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### Authors

Cooter, Robert D.  
Porat, Ariel

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# Total Liability for Excessive Harm

by

Robert Cooter

Law School, University of California at Berkeley

email: [rcooter@law.berkeley.edu](mailto:rcooter@law.berkeley.edu)

and

Ariel Porat

Faculty of Law, Tel Aviv University

email: [porata@post.tau.ac.il](mailto:porata@post.tau.ac.il)

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## Abstract

In many circumstances, the total harm caused by everyone is verifiable, and the harm caused by each individual is unverifiable. For example, the environmental agency can measure the total harm caused by pollution much easier than it can measure the harm caused by each individual polluter. In these circumstances, implementing the usual liability rules or externality taxes is impossible. We propose a novel solution: Hold each participant in the activity responsible for all of the excessive harm that everyone causes. By “excessive harm” we mean the difference between the total harm caused by all injurers and the optimal total harm. We call this rule “total liability for excessive harm.” We show that total liability for excessive harm creates incentives for efficient precaution and activity level. Consequently, actual harm is not excessive and actual liability is nil. For example, the environmental agency can set a target for clean air and announce that each factory is liable for pollution by all factories that exceeds the target. Since the liability rule causes the factories to hit the target, they pay no damages. Thus the environmental agency gains control over emissions without having to monitor individual polluters, and the polluters do not have to pay damages or conform to bureaucratic regulations.

# Total Liability for Excessive Harm

Robert Cooter and Ariel Porat\*

## Introduction

In many circumstances, individual contributions to social harm are “unverifiable,” by which we mean “not provable to a tribunal.” For example, the environmental agency often cannot prove the extent of each polluter’s emissions. In these circumstances, the usual liability rules cannot be implemented. For example, implementing a rule of negligence or a rule of strict liability requires verifying the damage that individual injurers actually caused. When we turn from private to public law, the same problem arises. For example, implementing an externality tax (“Pigouvian tax”), a fine for excessive emissions, or a system of transferable pollution rights, requires verifying the damage that individual injurers actually caused.

Even if each individual’s contribution to social harm is unverifiable, the total harm caused by everyone is sometimes verifiable. For example, the environmental agency can measure total pollution much easier than it can measure the harm caused by each individual polluter. We propose a novel rule to control social costs in these circumstances: Hold each participant in the activity responsible for all of the excessive harm that everyone causes. By “excessive harm” we mean the difference between the total harm caused by all injurers and the optimal total harm. We call this rule “total liability for excessive harm.”

We will show that total liability for excessive harm creates incentives for efficient precaution and activity level, even though neither of them is verifiable. Incentives are efficient because each injurer internalizes the full benefit and cost of reducing the harm that he causes. Consequently, actual harm is not excessive and actual liability is nil. For

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\* Robert Cooter is Herman Selvin Professor of Law, University of California at Berkeley. Ariel Porat is Dean and Professor of Law, Tel Aviv University Faculty of Law. The authors are grateful for comments from Aaron Edlin, Daniel Farber, Steve Sugarman, Omri Yadlin, participants in the law faculty workshop at Haifa University, and participants in the Berkeley Law and Economics Workshop.

example, the environmental agency can set a target for clean air and announce that each factory is liable for pollution by all factories that exceeds the target. Since the liability rule causes the factories to hit the target, they pay no damages. Thus the environmental agency gains control over emissions without having to monitor individual polluters, and the polluters do not have to pay damages or conform to bureaucratic regulations.

To illustrate with numbers, assume that 2 factories each emit pollution of 150 into a river, and 3 factories each emit pollution of 100, so total pollution equals 600. The environmental agency measures total pollution in the river, estimates the socially efficient level of pollution, and sets a target of 500. If the environmental agency adopts our proposal, it will announce that each factory will be liable in the future for actual pollution that exceeds the target. For example, if the factories continue polluting as in the past, each of the five factories will be liable for 100. We will show that the factories will respond by reducing pollution until its total equals 500.

