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Efficient liability law when parties genuinely disagree

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Efficient liability law when parties genuinely disagree

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Abstract

This article compares the classic liability rules, negligence and strict liability, under the hypothesis that injurers and victims formulate subjective beliefs about the probabilities of harm. Parties may reasonably disagree in their assessment of the precautionary measures available: a measure regarded as safe by one party may be regarded as not safe by the other. By relying on the notions of Pareto efficiency and "No Betting" Pareto efficiency, the article shows that negligence is the optimal liability rule when injurers believe that the probability of harm is always higher than the victims do, while strict liability with overcompensatory damages is the optimal rule in the opposite case. The same results apply to bilateral accidents and, specifically, to product-related harms in competitive markets. Overcompensatory ("punitive") damages provide consumers with insurance against their own pessimism.

Keywords: *negligence vs. strict liability, products liability, scientific uncertainty, No Betting Pareto Dominance*

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Non-technical summary

This paper addresses the issue of disagreement in a liability setup. When a potential injurer and a potential victim entertain different statistical models about the occurrence of harm, the issue arises about which statistical model (the injurer s or the victim s) should guide the precaution decision.
I compare the two classic liability rules: strict liability and negligence. Under strict liability, the precaution level is driven predominantly by the statistical model of the injurer. Under negligence, the precaution level is driven by the statistical model of the victim.
When the injurer is "risk-optimistic," in the sense that she believes that the probability of harm is always lower than the victim does, the optimal liability rule is strict liability with overcompensatory damages. When the injurer is "risk-pessimistic," in the sense that she believes that the probability of harm is always higher than the victim does, the optimal liability rule is negligence.

1 Introduction

A basic tenet of the liability system is that parties should take those precautions whose benefits exceed costs. This idea is neatly crystallized by Judge Hand's rule, which posits that, in order to determine the duty of the parties, courts should consider: i) the probability of injury brought about by the precautionary measures available, ii) the gravity of the resulting injuries, and iii) the cost of precautions. Injurers are encouraged to adopt - as liability otherwise ensues - the precautionary measures whose benefits in terms of risk reduction outweigh the costs.[1]

Most of the literature on the economics of torts assumes that the probability of injury associated to alternative precautionary measures is an objective probability known to all parties. In this paper, I consider the case in which, due to the lack of conclusive evidence, parties entertain *subjective beliefs* about the probability of injury.[2] As a result, parties may assess precautionary measures in different, and possibly opposing, ways: a measure regarded as safe by one party may be regarded as unsafe by the other.

The case for divergent beliefs is particularly strong with respect to technologies that are new and that are, therefore, relatively untested,[3] and with respect to harmful substances that affect the human body in a complex manner.[4] Disagreement can also arise with respect to older technologies, like nuclear power, that tend to produce adverse events with a very low frequency.

In this paper, I assume that the beliefs formulated by prospective injurers and victims (hereinafter, "injurer" and "victim")" are *reasonable*, that is, they are compatible with the evidence available. In this sense, I depart from the behavioral literature, which emphasizes the myriad of biases and mistakes that affect people's relationship with the

[1] *United States v. Carroll Towing Co.*, 159 F.2d 169 (2d Cir. 1947).

[2] Subjective probabilities are associated with the names of Frank Ramsey, Bruno de Finetti, and Leonard Savage. Subjective probabilities are sometimes called "epistemic" probabilities.

[3] A study by the Rand corporation estimates that, to demonstrate their full reliability in terms of fatalities and injuries, self-driving cars would have to be driven for billions of miles, which could take - at the current pace - hundreds of years (Kalra and Paddock (2016)).

[4] The IARC lists more that 300 substances (including Glyphosate) as "probably" or "possibly" carcinogenic to humans. Substances can also raise concerns if they are mutagenic, toxic, or potentially endocrine-disrupting (like Bisphenol A). Scientific uncertainty tends to loom large in all toxic torts (see Geistfeld (2021)).

concept of risk.[5] While I recognize that careful reflection would allow parties to correct (most of) their mistakes, I assume that the self-correction process may not converge to a unique set of shared beliefs (a "statistical model"): parties may reasonably agree to disagree.[6] Under this assumption, I carry out the normative analysis by focussing on Pareto efficiency. In other words, I identify the features that the liability system would have if parties could decide the remedies together.[7]

When parties formulate different evaluations of the same risk prospect, the transfer of the loss from the party that believes the loss to be more probable to the party that believes it to be less probable creates surplus. In such a situation, the liability system should purse two distinct goals: i) it should provide the injurer with incentives to take precaution (*deterrence*), and ii) it should allocate the loss to the party that is more willing to bear it (*risk allocation*). In the paper, I compare the classic liability rules: strict liability and negligence.

Under strict liability, the injurer pays damages to the victim when harm materializes, independently of the precautionary measure adopted. The injurer minimizes her expected "cost of accidents," which includes the cost of precaution and the expected damages awards. Here, the policy variable in the hands of the lawmaker is the level of damages, which might be greater or smaller than the harm suffered by the victim. I show that optimal damages are undercompensatory if the injurer is relatively risk-pessimistic (the injurer believes that the probability of harm is larger that the victim does), while they are overcompensatory if the injurer is relatively risk-optimistic. Belief divergence provides a novel rationale for punitive damages.

Under a negligence regime the loss falls on the victim if, and only if, the injurer adopts a precaution level below the standard of care decided by the lawmaker. The

[5] See Halbersberg and Guttel (2014) and Luppi and Parisi (2018), and references therein.

[6] Parties know that their priors differ. So, even if they face the same piece of evidence, they end up with (publicly known) different posteriors. In the terminology of Aumann (1976), they "agree to disagree." Conversely, had they started with a common prior, they could not have ended up with (publicly known) different posteriors, even if they had received different pieces of information, for the posteriors would have revealed the information. See Morris (1995). A comprehensive survey of "model uncertainty" in decision theory is provided by Marinacci (2015).

