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ERRORS AND THE FUNCTIONING OF TORT LIABILITY

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ABSTRACT

The functioning of liability may be plagued by errors in determining damages and in setting due care. This article shows that errors may distort the incentives to take precaution in different ways, depending on whether they occur under rules – when a regulator defines due care and courts set the amount of damages – or standards – when courts set both damages and due care on a case-by-case basis. Thus, under rules, errors in determining damages and in setting due care occur independently of each other, while, under standards, an error in damages may trigger a corresponding error in due care. This concurrence radically changes the predictions of the literature both when errors are perfectly anticipated (biases) and when they occur randomly (uncertainty). This article further examines the extent to which judges can correct inefficient decisions by regulators and vice versa, and studies the effects of errors when the precaution technology changes.

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1 Introduction

The functioning of liability may be plagued by errors in determining damages and in setting due care. It is common to study the effects of errors in two stereotypical cases: biases and uncertainty.[1] Biases are errors that can be perfectly predicted in individual cases.[2] Uncertainty, in contrast, refers to errors that cannot be anticipated but their probability distribution is known, and their average generally corresponds to the true value. Put differently, biases denote imprecision in the liability system, as the determination of damages or due care is very accurate but inexact; whereas uncertainty denotes inaccuracy, as the liability system precisely determines damages and due care on average but errs in individual cases.[3] This article shows that the effects of both types of errors on precaution decisions crucially depend upon whether liability is based on rules or standards.[4]

Under rules, a regulator defines due care, while damages are separately awarded following adjudication. Therefore, an error in due care does not necessarily imply an erroneous evaluation of the harm and vice versa. Those errors may well happen to occur at the same time, but they are not interdependent.[5] To the contrary, under standards, the law defines the due

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[1] In economics, risk is usually distinguished from uncertainty on the basis of whether or not objective probabilities are given; see Knight (1921). In law and economics, 'uncertainty' is often used to describe situations in which errors occur in a way that cannot be predicted (as for example when errors occur randomly), and thus parties choose their levels of precautions according to some probability function describing the functioning of the legal system, which is objectively given (risk, in an economic sense) or subjectively formed (uncertainty, in an economic sense). I will use the term 'uncertainty' as it is standard in the economic analysis of law although most economists would probably simply use the term error.

[2] Systematic errors are in general an example of biases.

[3] For a discussion on accuracy in tort liability see Kaplow and Shavell (1994 and 1996a).

[4] The choice between rules and standards attains to the optimal timing of detailed rule-making. Ehrlich and Posner (1974), Diver (1983), Ogus (1981 and 1992), Kaplow (1992) and Parisi, Fon and Ghei (2001) have analyzed this problem from an economic perspective. These contributions focus on two sets of issues: the cost of rule-making and the problem of acquiring information. This analysis instead raises a different issue and shows how the choice between rules and standards changes the effects of errors. For an overview of the literature on rules versus standards, see Kaplow (2000) at 508, who observes, "An initial obstacle in analyzing rules and standards involves matters of definition. […] For purposes of economic analysis, it is useful to define the difference between rules and standards as involving exclusively the distinction between whether the law is given content *ex ante* or *ex post*. […] This distinction between rules and standards is obviously one of degree, although it often is convenient to discuss it as an all-or-nothing choice. […] Moreover, even a given formal specification will have a different character depending upon what is understood about the mode of adjudication and upon what other information is available in advance. For example, if everyone knows that an adjudicator is likely to rely upon a recent government study that indicates the degree of danger posed by potentially hazardous substances, the situation will be almost the same as that under a rule that incorporated the study's results."

[5] At times, regulatory set due care levels only provide a minimum of due care that may not be sufficient to escape a finding of negligence in a subsequent trial. These types of situations more closely resemble liability standards than

level of care only in general terms and often by reference to vague criteria such as the 'reasonable man' or the '*bonus pater familias*'. The actual determination of due care in individual cases is made by the judge by weighing the cost of care against its benefit in terms of reduced accident loss.[6]

If for instance, the judge mistakenly overestimates the victim's harm, he is also likely to overrate due care. Therefore, under standards, errors concerning damages cause consequential – and not merely coincidental – errors in the setting of due care.[7] This may occur even when there is no natural correlation between the probabilities of errors concerning damages and due care, which in fact we will assume are independent of each other. However, a standard may not always result in joint errors. In fact, even if damages are correctly evaluated, due care may be incorrectly set due to error in the calculation of the injurer's precaution costs or in the likelihood of accidents, or to other reasons. Likewise, if the damage award is capped by law as in some large-scale accidents, errors may occur separately even under standards.[8]

With this caveat, while assessing the effects of error concerning the damage award under liability standards, the resulting change in the level of due care must also be considered. This circumstance radically challenges the traditional wisdom about the performance of different liability rules in the face of error. As it will be explained in the conclusion, errors may derive not only from an erroneous estimation by the judge or the regulator but also from a party's mistake in predicting the outcome of the adjudication.[9] For analytical purposes, the two instances can be treated within the same model.

The results of the analysis may be summarized as follows. We will consider a standard

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liability rules since the final determination of the due care level for the purpose of liability depends upon the judge's determination and, thus, among other things, upon his estimation of the harm. The economic literature on the joint use of regulation and liability is rather limited; see footnote 15 below.

[6] We assume throughout this article that a judge sets due care in this way. Should he adopt different criteria, our results will still partially apply to the extent that an error concerning the evaluation of the harm triggers an error with the same sign in the setting of due care. Scholarship on the topic has long endorsed the Learned Hand rule as an example of an economically sound way to give content to vague due care standards. See *United States v. Carroll Towing Co*., 159 F.2d 169 (2d Cir. 1947). See Posner (1972).

[7] See Kaplow and Shavell (1986b) at 753, Kahan (1989) at 435, note 26, and Arlen (2000) at 694 briefly noticing this issue. This article is distinct from the previously noted as it further elaborates on this point.

[8] In other words, in this article a wrong estimation of damages is a sufficient but not necessary condition for an error in due care.

