the chance interaction of all three that determines the likelihood that harm will result from $T$’s act. In this example, Theorem 1 implies that $V$ will suffer burns if and only if:

(a) $T$ overspills AND it rains, OR
(b) there is a leakage upstream, AND
(c) in addition to (a) or (b) $V$ takes a swim.

$B$ provides for a way in which the damage can come about in the absence of $T$’s act. $A'$ and $C$ each provide for the damage not being an inevitable consequence of the act. The need for both $A'$ and $C$ in the causal chain is that they provide for the following distinction. If $A'$ does not occur (if it does not rain) then the damage cannot flow from $T$'s act $A$. However, it might still come about because of $B$ (a leakage upstream). If $C$ does not occur (if $V$ does not swim) then the damage cannot arise, irrespective of both $A$ and $B$. In the absence of $A'$, $A$ and $B$ would connect at the same point in the causal chain and (in general) there is no reason to suppose that this will be so.

2.5. Causal probabilities

It follows from Theorem 1 that there are five paths through the causal chain to $D$:

$$D \iff ((A \cap A') \cap B) \cap C \quad (1.1)$$

$$D \iff ((A \cap A') \cap \sim B) \cap C \quad (1.2)$$

$$D \iff ((A \cap \sim A') \cap B) \cap C \quad (1.3)$$

$$D \iff ((\sim A \cap A') \cap B) \cap C \quad (1.4)$$

$$D \iff ((\sim A \cap \sim A') \cap B) \cap C \quad (1.5)$$

(7.1)–(7.3) combine to

$$D \iff A \cap (A' \cup B) \cap C \quad (2.1)$$
(7.4) and (7.5) combine to

\[ D \iff A \cap B \cap C \]  

(2.2)

Hence we have the probabilities

\[ P(D|A) = [P(A') + P(B) - P(A')P(B)]P(C) \]  

(3.1)

\[ P(D|\sim A) = P(B)P(C) \]  

(3.2)

For convenience of exposition we adopt the following notation, and relate this to our earlier illustration:

\[ P(A') = q = \text{Pr("nature acts")}; \]
\[ P(C) = p = \text{Pr("victim acts")}; \]
\[ 1 - P(B) = \pi = [1 - \text{Pr("other tortfeasors act")}] \]

so that

\[ P(D|A) = [1 - (1 - q)\pi]p \]  

(4.1)

\[ P(D|\sim A) = (1 - \pi)p \]  

(4.2)

Consider the probability of \( A \) causing \( D \) in the sense of causality. Given that \( A \) has occurred, the probability of \( D \) ensuing (i.e. \( P(A \Rightarrow D) \)) is \( P(D|A) \) which by (4.1) is \([1 - (1 - q)\pi]p\). In other words, (4.1) gives the probability of \( A \) causing \( D \) in the sense of causality.

Now consider the question in terms of causation. We are concerned with a situation in which both \( A \) and \( D \) have occurred. The question is whether \( D \) would have occurred even if \( A \) had not. Given that both \( A \) and \( D \) have occurred, the path through the causal chain must have been (1.1) or (1.2) or (1.3). In addition to \( A \), these include, respectively

\[ A' \cap B \cap C \]  

(5.1)

\[ A'\cap \sim B \cap C \]  

(5.2)

\[ \sim A' \cap B \cap C \]  

(5.3)

Now the composite events (5.1) and (5.3) also appear in paths (1.5) and (1.4) in which \( D \) occurs given \( \sim A \). In other words, these composite events lead to \( D \) irrespective of whether \( A \) is done. On the other hand, (5.2) leads to \( D \) only if \( A \) is done. The probabilities of these three composite events are, respectively

\[ P(A' \cap B \cap C) = q(1 - \pi)p \]  

(6.1)
\( P(A' \cap \sim B \cap C) = q\pi p \)  
\( P(\sim A' \cap B \cap C) = (1 - q)(1 - \pi)p \)