[7] My efficiency analysis bears similarity to the tort doctrine of "assumption of risk," under which a fully informed individual can express her agency by deliberately consenting to take some risk.

injurer will typically prefer to be non-negligent and she will, therefore, comply with the standard. Since the risk will be shouldered by the victim, the standard of care should be pegged to the latter's statistical model: if the victim (reasonably) believes that precautions are highly effective at reducing the probability of harm, the standard should be set at a high level.[8] Note that, when the victim is relatively risk-pessimistic, negligence provides a poor risk allocation.

Strict liability and negligence are based on different statistical models and they yield different precaution levels. Yet, they can be easily compared. *If, given the precaution level induced by strict liability, the injurer is relatively risk-pessimistic, it is preferable to shift the loss from the injurer to the victim and to opt for the negligence rule. If, given the precaution level induced by negligence, the victim is relatively risk-pessimistic, it is preferable to shift the loss to the injurer and to opt for the strict liability rule.*

The same insight applies to bilateral care torts - in which the conducts of both injurer and victim affect the probability of harm - and, significantly, to product liability in competitive markets. When consumers are relatively more pessimistic than producers about the safety of the product, strict liability with contributory or comparative negligence is the efficient liability regime. In this ideal regime, damages should exceed harm. The damages prospect is highly valued by the pessimistic consumers, while it comes at a low (expected) cost to the producers.

The differential beliefs perspective complements the classic asymmetric information perspective, which argues that firms can offer warranties to *signal* the safety of their products (Spence (1977)). In the current model, firms (efficiently) offer overcompensation for product related harms not to convince doubtful consumers that their product is safe, but to insure them against their unwavering skepticism.

No betting. In the paper, I rely on the classic notion of Pareto efficiency, which considers an outcome as socially desirable if parties themselves would agree to it (and no third parties are affected). Pareto efficiency is usually regarded as a sensible "minimal" requirement: it allows the lawmaker to rule out outcomes that parties unanimously

[8] By pegging the precautionary standard to the victims' average beliefs, the model rationalizes the existence of different community-based (or jurisdiction-based) standards.

regard as inferior. It has been argued that Pareto efficiency is less compelling when parties entertain diverging beliefs.

The issue become clear if we consider pre-trial litigation. Suppose that two litigants believe that they will prevail in court. Both parties are willing to "bet" that they will win: they are willing to sink resources to try the odds of adjudication. Here, the trial represents a Pareto efficient outcome on the basis of expectations that cannot both be correct. So, even if both parties would vote for "trial" against "settlement," one cannot find a *common reason* that would support the decision to go to trial. In the terminology of Mongin (2016), this is a case of "spurious unanimity:" the agreement is unanimous, but it follows from the aggregation of incompatible viewpoints.[9]

This criticism has prompted Gilboa et al. (2014) to refine the Pareto criterion so as to winnow out agreements in which, under all circumstances, each party can only gain at the expense of the other one. The *No Betting Pareto Dominance* ($NBPD$) requirement postulates that an agreement represents a morally compelling improvement if: i) it is a Pareto improvement given the beliefs of the parties, and ii) one can find a hypothetical belief under which the agreement is a Pareto improvement, when this belief is shared by all parties.

I show that the efficiency rationale developed in this paper meets, to a very large extent, the *NBPD* criterion. Liability rules do not only allocate losses: they also determine the statistical model that guides the precautionary choice. On the latter point, parties can find a mutually beneficial agreement supported by a shared reasoning. For instance, they could recognize that a switch from strict liability to negligence is mutually beneficial if the victim's beliefs happen to be correct (they agree that, if that were the case, precautions should be pegged to the victim's statistical model). A similar argument applies to a switch from negligence to strict liability with compensatory damages. *NBPD* might fail, however, under a policy of large overcompensatory damages under strict liability. When damages highly exceed harm, they might induce such a large precaution expenditure, that not even the most optimistic beliefs can justify.

[9] The analysis of Spier and Prescott (2019) shows that one cannot find a common reason to support the decision to forgo settlement also in the case in which parties can write contingent contracts that mitigate the trial outcome (like "high-low" agreements).

Literature. The classical literature on the economics of torts, pioneered by Brown (1973) and Diamond (1974), analyses the impact of different liability rules using the concept of Nash equilibrium under a common prior. Under the hypothesis of risk neutrality, both strict liability and negligence are able to induce (the same level of) efficient precaution.[10] The classic literature follows traditional game theory and builds on the "Harsanyi doctrine," which posits that different rational agents independently placed in a situation of complete ignorance will necessarily formulate the same common belief.[11]

A more sophisticated perspective on the parties' beliefs has emerged in contemporary decision theory, which has focused on the difference between "aleatory uncertainty" (where the odds are known) and "epistemic uncertainty" (where the odds are unknown). Building on this literature, Teitelbaum (2007) presents a liability model in which victims lack confidence in their estimates of the probability of harm (in line with the neo-additive ambiguity model of Chateauneuf et al. (2007)). The lack of confidence "distorts" the victims away from the correct probability measure, inducing them to overweigh low probability risks. The efficient policy therefore requires victims to be insulated: the loss should be placed on the ambiguity-neutral injurer.[12]

Franzoni (2017) employs the smooth ambiguity model of Klibanoff et al. (2005) to account for the case in which parties entertain multiple prior beliefs. In that paper, I assume that parties' beliefs share the same mean, and focus on the impact of risk and ambiguity aversion. The optimal liability rule is the one that allocates the loss to the party that either formulates the most precise estimates of the probability of harm or is less averse to uncertainty. In the current model, I consider the simpler case in which parties are risk and ambiguity neutral. Yet, they entertain divergent beliefs because they rely on different statistical models (so, there is radical disagreement).[13]

Differently from tort theory, non-common priors have been popular in litigation

[10] See the extensive surveys of Shavell (2007) and Arlen (2013).

[11] The Harsany doctrine has been increasingly challenged both by theory and applied research (see Morris (1995), Marinacci (2015), and references therein).

[12] Chakravarty and Kelsey (2017) extend Teitelbaum's model to bilateral accidents and show how an ambiguity-neutral court can partially correct the distortion due to the parties' aversion to ambiguity.

[13] This parsimonious model captures most of the features associated with first-order risk and ambiguity aversion, in the sense of Segal and Spivak (1990) and Lang (2017). See Appendix A3.

theory, where the parties' observed failure to settle can be explained by their different expectations about the trial's outcome. Recent additions to this influential literature include Spier and Prescott (2019) and Vasserman and Yildiz (2019).