[9] Parties' errors in predicting the consequences of accidents, understanding the due care requirements, or anticipating the decisions of courts may be due to different reasons. Economics has recently joint efforts with psychology, sociology, biology and neurosciences in order to achieve a more thorough understanding of human behavior and explain the sources and the reasons of seemingly irrational behavior. In the present analysis, we take the errors as given, without inquiring into their causes; for a state of the art exposition, see Parisi and Smith (forthcoming).

unilateral-precaution model and test three rules: strict liability; the negligence rule with full damages; and the negligence rule with incremental damages – under which negligent injurers do not pay for damages that would have occurred anyway even if they had been non-negligent, that is, they do not pay for damages that have not been caused by their negligence.[10]

In relation to bias, the literature has concluded that the distortions of incentives due to a non-compensatory damage award may be partially corrected by an optimal standard of due care, and vice versa. From this setting, several results follow. First, the equilibrium level of precaution under strict liability has been shown to differ from that under negligence, given the same error in the evaluation of the harm.[11] Second, it has been shown that sub-optimal due-care standards are, at times, overturned by injurers who find it advantageous to take optimal care and pay damages rather than to take due care.[12] Third, it has been noticed that the interaction of the causation rule with the determination of negligence – that is, whether negligent injurers pay full or incremental damages – quantitatively changes these results.[13]

My contention is that if damages and due care are set jointly – as under standards – instead of being set independently of each other – as under rules – both negligence rules considered in this analysis yield the same equilibrium level of precaution as strict liability.

In relation to uncertainty concerning the damage award, the literature on this topic has concluded that it does not affect accident prevention. The effect of uncertainty concerning due care, instead, depends upon whether or not negligence is applied in connection with a causation rule.[14] I show that this latter result is also qualitatively valid when errors occur jointly but their quantitative effect changes. Namely, under negligence with full damages, both over-precaution and under-precaution may result; while over-precaution is more serious when

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[10] In this article, we build upon the now standard model of Brown (1973). The first analysis on the effect of errors on the performance of liability rules may be found in Diamond (1974). See further analysis in Cooter (1984), Shavell (1987) at 79-83, 93-97, Cooter and Ulen (2003) at 337–342, and Arlen (2000) at 693–695 for biases and uncertainty. Summers (1983) and Shavell (1986), while analyzing the issue of insolvency, make claims related to the effect of biases. Calfee and Craswell (1984) and Craswell and Calfee (1986) specifically analyzed uncertainty. Grady (1983) first noticed that the causation rule – or the incremental damage rule, which discharges from the negligent injurer's liability the consequences of accidents that would have occurred anyway, even if the injurer had been non–negligent – may change the functioning of negligence as an incentive device. Craswell and Calfee (1986) consider this rule in connection with uncertainty. Kahan (1989) further analyzed this topic in the face of biases.

[11] See Shavell (1987) at 83 and Cooter and Ulen (2003).

[12] Under the standard model of negligence, an excessive due care standard accompanied by correct damage estimation leads injurers to take the (excessive) due level of care in order to avoid liability, unless the extra cost of precaution is so high that it overcomes the reduced liability costs. In such an extreme case, the negligence rule becomes similar to a strict liability rule and injurers take due care. See Diamond (1974) and Shavell (1987) at 83 and 97–99 on this point.

[13] See Kahan (1989).

errors occur jointly, under-precaution might actually be mitigated or worsened by joint errors. Under negligence with incremental damages, only under-precaution results, and joint errors reduce this effect.

This article further examines the possibility for judges to correct for errors made by regulators and vice versa. It is shown that such possibility is of very limited reach and depends upon whether or not causation interacts with negligence.[15] As a secondary objective, this article systematizes the theory of errors in tort liability and reduces the different approaches taken in the literature into a unitary framework. An integrated formal analysis of the effects of errors on tort liability has not yet been explored in the literature.

Results are given in several simple propositions[16] that are subsequently formally proven. The table offers a useful synoptic synthesis. Sections 2 to 5 contain the formal analysis of the standard case in which injurers' precaution reduces the probability of accidents and victims are passive. In section 2, we will study the effect of bias under rules. Since the judge sets the damage award and the regulator sets due care, we will also inquire to what extent they can mutually correct each other's errors. In section 3, we will turn to the effects of bias under standards and show that the equilibrium levels of precaution are different. In this case, the judge sets both damages and due care, and, hence, there is no room for regulatory corrections.[17] In section 4, we will study the effects of uncertainty under rules. In this case, errors concerning the damage award will be shown to have no effect, and, hence, we only consider how judges could correct regulators' errors in setting due care. In section 5, we will finally study the effects of uncertainty under standards and again show that the equilibrium levels of precaution differ from the case of rules. Section 6 extends my findings to different precaution technologies and accounts for the injurers' ability to also reduce the magnitude of

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[14] See Craswell and Calfee (1986).

[15] The literature has long studied the relative merits of regulation and liability; see Wittman (1977) and Shavell (1984a). However, contributions on the joint use of regulation and liability are quite rare. Shavell (1984b) employs a model in which the performance of liability is undermined by insolvency and the performance of regulation by lack of information; Kolstad, Ulen and Johnson (1990) study how regulation can reduce the problems that uncertainty creates for liability in a setting similar to Craswell and Calfee (1986); Burrows (1999) focuses on situations in which neither regulation nor liability operate with certainty; finally, Schmitz (2000) studies the joint use of liability and regulation when wealth varies among individuals. The points that will be developed in this article have not been developed in earlier literature and relate instead to how courts and regulators can correct each other's biases under standards. Craswell and Calfee (1986) make a related point for the case of uncertainty.

[16] When results have been proven elsewhere in the literature, reference is given to the original formulation. The reader will notice that in most cases, although following the logic suggested in the literature, proofs are given in a different way in order to make them comparable with each other.

[17] We do not consider the obvious case in which the regulator can mandate specific damage awards or due care

the accidental harm. Section 7 concludes and shows that the analysis can also be applied to study the effects of injurers' errors in predicting the magnitude of damages and the levels of due care.