Given both \( A \) and \( D \), one of (6.1)–(6.3) must have occurred but we don’t know which. The probability that \( D \) would have occurred if \( A \) had not been done is, therefore, the probability that the composite event which in fact occurred was either (6.1) or (6.3) (given that one of the three composite events occurred), i.e.

\[
\frac{q(1 - \pi)p + (1 - q)(1 - \pi)p}{q(1 - \pi)p + q\pi p + (1 - q)(1 - \pi)p} = (1 - \pi)[1 - (1 - q)\pi]
\]

Correspondingly, the probability that \( (ceteris paribus) D \) would not have occurred had \( A \) not been done is

\[
q\pi/[1 - (1 - q)\pi]
\]

Summing up, the probability that \( A \) caused \( D \) is:

in the sense of \textit{causality}, \( [1 - (1 - q)\pi]p \equiv k \);

in the sense of \textit{causation}, \( q\pi/[1 - (1 - q)\pi] \equiv c \).

In most instances, \( k \) is likely to differ from \( c \). \( k \) answers the question “when \( T \) did \( A \), how likely did this make \( D \)?”. \( c \) answers the question “how likely is it that but for \( T \) doing \( A \), \( D \) would not have happened?”

The following limiting case assists in comparing and contrasting \( k \) and \( c \). If the compound event \( A' \) is certain to occur (equivalently, if there is no event in the position of \( A' \) then \( q = 1 \), \( k = p \) and \( c = \pi \). When \( T \) does \( A \) she creates a situation which \( D \) results iff \( C \) then occurs, and this happens with probability \( p \). It is immaterial whether or not \( B \) also occurs. On the other hand, \( p \) is irrelevant from the perspective of causation. Given that both \( A \) and \( D \) have as a matter of fact occurred, the probability that \( D \) would have happened even if \( A \) had not is \( 1 - \pi = P(B) \), i.e. the probability that \( B \) also occurred. The probability in causality and the probability in causation relate to different questions about implicit events.

2.5.1. A graphical illustration

By way of an illustration of the extent to which this distinction can give rise to significant differences in computed probabilities, the following diagram (Fig. 2) shows the result of a simulation in which \( p \) and \( q \) are held constant with a value of 0.3 and 0.2, respectively, but \( \pi \) (the probability of action by other tortfeasors, or background risk) is allowed to vary.

The impact of varying \( \pi \) on the probabilities in causality \( (k) \) and causation \( (c) \) can be seen clearly: Only when the probability that other tortfeasors have acted is approximately 0.52 do the two probabilities coincide.

The intuition behind the above illustration is straightforward. When background risk is absent it is certain that but for \( T \)’s act, the victim would not have been harmed (no pollution would have occurred); hence when \( \pi = 1 \), \( c = 1 \). Similarly, when it is certain that other
tortfeasors have acted ($\pi = 0$), it is impossible to say that but for $T$'s act, the victim would not have been harmed; hence when $\pi = 0$, $c = 0$. By contrast, when it is certain that other tortfeasors have acted, the probability in causality, $k$, that the victim is harmed following $T$'s act will clearly depend on the probability that $V$ is exposed to the pollution that is certain to be present; hence when $\pi = 0$, $k = 0.3$. As the presence of background risk falls, the probability that pollution is present also falls, and in the limiting case where there is no background risk, the probability of victim harm following $T$'s act $A$ will be $pq$, the product of the probability that nature acts to allow $T$'s pollution into the river, and the probability that $V$ is exposed to that pollution through swimming; hence when $\pi = 1$, $k = 0.06$. Clearly, these concepts of causation and causality yield very different probability measures. In the following section we explore the consequences of this ambiguity in relation to the efficiency of (strict) liability rules.