Section 2 provides the introductory definitions. Section 3 analyses strict liability and Section 4 negligence. The two liability rules are compared in Section 5. Section 6 examines *No Betting Pareto Dominance.* Section 7 extends the results to product liability, while Section 8 concludes.

2 Divergent beliefs

Let x denote the (continuous) level of the precaution exerted by the injurer. When precautions x are taken, the injurer believes that the probability of harm is $p_I(x)$, while the victim believes that the probability of harm is $p_V(x)$. I assume that these beliefs are compatible with the evidence available at the time when the activity is carried out, that they are known, and that they cannot be manipulated.[14] These beliefs originate from explanatory models that provide alternative causal links between the conduct of the injurer and the eventual injury suffered by the victim. For the sake of simplicity, I assume that these beliefs are continuous and continuously differentiable, and that $p_I'(x) < 0$ and $p_V'(x) < 0$ for all $x \geq 0$.[15] Both the injurer and the victim are risk-neutral. For technical purposes, I also posit that $\lim_{x\to\infty} p_I''(x) = 0^+$. This assumption will allow me to rule out unbounded solutions.

Parties agree on the magnitude of harm suffered by the victim, h, and the cost of precaution, $c(x)$. The cost of precaution is increasing and convex (with $c'(0) = c''(0) = 0$, and $\lim_{x\to\infty} c'(x) = \infty$).

The following diagrams illustrate several patterns of belief divergence.

[14] Beliefs could also be "imprecise," in the sense that, given x, parties expect the probability of harm to belong to a range, say $p(x) \in [\underline{p}(x), \overline{p}(x)]$, and assign a likelihood to each value belonging to the interval ("multiple prior model"). If individuals are ambiguity neutral, as I assume, the imprecision of the beliefs is irrelevant: all that matters is the mean value of the beliefs.

[15] This assumption rules out the case in which a precautionary measure is regarded as risk-reducing by one party and risk-increasing by the other. The main result of the paper, however, does not depend on this assumption (see footnote 24).

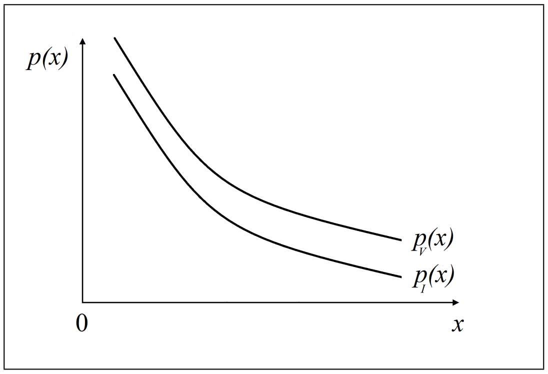

Fig. 1.

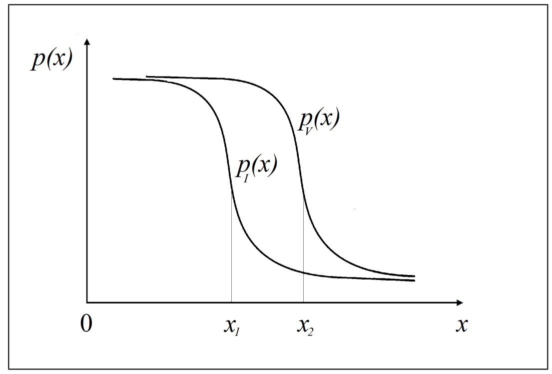

Fig 2.

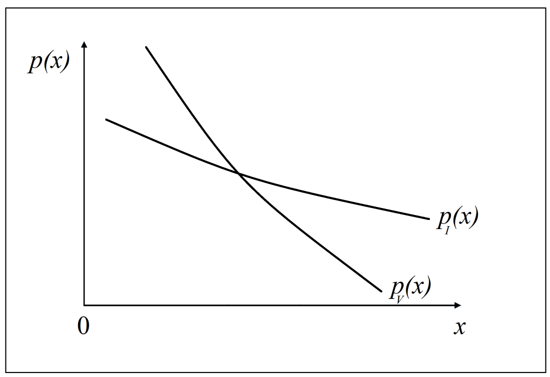

Fig 3.

In Fig. 1 parties agree on the efficacy of precaution (p_V and p_I have the same slopes), but they disagree on the magnitude of the risk. In Fig. 2 parties disagree about the "safety threshold" emerging from a dose-respose model: the injurer believes that safety is achieved with precaution level x_1, while the victim believes that it is achieved with precaution level x_2. In Fig. 3 parties disagree on the efficacy of precaution: the victim assigns to precautions a greater capacity to reduce risk.

In places, I will consider these special cases: i) the injurer is *relatively risk-optimistic* if $p_I(x) < p_V(x)$ for all $x \geq 0$; ii) the injurer is *relatively precaution-optimistic* if $|p_I'(x)| > |p_V'(x)|$ for all $x \geq 0$ (the injurer always believes that precautions are more effective at reducing the probability of risk than the victim does). The reverse definitions apply in the case of "pessimism."

In Fig. 1 and 2 the Injurer is relatively risk-optimistic but not precaution-optimistic; in Fig. 3 the injurer is relatively precaution-pessimistic but not risk-pessimistic.

The lawmaker decides the liability rule governing the activity and, when the injurer is liable, the amount of the damages $d \geq 0$ to be awarded to the victim. I will compare the two classic liability rules: strict liability and negligence.[16]

3 Strict liability

Under strict liability, the injurer is liable for the harm caused to the victim independently of the level of precaution taken.[17] The cost of accidents for the injurer is

$$L_I^s(x) = c(x) + p_I(x)\, d.$$

It includes the cost of precaution and the expected liability (calculated using the injurer's beliefs).[18] The injurer minimizes $L_I^s(x)$ and thus selects x^s so that

$$c'(x^s) = -p_I'(x^s)\ \ d: \tag{1}$$

one dollar spent in precaution reduces her expected liability by one dollar. The level of precaution is pegged to the injurer's statistical model. From (1), we know that x^s increases with d. With an abuse of notation, in places I will write $x^s = x^s(d)$.