2 Bias under rules

We will consider accidents occurring between two risk-neutral, rational, and wealth-maximizing parties: a victim (the party that suffers harm) and an injurer (the other party). Only the injurer may take precaution to reduce the probability of an accident; the victim is passive. Causation will be assumed to be satisfactorily established and to interact with the determination of negligence in either of two ways: a negligent injurer always pays full damages to the victim, or a negligent injurer pays incremental damages to the victim, that is, he pays damages only in those cases in which the accident would not have occurred had the injurer been non-negligent. Let:

x	=	injurer's level of care, $x \geq 0$;
z	=	the due level of care, $z \geq 0$;
$p(x)$	=	probability of an accident, $0<p<1$, $p'<0$, $p''>0$;
H	=	victim's harm, $H>0$;
D	=	damage award, $D>0$.

All functions are assumed to be twice continuously differentiable. The social cost of an accident is defined as the sum of the victim's expected harm and the injurer's cost of care.[18] The socially optimal level of precaution is the level of x that minimizes this sum. Let x^* denote the level of x that solves:

$$(1) \qquad \min_x \left[p(x)H + x \right].$$

The first–order condition yields $p'(x^*)H = -1$;[19] x^* is assumed to be positive; we will refer to x^* as the (socially) optimal level of care. We will use strict liability as a benchmark case.

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levels.

[18] For convenience, care is assumed to have a unitary cost. Consequently, x denotes both the level and the cost of care. Relaxing this assumption does not alter the results of the analysis.

[19] It is easily shown that the second–order condition is satisfied.

Proposition 1. Under strict liability, over-compensation yields over-precaution, and under-compensation yields under-precaution.

Proof. Under strict liability, the injurer always pays damages independently of his level of precaution. Hence, he sets his level of precaution so as to solve the following problem:

(2) $$\min_x \left[p(x)D + x \right].$$

Let x^ be the level of x that solves Exp. (2). The first–order condition yields $p'(x\hat{})D = -1$. It is evident that if D is equal to H, then x^ will be equal to x^*; that is, if the injurer internalizes exactly the victim's loss, he will take the optimal level of precaution since he exactly bears the social cost. If D is greater (less) than H, then x^ will be greater (less) than x^*; that is, the injurer will take too much (too little) precaution if he pays over- (under-) compensatory damages to the victim. ■

In the following sections x^ will always denote the level of x that the injurer would take under strict liability.

2.1 Bias in damages under rules

Under rules, damages are determined by the judge on a case-by-case basis, while the level of due care is set ex ante by a regulator. We will now consider the effect of errors under the simple negligence rule and compare that effect with the benchmark case of strict liability. Negligence performs differently depending on whether or not it functions in conjunction with a causation rule. Negligence with full damages presents the injurer with a discontinuous cost function, as he pays full damages if negligent ($x<z$) and none if non-negligent ($x \geq z$). The causation rule eliminates this discontinuity because negligent injurers only pay the incremental damage due to their negligence. Thus, their cost rises continuously when they reduce their level of precaution below the due level. This difference causes the two rules to react differently to errors.

Proposition 2. Under negligence with full damages, if due care is optimal, over-compensation and moderate under-compensation produce no effect, while serious under-compensation yields under-precaution.

Proof. Under this rule[20] the injurer pays damages to the victim if he is negligent. Let $z = x^*$ be the level of due care. Hence, the injurer's minimization problem is:

$$\min_x \begin{cases} p(x)D + x & \text{if} \quad x < x^* \\ x & \text{if} \quad x \geq x^* \end{cases}. \tag{3}$$

The second expression is minimized by x^*. The injurer will take the optimal level of precaution x^* if $x^* \leq p(x)D+x$, for all $x<x^*$. The decision critically depends upon D. With $D \geq H$ the right–hand side of the inequality is minimized by $x^\wedge \geq x^*$ and, hence, it increases whenever x decreases below x^*. Thus, the injurer will take x^*. With $D<H$, the right–hand side of the inequality is minimized by $x^\wedge < x^*$. If D is sufficiently high, then the injurer will still find it advantageous to take x^*, but when D is low enough, the cost of paying damages to the victim plus a low precaution cost might be less than the cost of optimal precaution and the injurer will be induced to take $x^\wedge$. D is low enough if $D<(x^*-x^\wedge)/p(x^\wedge)$. ■

Proposition 3. Under negligence with incremental damages, if due care is optimal, then over-compensation produces no effect, while under-compensation yields under-precaution.

Proof. Under this rule,[21] the negligent injurer does not pay for the accidents that would have occurred even if he had been non-negligent. In fact, the socially optimal level of care x^* does not imply a reduction in the probability of accidents to zero. Hence, at this level of care, some accidents still occur. The expected harm due to these accidents is $p(x^*)H$. Contrary to the previous subsection, in this case, the causal inquiry relieves the injurer of liability for those accidents that cannot be avoided by taking due care. Therefore, the injurer's minimization problem is:

$$\min_x \begin{cases} [p(x) - p(x^*)]D + x & \text{if} \quad x < x^* \\ x & \text{if} \quad x \geq x^* \end{cases}. \tag{4}$$

Since $p(x^*)D$ is a constant, the first expression in (4) is minimized by the same x that minimizes the first expression in (3). However, the decision whether or not to take x^* changes, as it depends upon whether or not $x^* \leq [p(x)-p(x^*)]D+x$, with $x<x^*$. With $D \geq H$, the injurer will

[20] See Cooter (1984) at 1539 noting that a moderate change in the damage award will not affect the behavior of the injurer under a negligence rule. See Summers (1983) at 157–159 and Shavell (1986) at 47–49 on damages inferior to the harm.

[21] See Kahan (1989) at 434–436, 445–446.

take x^* for the same reason as in the previous case. On the contrary, with $D<H$, the inequality may be rewritten as $p(x^*)D+x^*\leq p(x)D+x$; the right–hand side is minimized by $x\hat{}<x^*$ and is, by hypothesis, always less than the left–hand side. Thus, the injurer will always take $x\hat{}<x^*$. Contrary to the previous case, under-compensation always generates under-precaution irrespective of the magnitude of the error. ■

2.2 Bias in due care under rules

Let us now move to the analysis of erroneous determination of the negligence standard, under the assumption that damages correspond to the harm, $D = H$.