The rule of total liability for excessive harm actually combines two forms of liability: the rule of liability for excessive harm and the rule of total liability. “Excessive harm” refers to the fact that the injurer is liable for harm that exceeds a legal target. “Total liability” refers to the fact that each injurer is liable for the harm caused by all injurers. We will examine these two forms of liability separately. Part I analyzes the rule of liability for excessive harm caused by an individual. Thus Part I assumes verifiability of harm caused by each individual. Given verifiability of individual harm, we show that liability for excessive harm results in efficient precaution and activity level. We do not discuss total liability in Part I. Part II analyzes the rule of total liability for excessive harm. Thus Part II assumes unverifiable harm caused by individuals. We show the superiority of the rule of total liability for excessive harm over its alternatives.

The economic analysis of liability usually distinguishes between precaution and activity level. For example, a motorist decides how carefully to drive and how much to drive. Similarly, an industrialist decides how carefully to produce and how much to produce. This paper also emphasizes the neglected distinction between participation and activity level. To illustrate, an individual decides whether to buy a car. Deciding to participate in driving by buying a car is distinct from deciding how much to drive.

Similarly, deciding to participate in manufacturing by building a factory is distinct from deciding how much to produce in it.

When liability is approached from the viewpoint of verifiability, participation and activity level should be distinguished, not treated as one. They should be distinguished because participation, which requires initial investment, is relatively easy to verify, whereas activity level is relatively difficult to verify. To illustrate, it is relatively easy to determine the number of cars and the number of factories, and it is relatively difficult to determine how much each car is driven or how much each factory produces. Consequently, authorities can tax participation in circumstances where activity level is not taxable.

Unlike most of the existing literature, we analyze “participation” separately from “activity level.” We show that the rule of liability for excessive harm results in optimal activity level. We also show that the rule of liability for excessive harm results in excessive participation. To illustrate, the rule of liability for excessive harm by polluting factories leads to the optimal amount of production by each factory (optimal activity level), and too many factories (excessive participation). To obtain optimal incentives to participate, we advocate imposing a participation tax. By setting a participation tax at the right level, participation falls from excessive to optimal. Part III compares participation level under alternative liability rules to optimal participation and explains how to optimize the participation tax rate.

Part IV extends the analysis to situations where some injurers act irrationally or erroneously, and the authorities make errors in applying the rule of total liability for excessive harm. Part V extends the analysis to the incentives of victims. Part VI discusses applications through some additional examples. After the conclusion in Part VII, a mathematical appendix proves the propositions formulated in the paper.

## **I. Liability for Excessive Harm**

Analyzing the efficiency of alternative liability rules is a significant achievement of the economic analysis of law.<sup>1</sup> We build on this analysis by repeating the familiar

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<sup>1</sup> See Guido Calabresi, *The Costs of Accidents* (1970); John Brown, "Toward an Economic Theory of Liability," 2 *J. Legal Studies* 323-349 (1973); Stephen Shavell, "Strict Liability vs. Negligence" 9 *J. Legal*

results and extending them to the novel rule of liability for excessive harm. We begin with this example.

Example 1. An industrialist must decide whether or not to build a factory that will cost  $k$ . If the industrialist builds the factory, its smoke will cause harm  $h$  to the neighbors. Without abatement, harm  $h$  equals 150. By taking precautions costing 15, the factory can reduce the actual harm by 30. Further, by reducing production at a cost of 10 in foregone profits, the factory can reduce the actual harm by 20. Socially optimal behavior requires the factory to take precaution and reduce activity level, thus abating by 50 at a cost of 25. Socially optimal abatement results in optimal harm  $h^*$  equal to 100.

We will consider the incentive effects of different liability rules in example 1. Our discussion initially assumes that transaction costs prevent the industrialist and the neighbors from bargaining with each other. We also assume that, unlike the industrialist, the neighbors can do nothing to reduce harm.