The cost of accidents for the victim is

$$L_V^s(d) = p_V(x^s)(h - d).$$

[16] These liability rules replicate two distinct contractual patterns. Strict liability is formally equivalent to the case in which precautions are not contractible and (unidirectional) contingent transfers are feasible. Negligence corresponds to the case in which precautions are contractible and contingent transfers are not feasible (or they are feasible only if the injurer fails to deliver the stipulated precaution level). These "constrained" contracts would be clearly dominated by a contract that includes both precautions and contingent transfers.

[17] For simplicity, the scope of liability - the set of the injuries for which the injurer can be held liable - is taken as given. If the scope has to be pegged to some statistical model, it should be the victim's.

[18] The minimization problem is well behaved if: $c''(x) + p_I''(x)\, d > 0$ for all $x > 0$, which is assumed to hold.

The latter is equal to expected uncompensated harm, i.e., the difference between harm suffered and damages received, times the probability that harm occurs. Note that $L_V^s(d)$ can be negative, because damages can exceed harm (and thus the victim can benefit from the accident).

We can now turn to the Pareto efficient policy, that is, the policy that minimizes Social Loss (the total cost of accidents):

$$SL^s(d) = L_I^s(x^s) + L_V^s(d) = c(x^s) + p_V(x^s)h + [p_I(x^s) - p_V(x^s)]d.$$

Social Loss includes the precaution costs borne by the injurer, the expected harm borne by the victim, and an additional term that captures the disagreement between injurer and victim about the probability that damages will be awarded.

We get:

$$\frac{\partial SL^s(d)}{\partial d} = \frac{\partial L_I^s(x^s)}{\partial x^s}\frac{\partial x^s}{\partial d} + \frac{\partial L_V^s(x^s)}{\partial x^s}\frac{\partial x^s}{\partial d} + [p_I(x^s) - p_V(x^s)].$$

Since $\frac{\partial L_I(x^s)}{\partial x^s} = 0$ (from eq. 1), we get

$$\frac{\partial SL^s(d)}{\partial d} = p_V'(x^s)\,\frac{\partial x^s}{\partial d}(h-d) + [p_I(x^s) - p_V(x^s)]. \tag{2}$$

An increase in damages has two effects: it increases the incentives for the injurer to invest in precaution and thus reduce the uncompensated harm borne by the victim, and it shifts risk from the victim to the injurer. The former effect reduces social loss only if damages are undercompensatory ($d < h$). If damages are overcompensatory, the victim is harmed by an increase in precaution. The risk transfer effect reduces social loss if, and only if, the injurer believes harm to be less likely than the victim does.

If parties share the same beliefs, only the first effect matters and optimal damages are perfectly compensatory: $d^* = h$. If parties do not share the same belief, damages should also cater for the optimal allocation of risk. Starting at $d = h$, a change in damages has a negligible impact on the first effect (there is no externality), while it allows for the transfer of risk from the pessimistic to the optimistic party. So, damages should increase if $p_I(x^s) < p_V(x^s)$, while they should decrease if $p_I(x^s) > p_V(x^s)$.

The previous observation provides us with the optimal direction of change at $d = h$. Assuming that SL^s is quasi-convex, this piece of information is sufficient to identify the global optimum.[19]

Proposition 1 *Strict liability. Optimal damages strike a balance between the goal of discouraging the generation of uncompensated harm and the need to efficiently allocate risk:*

$$-\frac{\partial x^s}{\partial d} p_V'(x^s) \ (h - d^*) = p_I(x^s) - p_V(x^s). \tag{3}$$

If the injurer believes that harm is more probable than the victim does at $d = h$, optimal damages are undercompensatory. If the victim believes that harm is more probable than the injurer does at $d = h$, optimal damages are overcompensatory.

Note that the force that drives damages away from the fully compensatory solution is the disagreement about the probability of harm, and not about the efficacy of precaution $[p'(x)]$. Optimal damages are further away from the compensatory level, the greater this disagreement. If the victim's beliefs about the probability of harm shift upwards, optimal damages increase and the injurer takes additional precautions.

The divergence of beliefs provides a justification for punitive damages different from the classic one, pegged to the possibility that the responsible party escapes liability. Here, overcompensatory damages serve an allocative function: they provide the victim with a "lottery ticket" to which he attaches a value that exceeds the cost for the injurer.[20]

Remark. The set up can be easily extended to the case with K injurers (each with her own belief $p_{Ii}(x)$) and M random victims (each with his own belief $p_{Vj}(x)$).[21] Optimal

[19] Optimal damages are positive and bounded above. See Appendix A1.

[20] In the strict liability regime, the injurer decides the precaution level on the basis of her risk model. If this risk model ends up placing a disproportionate probability of harm on the victim (from the latter's point of view), punitive damages are not an implausible outcome. The injurer, in fact, could be accused of taking a "reckless behavior," to display "indifference to risk," or - quoting the famous Pinto cars case - to manifest "a conscious disregard of the probability that [her] conduct will result in injury to others." See Sharkey (2013) for an overview.

[21] For simplicity, I assume that harms are simply additive. So, each victim can be involved in up to M independent accidents.

damages should here solve:

$$-\sum_{i=1}^{K} \frac{\partial x_i^s}{\partial d}\ \overline{p}_V'\left(x_i^s\right)\left(h-d^*\right)=\sum_{i=1}^{K}\left[p_{I_i}\left(x_i^s\right)-\overline{p}_V\left(x_i^s\right)\right],$$

where $\overline{p}_V'\left(x_i^s\right)$ is the expected decrease in the probability of harm caused by injurer i: $\overline{p}_V'\left(x_i^s\right)=\frac{1}{M}\sum_{j=1}^{M} p_{Vj}'\left(x^s\right)$, and $\overline{p}_V\left(x_i^s\right)$ is the average probability of harm: $\overline{p}_V\left(x_i^s\right)=\frac{1}{M}\sum_{j=1}^{M} p_{Vj}\left(x^s\right)$, both calculated from the victims' standpoint.