Proposition 4. Under negligence with full damages, if damages are equal to the harm, the injurer takes due care if it is lower or moderately higher than optimal care. If due care is seriously higher than optimal care, then the injurer takes optimal care.

Proof.[22] Under this rule, the injurer's problem is:

$$\min_x \begin{cases} p(x)H + x & \text{if} \quad x < z \\ x & \text{if} \quad x \geq z \end{cases}. \tag{5}$$

The second expression is minimized by z. The choice of x depends upon whether or not the cost of following due care is less than (equal to) the cost of being negligent and paying damages: $z\leq p(x)H+x$, with $x<z$. With $z\leq x^*$ the right–hand side of the inequality increases whenever x decreases below z, and the injurer will always find it advantageous to take z. However, with $z>x^*$, the right-hand side is minimized by x^*. The injurer will take z only up to the point at which the required due care does not exceed the social cost at the optimal level of precaution, that is, as long as $z\leq p(x^*)H+x^*$. Otherwise, he will take x^*. ■

Proposition 5. Under negligence with incremental damages, if damages are equal to the harm, the injurer takes due care if it is lower than optimal care. If due care is higher than optimal care, the injurer always takes optimal care.

Proof.[23] Under this rule, the injurer's problem is:[24]

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[22] See Diamond (1974) at 116–123 and Shavell (1987) at 83, 97–99.
[23] See Kahan (1989) at 432–434, 445.

(6) $$\min_x \begin{cases} [p(x) - p(z)]H + x & \text{if} \quad x < z \\ x & \text{if} \quad x \geq z \end{cases}.$$

The choice of x depends upon whether or not $z \leq [p(x) - p(z)]H + x$, with $x < z$. With $z \leq x^*$, the injurer takes z for the same reason as in the previous subsection. On the contrary, with $z > x^*$, the injurer always takes x^*, as the right–hand side of the inequality is minimized by x^* and, with $x = x^*$, the inequality may be rewritten as $p(z)H + z \leq p(x^*)H + x^*$, which is never satisfied by hypothesis. ■

2.3 The regulator's correction for under-compensatory damages awarded by the judge

If judges err in determining the damage award, then the social cost could be lowered by a regulatory policy that lowers due care below the optimal level. This policy is socially advantageous when, by lowering due care, it is possible to induce non-negligent behavior on the part of injurers that would otherwise take even lower levels of care. Injurers may find it advantageous to do so because by taking due care they are free of liability. This is only possible under negligence with full damages. Under negligence with incremental damages, injurers only pay for damages that would not have occurred if they had taken due care. Hence, by reducing due care, the negligent injurers' liability is also reduced, and the incentive to abide by the due care level is completely eroded. We have already shown that over-compensation does not alter the injurer's level of precaution under negligence; thus, we focus on under-compensation.

Proposition 6. Under negligence with full damages, the effects of under-compensation can be mitigated by lowering due care below the optimal level. Under negligence with incremental damages, the effects of under-compensation cannot be corrected.

Proof. From proposition 2, we know that, if there is no causation rule and $z = x^* > p(x^\wedge)D + x^\wedge$, the injurer takes $x^\wedge < x^*$. The regulator can then lower z below x^* such that $z \leq p(x^\wedge)D + x^\wedge$, and, thus, the injurer takes z instead of $x^\wedge$. It is easy to see that there exists some z such that $x^\wedge < z < x^*$; that is, z yields a lower level of social cost than $x^\wedge$. From proposition 3, we know that under negligence with incremental damages, if $z = x^* > [p(x^\wedge) - p(z)]D + x^\wedge$, then the injurer takes

[24] Exp. (6) differs from Exp. (4) because in this subsection we assume that due care z is not set at the optimal level x^*.

$x^\wedge < x^*$. The former expression may be rewritten as $p(z)D+z>p(x^\wedge)D+x^\wedge$. It is easy to see that the only value that makes the right- and the left-hand sides equal is $x^\wedge$. Thus, the regulator cannot improve prevention by lowering due care. ■

2.4 The judge's correction for sub-optimal due care set by the regulator

This section examines the possibility for judges to correct inefficient rules concerning due care by means of altering the damage award above or below the value of the harm to the victim. If due care is lower than optimal, it is impossible to induce the injurer to take a higher level of care by increasing the damage award, as non-negligent injurers are free of liability. If due care is excessive, we have already shown that only under negligence with full damages will injurers take such an excessive level of care unless due care is above a certain threshold.

This effect can be corrected by reducing the damage award. By doing so, the judge makes it less expensive for the injurer to be negligent and may induce the injurer to reduce his level of precaution. This policy counteracts over-precaution by creating under-precaution and may, under certain conditions, produce socially desirable effects by reducing the social cost.

Proposition 7. Under negligence with full damages, if due care is higher than optimal, the injurer can be induced to take a lower level of care by lowering the damage award. If due care is lower than optimal, then the injurer cannot be induced to take a higher level of care. Under negligence with incremental damages, the effects of higher-than-optimal and lower-than-optimal due care cannot be corrected.

Proof. Under negligence with full damages, if due care z is less than x^*, the injurer takes z. Proposition 2 implies that raising the damage award does not produce any effect on the injurer's precaution. Lowering the damage award might only induce the injurer to lower his level of precaution further. Thus, if $z<x^*$, the outcome cannot be improved by adjusting the damage award. From Proposition 2, if $z>x^*$ and $z<p(x^*)H+x^*$, the injurer takes z. By setting $D<H$, such that $z\geq p(x^\wedge)D+x^\wedge$ (where $x^\wedge$ minimizes the right-hand side and is less than x^*), the judge can induce the injurer to take $x^\wedge$ instead of z. This policy reduces the social cost if z is sufficiently greater than x^*, that is, if $p(x^\wedge)H+x^\wedge<p(z)H+z$.[25] Under negligence with

[25] It is easy to see that the higher the due care level z, the higher the level of $D<H$ that induces the injurer to take z, thus the closer $x^\wedge$ to x^* and the lower the social cost associated with $x^\wedge$. On the contrary, the social cost associated with z rises with z.