3. Liability under causal uncertainty

3.1. Alternative allocation rules given causal uncertainty

The question arises as to how the legal system should allocate tort liability in the absence of certainty of causation. In fact, four options exist:

1. if there is felt to be any non-negligible probability that a given activity caused harm, all victims receive 100% compensation—an all or nothing liability rule with victim preference;
2. if there is felt to be a non-negligible probability that a given activity did not cause harm, then all victims are refused compensation—an all or nothing liability rule with injurer preference;

3. compensation is awarded only when the probability that the harm was caused by the tort passes a certain threshold of, say, 0.5—a threshold liability rule. If the probability is lower than the threshold, the victim receives no compensation at all, if the probability is higher than the threshold, the victim receives full compensation. This threshold rule is known in the American literature as the “more probable than not” solution, referring to the fact that the plaintiff must convince the judge that it is “more probable than not” that its damage was caused by the tort; 

4. if the probability of harm is assessed as, say, 0.3, then the victim can receive compensation for 30% of the damage caused—a proportional liability rule.

Each of these options, therefore, depend on the evidence presented to the courts as to the probability that the tortfeasor caused the harm. But we have established above that the notion of causation, and associated probabilities, is not straightforward. There are alternative ways of measuring these probabilities, and it is, therefore, necessary to be clear about the efficiency properties of using the alternative measures when choosing between the four allocation options available to us.

In practice, the courts typically call on expert opinion as to the likelihood that a given activity causes a known damage, expressed as a probability. Thus, experts could assess that there is, say, a 30% probability that a certain drug or activity may cause a specific health consequence for a particular individual. This probability is referred to in the literature as the “probability of causation” and can be estimated by dividing the excess risk by the sum of the background risk and the excess risk. This so-called probability of causation formula has been used in radiobiology to establish the likelihood that, for example, an employee in a nuclear power plant incurred cancer as a result of his work for the power plant. This probability, together with an allocation rule, can be used to determine whether victims receive compensation, and how much.

As mentioned earlier, the law and economics literature has favoured the use of a proportional liability rule in circumstances where causal uncertainty is high. However, there has been little consideration given to the issues raised in this paper. Shavell refers to the “probability of causation” in the context of his model, but it seems that he is referring to the formula described in the previous paragraph, and therefore, to a scientific determination of causality (in our terms). Subsequent contributions to the law and economics literature have not questioned this assumption. In the remainder of this paper we consider the effi-

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7 This is referred to as the “balance of probabilities” in English law. In principle, of course, rules 1 and 2 are types of threshold liability rules with the threshold set at 0 and 100%, respectively.

8 Note that this is “first order” uncertainty—we cannot be sure whether act A causes harm D, but we can assign a unique probability (if there were a large number of similar cases of harm, this is the proportion we would expect to be caused by A); “second order” uncertainty (or “ambiguity”) exists if experts disagree about the probability. We ignore considerations of ambiguity in this paper, but see Faure and Fenn (1999) for a review.

ciency properties of alternative allocation rules under alternative approaches to measuring probabilities.

3.2. Causation, causality and efficiency

Although causation is the traditional concept in law, the probability in causality is the more immediately pertinent from the perspective of assessing the effect of \( A \) being done on the probability that \( D \) will occur. In particular, this is the immediately pertinent probability from the perspective of \( T \) deciding whether or not to do \( A \).

Let \( L \) be the quantum of damages that \( T \) will pay if she does \( A \) and \( D \) occurs and \( T \) is held liable for \( D \). If a rational \( T \) is ever to do \( A \) then doing \( A \) must occasion \( T \) some benefit to set against the contingent penalty. Let \( G \) be \( T \)'s assessment of this benefit. Assume that \( T \) knows fully and accurately all pertinent probabilities, the legal rules for attributing liability and the amount of prospective damages \( L \), and that \( T \) is risk neutral.