4 Negligence

Under a negligence rule, the injurer is liable for damages only if she does not meet the standard of care $\bar{x}$. Care is assumed to be verifiable in court. Here, the tool in the hands of the lawmaker is the standard of care $\bar{x}$. For simplicity, the damages paid by the negligent injurer are assumed to be compensatory: $d=h$.

The cost of accidents for the injurer is

$$L_I^n(x)=\begin{cases} c(x)+p_I(x)\,h & \text{if } x<\bar{x}, \\ c(x) & \text{if } x\geq\bar{x}. \end{cases}$$

The injurer prefers to meet the standard if

$$c(\bar{x})<c\left(x^s(h)\right)+p_I\left(x^s(h)\right)h, \tag{4}$$

where $x^s(h)$ minimizes the injurer's cost of accident when she is liable for damages $d=h$ (see eq. 1). In theory, we can have situations in which inequality (4) does not hold, and the injurer prefers to bear liability. This case can arise when the injurer is highly risk-optimistic and precaution-pessimistic. From a normative perspective, however, we can ignore this possibility because, when the injurer prefers to be negligent (and bear liability), the lawmaker itself prefers strict liability to negligence.[22]

[22] If the injurer prefers to be negligent, then: $c(x(h))+p_I(x(h))\,h<c(\bar{x})$. In turn, since $d=d^*$ minimizes social loss under strict liability, we have $c(x^s)+p_I(x^s)\,d^*+p_V(x^s)(h-d^*)\leq c(x(h))+p_I(x(h))\,h$. This implies that $c(x^s)+p_I(x^s)\,d^*+p_V(x^s)(h-d^*)<c(\bar{x})+p_V(\bar{x})\,h$: the lawmaker

The optimal standard of care (assuming that it is met) should be set so as to minimize

$$SL^{n}\left(\bar{x}\right)=L_{I}^{n}\left(\bar{x}\right)+L_{V}^{n}\left(\bar{x}\right)=c\left(\bar{x}\right)+p_{V}\left(\bar{x}\right)h.$$

The injurer bears the cost of precaution while the victim bears the risk of harm.

The optimal standard x^{n} should thus solve:[23]

$$c'\left(x^{n}\right)=-p_{V}'\left(x^{n}\right)h. \tag{5}$$

An additional dollar spent in precaution reduces the harm expected by the victim by one dollar.

Proposition 2 *Negligence. The efficient standard of care balances the cost of precaution borne by the injurer with the risk borne by the victim (eq. 5).*

In the determination of the standard of care, courts should realize that if the injurer meets the standard prescribed by the law, the risk falls on the victim. The "reasonable person" upon which the standard is defined is thus a person that puts herself in the shoes of those who might be harmed (and not in her own). If the victim believes that precautions are highly effective, the standard of care should be high.

Remark. If victims are randomly drawn from a set of M individuals with different beliefs, the optimal standard x^{n} should solve:

$$c'\left(x^{n}\right)=-\frac{1}{M}\sum_{j=1}^{M}p_{Vj}'\left(x^{n}\right)\ h: \tag{6}$$

the efficient standard is molded by the *average* belief in the relevant community. Variability in beliefs implies that a conduct regarded as negligent in jurisdiction A can be regarded as non-negligent in jurisdiction B.

We can now compare the performance of the two liability regimes.

prefers strict liability to negligence.

[23] The condition: $c''\left(x\right)+p_{V}''\left(x\right)h>0$ for all $x>0$ is sufficient to guarantee the convexity of the minimization problem.

5 Strict liability vs. negligence

To compare the two liability rules, let us first consider the level of precaution emerging under each of them.

Under strict liability, the optimal level of care solves:

$$c'(x^s) = -p'_I(x^s)\,d^*,$$

where $d^* > h$ if, and only if, $p_I(x^s) < p_V(x^s)$ at $d = h$.

Under negligence, the optimal level of care solves:

$$c'(x^n) = -p'_V(x^n)\,h.$$

The following simple conditions are sufficient (though not necessary) to determine the relationship between x^s and x^n.

Lemma 1 *If the injurer is relatively risk- and precaution-optimistic, then $x^s > x^n$.*

If the injurer is relatively risk- and precaution-pessimistic, then $x^s < x^n$.

If the injurer is relatively precaution-optimistic, then $x^s(h) > x^n$. If she is also relatively risk-optimistic, then $d^* > h$, and $x^s(d^*) > x^s(h) > x^n$. The opposite applies when the injurer is relatively risk and precaution-pessimistic.

Let us now compare social loss under the two regimes. We have:

$$\begin{aligned} &SL^n(x^n) < SL^s(d^*) \Leftrightarrow \\ &c(x^n) + p_V(x^n)\,h < c(x^s) + p_V(x^s)\,h + [p_I(x^s) - p_V(x^s)]\,d^*. \end{aligned} \tag{7}$$

The socially preferable liability rule is the one that yields the least social loss.

The following result provides two simple dominance conditions:

Proposition 3 ***The efficient liability rule***

i) If $p_I(x^s) > p_V(x^s)$, negligence dominates strict liability.

ii) If $p_I(x^n) < p_V(x^n)$, strict liability dominates negligence.

Proof. i) We have $SL^n(x^n) < SL^s(d^*)$ if and only if

$$c(x^n) + p_V(x^n)h - [c(x^s) + p_V(x^s)h] < [p_I(x^s) - p_V(x^s)]d^*.$$

Since $x^n = \arg\min_x [c(x) + p_V(x)h]$, the term on the LHS cannot be positive. So, if $p_I(x^s) > p_V(x^s)$, then $SL^n(x^n) < SL^s(d^*)$. ii) Since $d^* = \arg\min_d [SL^s(d)]$, we must have

$$SL^s(d^*) \leq SL^s(h) = c(x^s(h)) + p_I(x^s(h))h.$$

In turn, since, $x^s(h) = \arg\min_x [c(x) + p_I(x)h]$, we must have

$$c(x^s(h)) + p_I(x^s(h))h \leq c(x^n) + [p_I(x^n)]h.$$

So, if we have: $p_I(x^n) < p_V(x^n)$, then

$$SL^s(d^*) \leq c(x^n) + p_I(x^n)h < c(x^n) + p_V(x^n)h = SL^n(x^n). \blacksquare$$

Conditions i) and ii) allow us to identify the least-cost risk bearer. If the victim believes that harm is less likely than the injurer does, at the precaution level arising under strict liability, then negligence is the optimal rule. If the injurer believes that harm is less likely than the victim does, at the precaution level arising under negligence, then strict liability is the optimal rule.[24]

Note that conditions i) and ii) are "local" ones (they apply to two specific precaution levels). So, we can have situations in which neither condition holds. In that case, liability rules can be compared by directly referring to ineq. (7).