incremental damages, only $z<x^*$ affects precaution. Therefore, the outcome cannot be improved for the same reason given above in this proof. ■

3 Bias under standards

Under standards, the judge sets the damage award and determines the level of due care. If the judge calculates due care according to a Hand formula type of reasoning, he will deduce the level of care that the injurer should have taken on the basis of the probability of the accident and of the victim's harm. Thus, if he overestimates the harm, he will also over-tailor due care and vice versa. As a result, error concerning due care is likely to occur jointly with an error in damages. It is shown here that both negligence rules considered yield the same outcome as strict liability. The reason is simple. Since the judge sets the level of due care on the basis of his estimation of damages, he will set it at a level that minimizes the cost of care and the expected accident loss given by that estimation. Such a level of care is exactly the same as the injurer would choose under strict liability since he bears those same costs.

Proposition 8. Under negligence with full damages, if damages and due care are set jointly, the injurer always takes due care, which is equal to the level of precaution that the injurer takes under strict liability given the same damage award.

Proof. If the victims' harm is evaluated at $D\neq H$, the due care standard will be calculated as to minimize $p(x)D+x$ instead of $p(x)H+x$. Hence, due care will be set at $z\neq x^*$. The injurers' minimization problem is:

$$\min_x \begin{cases} p(x)D + x & \text{if} \quad x < z \\ x & \text{if} \quad x \geq z \end{cases}. \tag{7}$$

Since z minimizes $p(x)D+x$, the first expression in (7) increases whenever x decreases below z. The second expression is minimized by z. Clearly, for any D, the injurer will take z, whatever that may be. Moreover, an erroneous damage award induces the setting of due care at a level that is the same as the level of care that the injurer would take under strict liability, $z = x^\wedge$, which can be verified by reconsidering Exp. (2). ■

Proposition 9. Under negligence with incremental damages, if damages and due care are set

jointly, the injurer always takes due care, which is equal to the level of precaution that the injurer takes under strict liability given the same damage award.

Proof. Under this rule, the injurer's minimization problem is:

$$\min_x \begin{cases} [p(x) - p(z)]D + x & \text{if} \quad x < z \\ x & \text{if} \quad x \geq z \end{cases}. \tag{8}$$

Since $p(z)D$ is a constant term, z minimizes $[p(x)–p(z)]D+x$. Thus, the first expression in (8) increases whenever x decreases below z. The second expression is minimized by z. Hence, the injurer will take z whatever that may be. As before, an erroneous damage award yields a level of due care that is the same as the level of precaution that the injurer would take under strict liability. ■

4 Uncertainty under rules

In this section, we consider error with regard to the damage award or the due care level that cannot be predicted in individual cases. We first assume that, for a given z, D varies between 0 and ∞ according to a distribution function $g(D)$, with $g(D)>0$ over the relevant region and $g(D) = 0$ elsewhere, and a cumulative distribution $G(D)$. Further, we consider that, for a given D, z varies between 0 and ∞ according to a distribution function $f(z)$ and a cumulative distribution $F(z)$ with the same characteristics as g. The two distributions are independent of each other. In order to isolate the effects of uncertainty and distinguish them from those of biases, we assume that the determination of the damage award or of due care, although erroneous in individual cases, is correct in average. Thus, we assume $\int_0^\infty D\ dG(D) = H$ and $\int_0^\infty z\ dF(z) = x^*$, respectively.

Two effects concur when the due care level is affected by uncertainty. On the one hand, increasing the level of precaution reduces the probability of being found non-negligent in addition to reducing the expected liability, thus enhancing the benefit of precaution. On the other hand, it is not certain that, by taking more care, the injurer will escape liability, and hence, it is more expensive for the injurer to comply with due care. Under negligence with full damages, either effect can dominate. Under negligence with incremental damages, the latter always prevails as the former is eroded by the fact that a negligent injurer pays a reduced

damage award. We have already shown while discussing biases that under this rule it is never convenient to comply with excessive due care levels, even if non-compliance means paying damages to the victim.

Proposition 10. Under all rules, with efficient due care levels, uncertainty concerning the determination of damages does not affect the injurer's precaution.

Proof. Under strict liability, the injurer's minimization problem becomes:

$$(9) \qquad \min_x \left[p(x)\int_0^\infty DdG(D) + x \right] = \min_x \left[p(x)H + x \right].$$

Thus, the injurer takes x^*. The proof is analogous for negligence with full damages and negligence with incremental damages. ■

Proposition 11. Under negligence with full damages, if damages are equal to the harm and there is uncertainty concerning due care, the injurer may take under- or over-precaution.

Proof.[26] By taking a level of precaution x, the injurer escapes liability if due care falls below x – thus, with probability $F(x)$ – and pays damages otherwise – thus, with probability $1–F(x)$. Therefore, the injurer's minimization problem becomes:

$$(10) \qquad \min_x \left[\int_x^\infty p(x)HdF(z)+x \right] \qquad \text{or} \qquad \min_x \left[\left(1 - F(x)\right)p(x)H + x \right].$$

Differentiating Exp. (10)[27] and evaluating the result at x^*, where $1 = –p'(x^*)H$, we obtain:

$$(11) \qquad -p'(x^*)F(x^*)H - p(x^*)f(x^*)H$$

This expression may be either positive or negative. It follows that the level of precaution taken by the injurer may be greater than, equal to, or less than x^*, depending on the size of $f(x^*)$, $F(x^*)$ and $p(x^*)$. ■

[26] In this proof we follow the logic of Craswell and Calfee (1986) at 280-283, even though they do not discuss the level of care (more care, less accidents) but the level of a harmful activity (more activity, more accidents). Thus, their conclusions are conceptually the same but verbally opposed to ours.

[27] The first order condition for Exp. (10) yields $p'(x)[1–F(x)]H–f(x)p(x)H+1 = 0$. Following Craswell and Calfee (1986) at 282, we assume that the second order condition is satisfied.

Proposition 12. Under negligence with incremental damages, if damages are equal to the harm and there is uncertainty concerning due care, the injurer takes under-precaution.