Save in the limiting cases, \( T \)'s decision under the all or nothing liability rules is immediately obvious. Under the all or nothing rule with victim preference, \( T \) is always liable when she has done \( A \) and \( D \) occurs. She will, therefore, do \( A \) iff

\[
G > P(D|A)L = kL
\] (7)

Under all or nothing rule with injurer preference, \( T \) is never liable and (therefore) will always do \( A \).

As to threshold liability, this introduces the question of whether the probability which the court will compare with the threshold probability is \( k \) or \( c \) or something else. Suppose first that the probability to be used is \( k \) and that the threshold probability is \( p^* \). If \( k > p^* \) then threshold liability is equivalent to the all or nothing rule with victim preference. If \( T \) does \( A \) and \( D \) occurs then \( T \) will be liable and so \( T \) will do \( A \) iff inequality (14) is satisfied. If \( k < p^* \), \( T \) doing \( A \) will not be held liable and so \( T \) will always do \( A \). If \( c \) or some other probability is used in place of \( k \) then these results still obtain, *mutatis mutandis*.

For the purposes of the proportionate liability rule, let \( L \) be the full amount of damages in respect of the loss to \( V \). The proportionate liability rule is to the effect that if \( T \) does \( A \) and \( D \) occurs then \( T \) will be held liable but only for a proportion (say, \( r \)) of \( L \). \( r \) is, in some sense, the probability of \( A \) having caused \( D \). Under this rule, \( T \) will do \( A \) iff

\[
G > krL
\] (8)

Condition (7), which arises under all or nothing and threshold liability rules, is a special case of condition (8) with \( r = 1 \). The potential effect of \( A \) on \( V \) is the same whichever rule applies. Therefore, it is convenient to begin an analysis of the economic efficiency of the alternative rules with a consideration of the proportionate liability rule.

From \( V \)'s perspective, the effect of \( T \) doing \( A \) is to increase the probability of \( D \) occurring. Subtracting (3.2) from (3.1),

\[
P(D|A) - P(D|\sim A) = p\pi q
\] (9)
When $T$ does $A$ she increases the probability of $D$ by the amount $p\pi q$. Assuming that $V$, like $T$, is risk neutral, when $T$ does $A$ she suffers a loss equivalent to $p\pi qD$. Therefore, the nett change in welfare is (say) $W = G - p\pi qD$ and this is a nett gain iff

$$G > p\pi qD$$  \hspace{1cm} (10)

**Lemma 2.1.** $T$ will do socially efficient (in the Hicks-Kaldor sense) and only socially efficient acts $A$ iff $krL = p\pi qD$.

**Theorem 2.** Under proportionate liability, if

- $T$ and $V$ are risk neutral;
- $L = D$; and
- $r = c$

then $T$ will do socially efficient and only socially efficient acts $A$.

**Corollary 2.1.** If $r = k$ (save with probability zero) either $T$ will refrain from doing socially efficient acts or $T$ will do socially inefficient acts, but not both.

**Corollary 2.2.** Under an all or nothing liability rule with victim preference, and under a threshold rule where there would be liability, $T$ will refrain from doing socially efficient acts.

**Corollary 2.3.** Under an all or nothing liability rule with injurer preference, and under a threshold rule where there would be no liability, $T$ will do socially inefficient acts.

**Corollary 2.4.** Where $D$ cannot occur in the absence of $A$, but where $A$ does not necessarily imply $D$, social efficiency requires that and follows from a liable $T$ paying the full amount of damages.

These results are to the effect that social efficiency depends upon and follows from a liable $T$ paying only a proportion of the full amount of loss to $V$, the proportion being equal to the probability in causation, $c$. This derives from our assumption (in the general case) that it is possible for $D$ to occur in the absence of $A$. **Corollary 2.4** is to the effect that where this is not possible there arises the result that social efficiency requires the tortfeasor to pay the full amount of loss to the victim.