Special cases. When the injurer is *relatively risk-pessimistic*, strict liability alleviates the burden of the injurer by entailing undercompensatory damages. This, however, is not enough. The optimal liability rule is negligence, and it places all the risk on the victim. If the injurer is also relatively precaution-pessimistic, the level of care ends up being higher than under strict liability.

When the injurer is *relatively risk-optimistic*, the optimal rule is strict liability with

[24] Note that the proof of Proposition 3 only requires that the set of the precaution levels is compact and that the cost and the belief functions are lower semi-continuous.

overcompensatory damages. This rule entails a surplus-creating transfer of risk. If the injurer is also relatively precaution-optimistic, the precaution level ends up being higher that under negligence.

The difference in beliefs breaks the classic equivalence result, which posits that strict liability and negligence are equally able to induce the (same) efficient level of precaution.

6 No Betting Pareto Efficiency

In this section, I use the "No Betting" criterion developed by Gilboa et al. (2014) to distinguish trades based on purely antagonistic bets from trades that can, at least in theory, yield a win-win outcome. According to these authors: "unanimity about a given claim - say, that trade is desirable - becomes more compelling when *unanimity about the reasoning* that leads to it is also possible" (emphasis added). Specifically, a policy move meets the $NBPD$ criterion if: i) it is a Pareto improvement under the parties' beliefs, and ii) there exists at least one hypothetical belief under which the move remains a Pareto improvement, when this belief is shared by all affected parties.[25]

In Appendix A2, I first consider a move from strict liability to negligence and prove that it meets $NBPD$. This move can be supported by the belief of the optimistic party (the victim). Both parties agree that, if the victim were right, it would be better to peg the precaution level to the victim's statistical model instead of the injurer's.

A move from negligence to strict liability with compensatory damages ($d = h$) follows the same logic. Both parties agree that, if the injurer's beliefs were correct, precautions should be pegged to her statistical model.

The move from compensatory damages to optimal damages ($d = d^*$) is harder to justify. If damages are undercompensatory, the move can be supported by the hypothetical belief that the ensuing reduction in precaution will not result in an increase in the probability of harm. If damages are overcompensatory, the move might be

[25] Further explorations of the issue and alternative criteria for the choice of the hypothetical beliefs are provided by Brunnermeier et al. (2014), Gayer et al. (2014), and Danan et al. (2016).

supported by the hypothetical belief that the ensuing increase in precaution will cause a drastic decrease in the probability of harm. Even this belief, however, cannot support an excessively large increase in the precaution expenditure - see eq. (14) in A2.

The use of the $NBPD$ criterion reinforcers the notion that an agreement between parties with divergent beliefs is normatively compelling. It supports the efficiency rationale at the basis of the analysis.

7 Extensions: Product liability

Product liability concerns harms caused by defective products. Contrary to the cases of the previous sections, injurers and victims are now in a contractual relationship. In the presence of competitive markets, the choices of producers/injurers and consumers/victims are formally equivalent to those of the previous sections (see Shavell (2007) and Daughety and Reinganum (2018)). So, we get the same insights.

If consumers are *relatively risk-pessimistic*, strict liability should apply and damages should be overcompensatory. This would allow firms to retain consumers who are wary of the product by providing them with a lottery ticket, whose value is, in fact, the higher the more pessimistic they are. At the optimum, however, the prize for the harmed consumer cannot be too large, as this would lead firms to invest too much in precaution. If consumers are *relatively risk-optimistic*, negligence should apply and the standard of care should be pegged to the consumers' beliefs.[26]

The optimal liability rules maximize total surplus in the market. So, these are the (only) liability rules that would survive market competition, if firms could choose the liability rule they are subject to.

It should be emphasized how the policy prescriptions arising from the diverging beliefs model differ from those arising from the behavioral literature. The latter tends

[26] This observation resonates with the language of the frequently used *consumer expectation test*, which posits that a product is unreasonably dangerous if it is "dangerous to an extent beyond that which would be contemplated by the ordinary consumer" (*Restatement (Second) of Torts* § 402A, comment (g)). It should be noted that the efficient test is not an absolute one, but a relative one, where consumers' expectations are balanced against the cost of safety.

to support strict liability for product related harms as a way to protect consumers from their own mistakes. If consumers formulate erroneous estimates of the probability of harm, they end up attaching the wrong value to the product. This, in turn, distorts their consumption behavior (they buy too much or too little). Strict liability with compensatory damages provides here an "insulation strategy:" it protects consumers against their own miscalculations and it allows markets to regain their efficiency properties.[27] This view presupposes that the risk estimates of the consumers are wrong, while those of the production managers are correct. The pluralistic approach underlying the current model posits instead that the risk estimates of the consumers - as well as those of the managers - are legitimate ones, as far as they meet weak reasonableness criteria. The choice between strict liability and negligence is guided by the need to allocate the loss to the best risk bearer.[28]

Finally, it should be noted that the insights developed above carry over to the case in which consumers/victims can affect the probability of harm ("bilateral care"). In an Annex available upon request, I contrast negligence and strict liability with contributory negligence. The comparison of the liability rules follows a logic similar to that of Section 5. If injurers believe that harm is more likely than victims do at the precaution levels arising under strict liability with contributory negligence, then negligence is the optimal rule. If victims believe that harm is more likely than injurers do at the precaution levels arising under negligence, then strict liability with contributory negligence is the optimal rule.

[27] This perspective goes back to the early contributions of Spence (1977) and Shavell (1980). The concept of "insulation strategy" is developed by Jolls and Sunstein (2006).