Proof.[28] The injurer faces the same minimization problem as in the previous case, but for the fact that, if found negligent, he does not pay for damages $p(z)H$ that would have occurred anyway. However, this amount of allowed damages also varies depending upon the determination of due care z. Thus, his minimization problem becomes:

$$(12) \qquad \min_x \left[\int_x^{\infty} \big(p(x) - p(z)\big) H dF(z) + x \right].$$

Differentiating Exp. (12)[29] and evaluating the result at x^*, where $1 = -p'(x^*)H$, we obtain:

$$(13) \qquad -p'(x^*)F(x^*)H > 0 .$$

Thus, since the problem is convex, the level of precaution taken by the injurer is less than x^*.

■

Let us now examine the possibility for judges to correct the effect of uncertainty concerning due care by adjusting the damage award.

Proposition 13. Under negligence with full damages and under negligence with incremental damages, the effects of uncertainty concerning due care can be completely offset by adjusting the damage award.

Proof.[30] Under negligence with full damages, increasing the damage award may yield efficient precaution when error leads to under-precaution, and, vice versa, reducing the damage award may yield efficient precaution when error leads to under-precaution. If $D \neq H$, the injurer minimizes the following expression instead of Exp. (10):

$$(14) \qquad \min_x \big[\big(1 - F(x)\big) p(x) D + x \big].$$

The optimal damage award is a level of D such that the first order condition for Exp. (14)[31] is

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[28] In this proof, we follow Craswell and Calfee (1986) at 296.

[29] The first order condition for Exp. (12) yields $p'(x)[1-F(x)]H+1 = 0$; the second order condition is satisfied for any x, since it yields $p''(x)[1-F(x)]H-p'(x)f(x)H > 0$.

[30] In this proof we follow Craswell and Calfee (1986) at 294 and 297. They discuss the issue in terms of a damage multiplier.

[31] The first order condition for Exp. (14) yields $p'(x)[1-F(x)]D-f(x)p(x)D+1 = 0$; the second order condition is

satisfied at $x = x^*$, where $1 = -p'(x^*)H$. Substituting and rearranging we have:

$$(15) \qquad D^* = \frac{p'(x^*)H}{p'(x^*)\left[1 - F(x^*)\right] - p(x^*)f(x^*)}.$$

Thus, if $D = D^*$, the injurer takes the optimal level of care. Likewise, if $D \neq H$ under negligence with incremental damages, the injurer's problem of Exp. (12) becomes:

$$(16) \qquad \min_x \left[\int_x^\infty \left(p(x) - p(z)\right) D dF(z) + x \right].$$

Proceeding as above, it is easy to show that the optimal damage award in this case is always greater than the harm, since it is aimed at correcting under-precaution:[32]

$$(17) \qquad D^* = \frac{H}{1 - F(x^*)}. \blacksquare$$

5 Uncertainty under standards

Under standards, an error concerning the damage award will cause a corresponding error in the determination of due care. If there is uncertainty, by increasing his level of care, the injurer attains three effects at the same time. First, he reduces the probability that an accident occurs. Second, he reduces the probability that due care is greater than x, and he has to pay damages. Third, he curbs the range of possible damage awards he will have to pay. This latter effect is not obvious. In fact, the injurer does not directly affect the size of the damages; however, when his level of care is relatively high, he can only be found negligent if the due level of care is even higher. Since we are considering a situation in which the error in setting due care is driven by an error in determining the damage award, high due care levels indicate that the damage award has been overestimated. Therefore, increasing his level of precaution prevents the injurer from paying increasingly large damage awards. Consequently, since under standards the benefit of precaution is increasing with precaution levels, error generally induces higher levels of precaution than under rules.

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assumed to be satisfied as for Exp. (10). See also footnote 27.

[32] The first order condition for Exp. (16) yields $p'(x)[1-F(x)]D+1 = 0$; the second order condition is satisfied for any x, since it yields $p''(x)[1-F(x)]D-p'(x)f(x)D > 0$. Evaluating the first order condition at x^*, substituting $1 = -$

Nevertheless, under negligence with full damages, if rules induce very low levels of precaution, standards may yield lower precaution than rules. This effect is due to the fact that under rules, increasing care reduces the probability of paying at the margin a constant damage equal to H, while under standards it reduces the probability of paying at the margin a varying damage D, which is correlated to due care and hence, at low care levels, is also very low. Therefore, the marginal benefit of precaution may be lower under standards than under rules and so may the incentives to take precaution.

This effect is absent in the negligence rule with incremental damages, because at low levels of precaution the amount of damages that the injurer can cause without paying decreases; in fact, he does not pay for the damage that would have occurred had he taken due care, but such a damage decreases with due care. The latter effect induces more precaution and counterbalances the dilution of incentives described above. Therefore, under negligence with incremental damages, the injurer takes more precaution under standards than under rules, even though precaution is lower than optimal anyway.

Proposition 14. Under negligence with full damages, if damages and due care are set jointly and there is uncertainty, the injurer may take under- or over-precaution. If rules yield over-precaution, standards will lead to even higher levels of precaution. If rules yield under-precaution, the level of precaution under standards may be higher or lower than under rules.

Proof. Since the judge sets due care on the basis of his estimation of damages, we can write the standard of due care as a function of the damage award: $z(D) = \text{argmin}[p(x)D+x]$. Given that D is distributed according to $g(D)$, then $z(D)$ will be distributed according to a distribution function $\varphi(z(D)) = g(D)$ and a cumulative distribution $\Phi(z(D)) = G(D)$ for any D. Moreover, since $z(D)$ is monotonically increasing in D, it is correct and more convenient to consider the damage award as a function of due care, that is, $D = D(z)$. Notice that both at the optimal level and on average D equals H, that is, $D(x^*) = H$ and $\int_0^\infty D(z)\ d\Phi(z) = H$. The injurer's minimization problem becomes:

$$(18) \qquad \min_x \left[\int_x^\infty p(x)D(z)d\Phi(z) + x \right].$$

$p'(x^*)H$, and rearranging, we have Exp. (17).