Assume for now that the industrialist in Example 1 builds the factory and consider the incentives created for the industrialist by a rule of strict liability. To implement the rule of strict liability, the authorities must be able to verify the actual harm caused by the factory, but they do not need to be able to verify the industrialist's precaution or activity level. Assuming verifiability of actual harm, a rule of strict liability for actual harm causes the industrialist to choose between not abating and paying damages of 150, or abating at a cost of 25 and paying damages of 100. Since the later is cheaper, industrialist will abate and total pollution will equal 100.

These facts corresponds to this familiar generalization:

Proposition 1. Strict liability. Assume that  $m$  actors participate in an activity with unverifiable activity levels and unverifiable precautions that cause external harm  $H$ . Assume that individual harm  $h^i$  is verifiable for all  $m$  participants. Strict liability of injurer  $i$  for the harm  $h^i$  creates socially optimal incentives with respect to his precautions and activity level.

Instead of strict liability, now consider the consequences of a negligence rule in Example 1. A negligence rule holds the polluter liable for harm caused by not taking socially optimal precaution, but does not hold him liable for inefficient activity level. If

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*Studies 1* (1980). For a summary of conclusions, see Robert Cooter and Thomas Ulen, *Law and Economics* (4<sup>th</sup> edition, 2003), chapter 8.

the industrialist's precautions are unverifiable, then liability for failing to take precaution is unprovable and results in no liability. Thus a negligence rule does not create effective incentives for unverifiable precautions. Assume, however, that individual precaution is verifiable, so a negligence rule creates effective incentives for precaution. In Example 1, an effective negligence rule causes polluter to choose between not taking precaution and paying damages of 30, or spending 15 on precaution and not paying damages. Since the later is cheaper, polluter will take precaution.

Under a negligence rule, however, polluter gains nothing by reducing activity level and foregoing profits. The industrialist has no incentive to reduce production at a cost of 10 in foregone profits in order to reduce the harm from pollution by 20. Thus the industrialist in Example 1 will take precaution and not restrain production. His pollution, consequently, will equal 120, whereas socially optimal pollution equals 100.

These facts corresponds to this familiar generalization:

Proposition 2. Negligence. Assume that  $m$  actors participate in an activity with unverifiable activity levels and verifiable precautions  $x_p^i$  that cause external harm  $H$ . Assume that individual harm  $h^i$  is verifiable for all  $m$  participants. Assume that law imposes a legal standard of care at the social optimum,  $x_p^{i*}$ , and injurer  $i$  is liable for the harm  $h^i$  that occurs when his care falls below the legal standard, but not otherwise. As long as the precautions are verifiable, his precautions will be efficient, and his activity level will be inefficient.

Propositions 1 and 2 indicate two major advantages of a rule of strict liability over a negligence rule. First, unlike a negligence rule, a rule of strict liability does not require verifying the injurer's actual precaution level. Second, strict liability induces efficient activity level, whereas a negligence rule does not.<sup>2</sup> Given these disadvantages, why are negligence rules so common? A negligence rule has two main advantages that encourage its adoption. First, some moralists argue that a negligence rule is fairer because faultless injurers are not held liable.<sup>3</sup> Second, economists argue that a negligence rule provides

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<sup>2</sup> Solving the problem of excessive activity level under a negligence rule requires a tax on the activity level. Courts cannot levy taxes.

<sup>3</sup> Cf Gary T. Schwartz, "Vitality of Negligence and the Ethics of Strict Liability" 15 *Ga. L. Rev.* 963 (1981); Ernest Weinrib, *The Idea of Private Law* (1995); Tony Honore, "Responsibility and Luck: The Moral Basis of Strict Liability" 104 *Law Quarterly Rev.* 530 (1988); Stephen R. Perry, "The Moral Foundation of Tort Law" 77 *Iowa L. Rev.* 449 (1992). For the argument that corrective justice mandates strict liability, see Richard Epstein, "A Theory of Strict Liability" 2 *J. Legal Studies* 151 (1973). For the argument that

better incentives than strict liability for victims. Specifically, a negligence rule can create incentives for efficient precaution and activity level by victims, as well as injurers.<sup>4</sup>

We will show that the new rule of liability for excessive harm has the two advantages of a rule of strict liability and also the two advantages of a negligence rule. First, like a rule of strict liability, a rule of liability for excessive harm does not require verifying the injurer's actual precaution. Instead, our new rule requires identifying the socially optimal level of harm. Later we discuss examples where verifying actual precaution is harder than verifying optimal harm.