The following remarks may offer some insight into the generalised result. Where $P(D \mid \sim A) = 0$, $T$ doing $A$ increases the probability of loss to $V$ by the probability in causality $k (= P(D \mid A)$ and increases the probability of loss to herself (by way of damages) by the same amount. In the absence of $T$ doing $A$ there is no risk to $V$ and no risk to $A$. In the more general case, if $T$ does not do $A$ she is at no risk, but $V$ is at risk in that $P(D \mid \sim A) > 0$. If $T$ does $A$, this increases the probability of loss to $V$ by $P(D \mid A) - P(D \mid \sim A)$ and increases the probability of loss to $T$ by the greater amount $P(D \mid A)$.
The ratio of these two increases in probability of loss is
\[ \frac{P(D|A) - P(D|\sim A)}{P(D|A)} = \frac{p\pi q}{k} = \frac{p\pi q}{[1 - (1 - q)\pi]} p = c \]

So, assuming that \( T \) pays the full amount of damages and that \( L = D \), when \( T \) does \( A \) the increase in loss to \( V \) is less than the increase in loss to \( T \) by a factor \( c \). Reducing the amount of damages payable by \( T \) by the same proportion \( c \) makes the increase in loss to \( T \) equal to the increase in loss to \( V \).

**Corollary 2.1** clarifies the position as to the appropriate interpretation of the probability to use in determining the proportion of damages payable to \( T \). Making the proportion equal to the probability in causation leads to social efficiency. Substituting the probability in causality results in inefficiency (save in the purely fortuitous case where the probabilities are equal).

### 3.2.1. Evidence on the probability in causation

Applying proportionate liability on a socially efficient basis requires expert opinion as to the probability in causation \( c \). The proportion of damages payable by \( T \) is
\[ r = c = \frac{q\pi}{(q\pi + 1 - \pi)} \Leftrightarrow r = \frac{pq\pi}{(pq\pi + 1 - \pi)} \Leftrightarrow r = \frac{[k - P(D|\sim A)]}{k} \]

(11)

So for the purposes of computing the appropriate proportion, it is necessary and sufficient for there to be adduced evidence of expert witnesses as to:

the probability in causality; and either
the probability of \( D \) in the absence of \( A \); or equivalently
the increase in the probability of \( D \) resulting from \( A \).

The probability in causality alone will not suffice. On the other hand, one would expect a statistical analysis of the effect of \( A \) to yield both \( P(D|A) \) and \( P(D|\sim A) \). This could be made available to the courts.

### 4. Conclusions

We began this paper by reviewing the various ways that the law of torts deals with the existence of causal uncertainty. Typically this arises where there are several possible sources of harm associated with a particular event, including the state of nature (background risk) as well as a multiplicity of potential tortfeasors. In that case the standard means of deciding liability based on the “balance of probabilities” does not work well, as most injurers would avoid responsibility for their actions. The alternative of proportionate liability as a direct solution to the problem is appealing, but we have shown in this paper that there are significant issues relating to the calculation of the proportion of damages required for efficiency.

The philosophical literature on causing leads us to the notion of implicit events making up a causal chain from which there derive the scientific concept of causality and the legal concept of causation, and the corresponding probabilities in causality and in causation. Each of these corresponds to a particular (and, in that, limited) aspect on the ordinary concept of
causing. In Section 3, we derived a necessary and sufficient structure of a causal chain, and showed that the effect of an act on the probabilities in causality and in causation depends not only on the act but also on its location within the causal chain.

As stated above, one proposed approach to the problem of dealing with causal uncertainty is through proportional liability, the defendant being liable for a proportion of the total cost of harm equal to the probability, in some sense, that the defendant indeed caused the harm. Our analysis leads to the conclusion that such a rule would produce social efficiency under the usual assumptions if and only if the proportion of damages is determined on the basis of the probability in causation, while choices over acts are of course informed by the probability in causality of their outcomes through the actor’s expected loss or gain. That is, in order to avoid social inefficiency it is necessary to present the potential tortfeasor with a regime in which the two alternative concepts of causing—causality and causation—combine symmetrically.