Differentiating Exp. (18)[33] and evaluating the result at x^*, we have:

$$(19) \qquad -p'(x^*)\int_0^{x^*} D(z)d\Phi(z) - p(x^*)\varphi(x^*)H\ .$$

This expression may be either positive or negative; thus, both under- and over-precaution may result. In order to compare the levels of precaution under standards and under rules, let us assume that $\varphi(z) = f(z)$. In this way, we assume that an error concerning z occurs with the same likelihood under rules and under standards, and hence, the only difference between rules and standards is that, under the latter, D also varies.[34] Under rules, the injurer takes a level of precaution x^r, which solves the first order condition for Exp. (10), $p(x)f(x)H–p'(x)[1–F(x)]H = 1$. Substituting $\varphi(z) = f(z)$ and $\Phi(z) = F(z)$ into the first derivative of Exp. (18), and evaluating the result at x^r,[35] we have:

$$(20) \qquad p'(x^r)\int_0^{x^r}\left[H - D(z)\right]dF(z) + p(x^r)\,f(x^r)\left[H - D(x^r)\right].$$

It easy to see that the first term in Exp. (20) is always negative because $\int_0^a D\ dF(D) < H$ for any finite value of a. This term measures the relative advantage of precaution in terms of a marginal reduction in the probability of accidents. The second term is negative (or zero) if $x^r \geq x^*$, that is, if over-precaution results under rules. This term measures the relative advantage of precaution in terms of a marginal reduction in the expected damage award. In this case, the sign of Exp. (20) is negative, and, thus, the level of precaution taken by the injurer under standards is higher than under rules. Otherwise, the sign is not clear, especially as $H–D(x^r)$ becomes positive when x^r decreases below x^*; therefore, with $x^r<x^*$, precaution under standards may be either higher or lower than under rules. ■

Proposition 15. Under negligence with incremental damages, if damages and due care are set

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[33] The first order condition for Exp. (18) yields $p'(x)\int_x^\infty D(z)\ d\Phi(z)–\varphi(x)p(x)D(x)+1 = 0$. Evaluating this expression at x^* and substituting $1 = –p'(x^*)H$, $H = \int_0^\infty D(z)\ d\Phi(z)$, and $D(x^*) = H$, we have Exp. (19). The second order condition is assumed to be satisfied as for Exp. (10). See also footnote 27.

[34] Without this assumption, differences in the levels of precaution under standards and under rules would be obviously due to the fact that errors occur according to different distribution functions and, namely, the distribution g in the case of standards – since errors in z are triggered by errors in D – and the distribution f in the case of rules – since errors in z are independent from errors in D.

[35] For the first derivative of Exp. (18) see footnote 33. Exp (20) is obtained by also substituting $1 = f(x^r)p(x^r)H–p'(x^r)[1–F(x^r)]H$, which may be rewritten as $f(x^r)p(x^r)H–p'(x^r)H+p'(x^r)\int_0^{x^r}H\ dF(z)$ or $f(x^r)p(x^r)H– p'(x^r)\int_0^\infty D(z)$

jointly and there is uncertainty, the injurer takes under-precaution. Such a level is higher than the level of precaution taken under rules.

Proof. Modifying Exp. (18), the injurer's minimization problem becomes:

$$(21) \qquad \min_x \left[\int_x^\infty \big(p(x) - p(z)\big) D(z) d\Phi(z) + x \right].$$

Differentiating Exp. (21)[36] and evaluating the result at x^*, we have:

$$(22) \qquad -p'(x^*) \int_0^{x^*} D(z) d\Phi(z) > 0 .$$

Therefore, the injurer takes under-precaution. In order to compare the levels of precaution under standards and under rules, let us assume $\varphi(z) = f(z)$ as above. Under rules, the injurer takes a level of precaution x^R, which solves the first order condition of Exp. (12), $p'(x)[1-F(x)]H = -1$. Differentiating Exp. (21)[37] and evaluating the result at x^R, we obtain:

$$(23) \qquad p'(x^R) \int_0^{x^R} \big[H - D(z)\big] dF(z) < 0 .$$

Therefore, the level of precaution taken under standards is higher than under rules. ■

[Table]

6 Extensions to different precaution technologies.

So far we have employed the standard model, which considers the injurer's ability to reduce the probability that an accident occurs, while holding the harm constant or randomly distributed but still out of the control of the injurer. Models of this form, $p(x)H$, only cover one of the possible precaution technologies available to injurers. In fact, in most real life circumstances, injurers can also reduce the magnitude of the loss. In car accidents, for

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$dF(z) + p'(x^r)\int_0^{x^r} H\, dF(z)$.

[36] The first order condition for Exp. (21) yields $p'(x)\int_x^\infty D(z)\, d\Phi(z) + 1 = 0$. Calculating this expression at x^*, and substituting $1 = -p'(x^*)H$ and $H = \int_0^\infty D(z)\, d\Phi(z)$, we have Exp. (22). The second order condition is satisfied for any x, since $p''(x)\int_x^\infty D(z)\, d\Phi(z) - p'(x)\varphi(z)D(z) > 0$.

example, caution while driving curbs both the probability of an accident and the magnitude of the harm. Research in the field of judgment proofness has shown that considering alternative precaution technologies to the standard probability model severely alters the predictions of the analysis.[38]

In this section, we will consider a stereotypical case, diametrically opposed to the probability model used so far. We will test the robustness of our results in situations of the following type: the probability of the accident is determined exogenously, while the magnitude of the harm is under the control of the injurer, $pH(x)$, and decreases according to the usual assumptions. It is easy to see that errors concerning due care affect this magnitude model in precisely the same way that we have seen so far. It is also easy to see that, also in this case, uncertainty on the damage award does not affect the functioning of any liability rule. The case of biases concerning the determination of damages remains to be analyzed.