Second, like a rule of strict liability, a rule of liability for excessive harm creates incentives for efficient activity level, not merely incentives for efficient precaution. Efficient incentives are created without needing to verify precaution or activity level. To illustrate by Example 1, "excessive harm" equals the difference between actual harm and optimal harm of 100. Liability for excessive harm causes polluter to choose between causing actual harm of 150 and paying damages of 50, or paying abatement costs of 25 and paying damages of 0. Since the later is cheaper, polluter will abate at the socially optimal level. Efficient abatement encompasses both efficient precaution and efficient activity level.

This conclusion generalizes as follows:

Proposition 3. Excessive harm. Assume that  $m$  actors participate in an activity with unverifiable activity levels and unverifiable precautions that cause verifiable external harm  $H$ . Assume the individual harm  $h^i$  and the optimal harm  $h^*$  are verifiable. Individual liability for excessive harm ( $h^i - h^*$ ) gives the injurer socially optimal incentives with respect to his precaution and activity level.

To understand why Proposition 3 is true, compare the difference in incentives between a rule of strict liability and a rule of liability for excessive harm. A rule of strict liability creates efficient incentives by making the injurer internalize the *total* benefits and costs of precaution and activity level. Total benefits and costs include marginal and infra-marginal benefits and costs. In contrast, a rule of liability for excessive harm creates

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sometimes a strict liability rule and sometimes a negligence rule is consistent with fairness, see George Fletcher, "Fairness and Utility in Tort Theory" 85 *Harv. L. Rev.* 537 (1972).

<sup>4</sup> See Richard Posner, "Strict Liability: A Comment" 2 *J. Legal Studies* 205 (1973); Cooter and Ulen, *supra* note 1, chapter 8.



efficient incentives by making the injurer internalize the *marginal* benefits and costs of precaution and activity level, but not the infra-marginal benefits and costs. The two rules differ in the allocation of infra-marginal costs. Specifically, when harm is optimal, the injurer bears its costs under a rule of strict liability, but not under a rule of liability for excessive harm. To illustrate by Example 1, a rule of strict liability causes polluter to abate and pay 100 for actual harm, whereas a rule of liability for excessive harm causes polluter to abate and not pay for actual harm of 100. Under both rules, the injurer saves 25 by abating (same marginal incentives), but the first rule allocates optimal harm of 100 (infra-marginal harm) to the injurer and the second rule does not.

The different way the two rules allocate infra-marginal costs explains why a rule of liability for excessive harm has the first advantage of a negligence rule: faultless actors are not held liable.<sup>5</sup> The different way the two rules allocate infra-marginal costs also explains why a rule of liability for excessive harm has the second advantage of a negligence rule: victims have better incentives. Under a rule of negligence or a rule of liability for excessive harm, rational injurers conform to the rule, so the cost of optimal harm remains where it falls. When harm remains with the victims on whom it falls, victims have an incentive to reduce the harm that they suffer.<sup>6</sup>

The rule of liability for excessive harm can be characterized as an improved negligence rule. Both the rule of excessive harm and the regular negligence rule aim at allocating any harm above the optimal level to the victim. Consequently, the two rules create similar incentives and costs for the victim.<sup>7</sup> Both rules also create efficient incentives for the injurer's precaution. The two rules differ, however, in their information requirements and their influence on the injurer's activity level. First, the implementation of the regular negligence rule requires the verification of actual and optimal precautions, whereas the rule of excessive harm requires the verification of actual and optimal harm. Second, the regular negligence rule could result in excessive activity level, while the rule of excessive harm results in optimal activity level.