In practice, it seems likely that the implementation of a proportional liability rule by the courts would be guided by rules of thumb: the courts may simply estimate the total damage done and divide that amongst the potential tortfeasors equally or in proportion to their activity levels. Alternatively they may rely on bargains between tortfeasors to achieve the same end as the consequence of joint and several liability or channeling. In either case we have shown that this would be inefficient and would result in overdeterrence. Our view is that each potential tortfeasor should face the prospect of paying damages in proportion to the probability in causation as estimated statistically with respect to that class of tortfeasors. This may require the courts to adopt a more sophisticated approach to the determination of liability when there is causal uncertainty, and for the extended use of statistical or scientific evidence.

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Appendix A. Proofs

Proof of Theorem 1. By Axiom (A.2), \( \exists \) a causal chain \( (U) \) such that:

(a) \( U \) does not include \( A \); and
(b) \( D \leftarrow U \).

Define \( V \) to be the union of all such chains of events \( U \). It follows that

\[ D \leftarrow V \]  \quad (A.1)

By Axiom (A.1), if \( V \) does not occur (in its entirety) and \( A \) does occur then \( D \) may occur. Therefore, \( \exists \) a causal chain \( W \) such that \( D \leftarrow A \cap W \).
Let $X$ be the union of all such chains of events $W$. It follows that

$$D \Leftarrow A \cap X \quad (A.2)$$

Now define $C$ to be the intersection of $X$ and $V$. Let $A'$ be the complement of $C$ in $X$ and $B$ be the complement of $C$ in $V$. By this construction, $A'$, $B$ and $C$ are disjoint. $(A.1)$ and $(A.2)$ can now be re-written as

$$D \Leftarrow B \cap C \quad (A.3)$$

$$D \Leftarrow A \cap A' \cap C \quad (A.4)$$

and so

$$D \Leftarrow ((A \cap A') \cup B) \cap C \quad (A.5)$$

By construction of $V$ and $X$, there is no chain of events (containing $A$ or otherwise) which leads to $D$ and is not included in either $V$ or $X$. Therefore,

$$D \Leftarrow ((A \cap A') \cup B) \cap C \quad (A.6)$$

**Proof of Lemma 2.1.** By comparison of (15), $T$’s decision rule, with (17), the condition for social efficiency.

**Proof of Theorem 2.** By Lemma 2.1, a necessary and sufficient condition for social efficiency is

$$krL = p\pi qD$$

Substituting conditions (b) and (c), this reduces to

$$kc = p\pi q$$

But

$$k = [1 - (1 - q)\pi]p$$

and

$$c = q\pi/[1 - (1 - q)\pi]$$

Hence, $kc = p\pi q$.

**Proof of Corollary 2.1.** Now $kr = k^2$. If $k < c$, $T$ will do acts where

$$k^2 D < G < kcD = p\pi qD$$

If $k > c$, $T$ will refrain from doing acts where

$$p\pi qD = kcD < G < k^2 D$$
Proof of Corollary 2.2. Now \( kr = k \). T will refrain from doing acts where

\[ p \pi qD = kcD < G < kD \]

Proof of Corollary 2.3. Now \( kr = 0 \). T will do acts where

\[ 0 < G < kcD = p \pi qD \]

Proof of Corollary 2.4. Where \( D \) cannot occur in the absence of \( A \) there is no such implicit event as \( B \). Equivalently, \( P(B) = 0 \), \( \pi = 1 \). Substituting \( \pi = 1 \) in \( c = q\pi/[1 - (1 - q)\pi] \) yields \( c = 1 \). By Theorem 2, social efficiency requires and follows from T paying a proportion \( c \) of the full damages, i.e. where \( c = 1 \), the full amount of damages. By assumption (b) of Theorem 2, \( L = D \).

References