Since the injurer can control the magnitude of the harm, it is necessary to specify the way in which the error might affect the size of damages. We consider two benchmark situations. First, error in damages could affect the total size of the damage award without impinging on it at the margin. An example is the following $D(x) = H(x)+\delta$, where δ is a measure of the error. It is easy to see that, in this case, no marginal effect is produced on precaution but only an inframarginal one, as the level of x that solves the minimization problem $\min_x[pD(x)+x]$ is the same that solves $\min_x[pH(x)+x]$. These types of errors do not produce any effect under strict liability. Graphically, they shift the injurer's cost curve upward or downward without changing the level of x that corresponds to the lowest cost. For the same reason, even under standards, they do not affect the determination of the due care level. Moreover, since both negligence rules considered in this study have been shown to be unaffected by an increase in the damage award, these types of errors do not produce any consequence in our framework.

Second, consider errors that affect both the total and the marginal value of the damage function: for example, $D(x) = \delta H(x)$. In this case, the minimization problem yields a sub-optimal solution that depends upon whether δ is greater or less than 1. It is easy to see that the effects produced by the error are qualitatively the same as under the standard probability model.

We can conclude that the analysis developed for probability models also applies to other

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[37] Exp. (23) is obtained by substituting $1 = -p'(x^R)[1-F(x^R)]H$, $H = \int_0^\infty D(z)\, dF(z)$ and rearranging.

precaution technologies with only one exception: errors concerning the damage award may have no marginal effect if precaution only reduces the magnitude of the harm.

7 Conclusions

In some instances, due care and damages are set independently and errors concerning the former might not correspond to errors in the latter. Due care, for example, could be erroneously set by a regulatory body although the damage award might be correctly determined by the courts on a case-by-case basis. We have suggested that this might occur when due care is embodied in ex ante rules. In addition, this analysis also explains the effects of prediction errors made by the injurer in connection to either the damage award or the standard of due care. Indeed, the injurer might have good information concerning the norm of conduct but poor hints regarding the consequences of accidents or vice versa.

In other cases, however, the same subject might calculate both variables mistakenly. For example, a judge might apply a sub-optimal due care standard because of an incorrect determination of damages. We have argued that this scenario could materialize when due care is vaguely defined in standards, such as the reasonable man or the *bonus pater familias*. In addition, the injurer might also underestimate the victim's harm and lower his expectations concerning the due care standard that will be applied in the course of a subsequent judgment. Thus, in this case, our analysis can be straightforwardly applied to the effect of wrongful expectations of injurers. In this framework, this article has principally aimed at making a distinction between those cases in which the two types of errors are perfectly correlated and those cases in which they are independent.

The body of literature that deals with the functioning of tort liability and the effects of biases may be interpreted as leading to the general conclusion that different liability rules respond differently to error. This article shows that these conclusions may be defended only if, under the negligence rule, error concerning the determination of the damage award occurs independently of error concerning the determination of the due care standard. However, if the standard of due care is calculated on the basis of a wrong estimate of damages, the two types of errors will jointly occur. In this case, strict liability and negligence react in the same way to error and the issue of causation does not change the results. The effect of uncertainty has been

[38] See Dari-Mattiacci and De Geest, *forthcoming*.

shown to change as well, but only quantitatively, when errors are allowed to occur jointly. In the case of uncertainty, joint errors still make different liability rules perform differently but yield, with one exception, higher levels of precautions than when errors occur separately.

The terms 'error' and 'erroneous' have been used here to emphasize that the actual determination of due care or damages may diverge from that which is required by the minimization of the social costs. This usage should not divert the reader's attention away from the fact that other considerations might induce the adoption of such determinations. The analysis provided so far should furnish a positive tool to ascertain the behavioral reactions to liability rules when the damage award and the determination of negligence vary.

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Table: The effect of errors on precaution in the standard model

x^* is the socially optimal level of care; z is the due care level; $x^\wedge$ is the level of care the injurer would take under strict liability (in the case of biases: $x^\wedge > x^*$ if damages are too high, $x^\wedge = x^*$ if damages are equal to the harm, and $x^\wedge < x^*$ if damages are too low, as stated in **Proposition 1**); in the case of uncertainty, $x^\wedge = x^*$; under negligence with full damages, x^r and x^s are the levels of care that the injurer takes under rules and standards, respectively, in the case of uncertainty; likewise, under negligence with incremental damages, x^R and x^S are the levels of care that the injurer takes under rules and standards, respectively, in the case of uncertainty. Corrective measures are considered only under rules, as the judge could correct the regulator and vice versa. Under standards, damages and due care are both set by the judge; thus, there is no room for corrective measures. The table also provides a roadmap through the propositions.

			Precaution			
			Negligence with full damages	Corrective measures	Negligence with incremental damages	Corrective measures
Bias	Rules	Damages too high	**Proposition 2** x^*	*Unnecessary*	**Proposition 3** x^*	*Unnecessary*
		Damages too low	**Proposition 2** x^* (if D is below a threshold the injurer takes $x^\wedge < x^*$)	**Proposition 6** Partially	**Proposition 3** $x^\wedge < x^*$	**Proposition 6** No
		Due care too high	**Proposition 4** $z > x^*$ (if z is above a threshold the injurer takes x^*)	**Proposition 7** Partially	**Proposition 5** x^*	*Unnecessary*
		Due care too low	**Proposition 4** $z < x^*$	**Proposition 7** No	**Proposition 5** $z < x^*$	**Proposition 7** No
	Standards	Damages and due care too high	**Proposition 8** $x^\wedge$	*Unavailable*	**Proposition 9** $x^\wedge$	*Unavailable*
		Damages and due care too low	**Proposition 8** $x^\wedge$	*Unavailable*	**Proposition 9** $x^\wedge$	*Unavailable*
Uncertainty	Rules	Uncertainty on damages	**Proposition 10** x^*	*Unnecessary*	**Proposition 10** x^*	*Unnecessary*
		Uncertainty on due care	**Proposition 11** $x^r <> x^*$	**Proposition 13** Yes	**Proposition 12** $x^R < x^*$	**Proposition 13** Yes
	Standards	Uncertainty on damages and due care	**Proposition 14** $x^s > x^r \geq x^*$ or $x^s <> x^r < x^*$	*Unavailable*	**Proposition 15** $x^R < x^S < x^*$	*Unavailable*