[28] On a practical level, the identification of the optimal risk bearer requires the elicitation of producers' and consumers' beliefs, which tend to be industry and country specific. A vast literature on the perception of risk can provide some insights. Lay people (consumers) tend to be relatively pessimistic compared to experts (producers) with respect to risks originating from chemical and biotech products, radioactive waste disposal, nuclear power, hunting, and spray cans. Consumers tend to be relatively optimistic with respect to electrical power, surgery, lawn mowers, swimming, skiing, and cycling (see Slovic (2010)). They also tend to underestimate the risks of driving. To the extent that the latter beliefs are reasonable, they support a negligence regime.

8 Final remarks

The assumption that parties entertain diverging beliefs about the probability of harm substantially enhances the realism of the analysis. The insights developed can be applied at different levels. At the basic level, injurer and victim can be two specific individuals (say a firm and its neighbor): here, the analysis shows how parties would directly handle the prospect of risk (through stipulated damages or a standard of behavior). At a more extended level, injurers and victims could represent specific groups, like the community of medical doctors and the community of the patients in a specific area. Here, the difference in the beliefs across jurisdictions can explain the emergence of community-based or country-based standards. Finally, for product related harms, the divergence in the beliefs of producers and consumers provides a role for "consumers expectations" in the determination of negligence and for punitive damages under strict liability.

The analysis assumes that lawmakers can somehow elicit the beliefs of the parties and that they can use them to determine the best risk bearer. With respect to new products (in the fields of AI, biotech, and nanotech), consumers might reasonably express some skepticisms. In such a situation, a strict liability regime offering overcompensatory damages would be efficient. Such a system would benefit, at the same time, both consumers and industry.

Appendix

A1. Optimal damages (strict liability). From (1), we get

$$\frac{\partial x^s}{\partial d} = -\frac{p_I'(x^s)}{c''(x^s) + p_I''(x^s)\, d} > 0. \tag{8}$$

x^s tends to zero for $d \to 0^+$ and it tends to infinity for $d \to \infty$. By plugging (8) into (2), we get

$$\frac{\partial SL^s(d)}{\partial d} = -p_V'(x^s)\ \frac{p_I'(x^s)}{c''(x^s) + p_I''(x^s)\, d}(h-d) + p_I(x^s) - p_V(x^s),$$

with

$$\lim_{d\to 0^+} \frac{\partial SL^s(d)}{\partial d} = p_V'(0)\, \frac{p_I'(0)}{c''(0)}\ h + p_I(0) - p_V(0) = -\infty,$$

since $c''(0)$ is nil, and

$$\begin{aligned}\lim_{d\to\infty} \frac{\partial SL^s(d)}{\partial d} &= -p_V'(x^s)\, p_I'(x^s)\ \frac{1}{\frac{c''(x^s)}{d} + p_I''(x^s)} \left(\frac{h}{d} - 1\right) + p_I(x^s) - p_V(x^s) \\ &= p_V'(x^s)\, p_I'(x^s)\ \frac{1}{p_I''(x^s)} + p_I(x^s) - p_V(x^s) > 0,\end{aligned}$$

since $\lim_{x^s\to\infty} p_I''(x^s) = 0^+$.[29]

A2. NBPD. Let us consider the efficiency of negligence vis-à-vis strict liability. Negligence Pareto dominates strict liability if a "trade" from the latter to the former benefits both parties. The losses incurred by the parties under the two regimes are

Strict Liability	*Negligence*
$L_I^s = c(x^s) + p_I(x^s)\, d^*,$	$L_I^n = c(x^n) + t,$
$L_V^s = p_V(x^s)(h - d^*),$	$L_V^n = p_V(x^n)\, h - t,$

where t is an (ex-ante) transfer from the injurer to the victim, needed to convince her to accept the move. Let us fix $t = p_V(x^n)\, h - p_V(x^s)(h - d^*)$.

[29] If also p_I, p_V, p_V', and p_I' converge to zero as $x \to \infty$, we have to assume that $p_I''(x)$ converges faster to zero than $\frac{p_V' p_I'}{p_V - p_I}$.

The parties' gains from trade are:

$$L_I^s - L_I^n = c(x^s) + p_I(x^s)\,d^* + p_V(x^s)(h - d^*) - [c(x^n) + p_V(x^n)\,h],$$
$$L_V^s - L_V^n = 0,$$

where $L_I^s - L_I^n > 0$ because we are considering the case in which the switch represents a Pareto improvement.

If parties take $p_V(x)$ as the "neutral" belief to asses the trade, we get $\widehat{L}_V^S - \widehat{L}_V^N = 0$ and

$$\begin{aligned}\widehat{L}_I^s - \widehat{L}_I^n &= c(x^s) + p_V(x^s)\,d^* - [c(x^n) + p_V(x^n)\,h - p_V(x^s)(h - d^*)] \\ &= c(x^s) + p_V(x^s)\,h^* - [c(x^n) + p_V(x^n)\,h] > 0,\end{aligned}$$

because $x^n = \arg\min_x [c(x) + p_V(x)\,h]$. So, the injurer gains also if she adopts the victim's belief. The common belief supporting $NBPD$ is the victim's belief.

The move from negligence to strict liability is more demanding, in terms of hypothetical beliefs. I consider a two-steps move: first, from negligence to strict liability with compensatory damages $(d = h)$, second, from strict liability with compensatory damages to strict liability with optimal damages $(d = d^*)$.

The move from negligence to strict liability with compensatory damages follows a logic similar to that explained above. Again, the common belief supporting $NBPD$ is that of the optimistic party (the injurer).

Let us focus on the move from compensatory damages to optimal damages. The losses are

Strict liability with comp. dam.	*Strict liability*
$L_I^{sc} = c(x^{sc}) + p_I(x^{sc})\,h,$	$L_I^s = c(x^s) + p_I(x^s)\,d^* + t,$
$L_V^{sc} = 0,$	$L_V^s = p_V(x^s)(h - d^*) - t,$

where x^{sc} is the precaution level chosen by the injurer when $d = h$. Note that $h - d^*$ can be positive or negative (to fix ideas, for the time being we can assume that it is positive).

In order to have $L_I^s < L_I^{sc}$ and $L_V^s \leq L_V^{sc}$, the transfer t should satisfy:

$$\begin{cases} t < c(x^{sc}) + p_I(x^{sc})\,h - c(x^s) - p_I(x^s)\,d^* \equiv \overline{t}, \\ t \geq p_V(x^s)(h - d^*) \equiv \underline{t}. \end{cases} \tag{9}$$

We have

$$\bar{t} \geq \underline{t} \Leftrightarrow c\left(x^{sc}\right) + p_I\left(x^{sc}\right) h \geq c\left(x^s\right) + p_I\left(x^s\right) d^* + p_V\left(x^s\right)\left(h - d^*\right), \tag{10}$$

which holds because the move is Pareto efficient (by assumption).

If the move were judged according to a hypothetical belief $p_H(x)$, losses would be:

Strict liability with comp. dam.	*Strict liability*
$\widehat{L}_I^{sc} = c\left(x^{sc}\right) + p_H\left(x^{sc}\right) h,$	$\widehat{L}_I^{s} = c\left(x^{s}\right) + p_H\left(x^{s}\right) d^* + t,$
$\widehat{L}_V^{sc} = 0,$	$\widehat{L}_V^{s} = p_H\left(x^{s}\right)\left(h - d^*\right) - t.$

The move would benefit both parties if

$$\begin{cases} t < c\left(x^{sc}\right) + p_H\left(x^{sc}\right) h - c\left(x^s\right) - p_H\left(x^s\right) d^* \equiv \bar{t}^H, \\ t \geq p_H\left(x^s\right)\left(h - d^*\right) \equiv \underline{t}^H, \end{cases} \tag{11}$$

with

$$\bar{t}^H \geq \underline{t}^H \Leftrightarrow c\left(x^{sc}\right) + p_H\left(x^{sc}\right) h \geq c\left(x^s\right) + p_H\left(x^s\right) h. \tag{12}$$

Inequality (12) is a necessary condition for $NBPD$. If $d^* < h$, it posits that the reduction in precaution expenditure driven by optimal damages exceeds the hypothetical increase in expected harm: $c\left(x^{sc}\right) - c\left(x^s\right) \geq p_H\left(x^s\right) h^* - p_H\left(x^{sc}\right) h$. If $d^* > h$, it posits that the hypothetical decrease in expected harm exceeds the increase in precaution expenditure: $c\left(x^s\right) - c\left(x^{sc}\right) \leq p_H\left(x^{sc}\right) h - p_H\left(x^s\right) h$.

The policy move meets $NBPD$ if one can find a t that meets both (9) and (11). This is the case if, and only if, $\bar{t}^H \geq \underline{t}$ and $\underline{t}^H \leq \bar{t}$, that is, if and only if:

$$\begin{cases} c\left(x^{sc}\right) + p_H\left(x^{sc}\right) h \geq c\left(x^s\right) + p_H\left(x^s\right) d^* + p_V\left(x^s\right)\left(h - d^*\right), \\ c\left(x^{sc}\right) + p_I\left(x^{sc}\right) h \geq c\left(x^s\right) + p_I\left(x^s\right) d^* + p_H\left(x^s\right)\left(h - d^*\right). \end{cases} \tag{13}$$

If we set $p_H\left(x^s\right) = p_V\left(x^s\right)$, the second equation of (13) is met thanks to (10). We are left with the first equation.

For the case with $d^* < h$, let us consider the hypothetical beliefs: $p_H\left(x^{sc}\right) = p_H\left(x^s\right) = p_V\left(x^s\right)$. The first inequality of (13) becomes:

$$c\left(x^{sc}\right) \geq c\left(x^s\right),$$

which is met because $x^{sc} > x^{s}$. The necessary condition (12) is also met. So, the reduction of damages from $d = h$ to $d = d^{*}$ is supported by the hypothetical belief that expected harm will not be affected by the ensuing reduction in precaution.

For the case with $d^{*} > h$, let us consider the (most favorable) hypothetical belief: $p_H(x^{sc}) = 1$. The first inequality of (13) becomes:

$$c(x^{s}) - c(x^{sc}) \leq [1 - p_V(x^{s})]\, h. \tag{14}$$

If condition (14) is met, also the necessary condition (12) is met. The increase in damages from $d = h$ to $d = d^{*}$ meets $NBPD$ if the ensuing increase in precaution expenditure is not too large.

A3. Other remarks. The model developed above allows the parties to evaluate in different ways the same risk prospect. As such, it has much in common with the case in which parties share the same beliefs but have different attitudes towards risk (Shavell (1982)). The main difference between the two approaches is that, in the divergent beliefs model, the cost of risk is of first order (it increases linearly with the magnitude of the loss), while in the classic EU model, the cost of risk is of second order (it increases exponentially with the magnitude of the loss). This difference becomes relevant when the injurer can harm many potential victims and losses add up. Here, the "risk structure" matters. Specifically, negligence tends to outperform strict liability if harms are positively correlated, and the other way around if harms are negatively correlated (Franzoni (2016)). This feature would be replicated by the divergent beliefs model if parties were assumed to be risk averse. A further implication of the difference between first- and second-order risk aversion concerns the way in which small risks are treated. Under second-order risk aversion, when the loss is small, the cost of risk becomes negligible. This implies that a small share of the loss must be placed on the victim and that, therefore, optimal damages cannot be perfectly compensatory (Shavell (1982)). Under the divergent beliefs model, small risks entail different costs for the parties. So, full compensation can be optimal. In fact, optimal compensation can even exceed harm. In the EU model, this can only occur if victims are risk lovers.

Since beliefs can take any shape, the differential beliefs model is extremely versatile. In fact, it can replicate the basis features of most non-EU models that display first-order risk and ambiguity aversion, including the neo-additive model, Rank Dependent Expected Utility and, on the condition that losses and gains are treated symmetrically, Prospect Theory. Under this interpretation, the injurer and the victim share the same belief about the probability of harm, but they attach a different "weight" to this probability. So, if the injurer attaches a greater weight to the probability of harm than the victim does, the injurer behaves like the relatively risk-pessimistic party, and vice-versa.

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