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<sup>5</sup> Moreover, one could argue that under a negligence rule, one type of faulty injurer escape liability: The injurers with optimal precaution and excessive activity level. However, they cannot escape liability under our rule of liability for excessive harm.

<sup>6</sup> Victims' incentives are analyzed in Part V.

<sup>7</sup> But not the *same* incentives and costs: under the regular negligence rule harms caused by inefficiently excessive activity would fall on the victim, while under the excessive liability rule those harms would fall on the injurer.

## II. Total Liability

Part I assumes that the actual harm caused by the individual injurer is verifiable, as required to implement a rule of strict liability, negligence, or liability for excessive harm. In practice, however, victims often suffer from harm caused by many injurers whose individual contributions are unverifiable. We will explain how to circumvent this problem by applying the principle of total liability, which holds each injurer liable for that harm that all of them caused. We will compare three forms of total liability and show that total liability for excessive harm is the best one.

To begin, we modify the preceding example.

Example 2. Each one of a large number of  $n$  identical industrialists must decide whether or not to build a factory that will cost  $k$ . Let  $m$  denote the number of factories that get built. Without abating, the smoke from each factory will cause social harm  $h$  equal to 150 and all  $m$  factories will cause total social harm  $H$  equal to  $150m$ . By taking precaution and reducing activity, each factory can abate. With abating at a cost of 25 per factory, the smoke from each factory will cause social harm  $h$  equal to 100 and all  $m$  factories will cause total social harm  $H$  equal to  $100m$ . Socially optimal behavior requires each factory to abate, so the optimal individual harm  $h^*$  equals 100 and the optimal total harm  $H^*$  equals  $100m$ .

Each industrialist has to submit the factory's design to officials. By examining the designs, officials can verify the total harm  $H^*$  that all  $m$  factories ideally cause. Officials can also verify the total harm  $H$  that all  $m$  factories actually cause. However, officials cannot verify the actual  $h$  caused by any individual factory or the actual precautions and activity level that determines  $h$ .<sup>8</sup>

Given the restrictions on verifiability in Example 2, officials must resort to a liability rule based on total harm. It is easy to think of many possible rules of liability for total harm. We will compare the incentive effects of the following three rules, which seem most important:

- i. strict total liability. Each of the  $m$  factories is liable for actual total pollution  $H$ .
- ii. total liability for excessive harm. Each of the  $m$  factories is liable for the amount that actual total pollution exceeds optimal total pollution:  $H - H^*$ .
- iii. proportionate liability: Each of the  $m$  factories is liable for an equal proportion of total pollution:  $H/m$ .

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<sup>8</sup> As in Example 1, we implicitly assume that the neighbors can do nothing to reduce harm, and transaction costs prevent the industrialist and the neighbors from solving the problem by private bargaining.

Under a rule of strict total liability, each factory that abates at a cost of 25 reduces its liability by 50. Consequently, each factory chooses to abate, as required for efficiency. This conclusion generalizes as follows:

Proposition 4. Strict total liability. Assume that  $m$  actors participate in an activity with unverifiable activity levels, unverifiable precautions and unverifiable individual harm  $h^i$ . Assume that actual total harm  $H$  is verifiable. Also assume that transaction costs prevent collusion among participants.<sup>9</sup> Liability for total harm  $H$  gives each injurer socially optimal incentives with respect to precautions and activity level.<sup>10</sup>

The truth of Proposition 4 is easily explained in terms of infra-marginal and marginal costs. With respect to the allocation of infra-marginal costs, the familiar rule of strict liability for individual harm differs from the novel rule of strict total liability. However, infra-marginal costs do not effect incentives for precaution and activity level of participants. With respect to the allocation of marginal costs, the familiar rule of strict liability for individual harm is the same as the novel rule of strict total liability. Marginal costs determine incentives for precaution and activity level of participants. As formulated in Proposition 1, strict liability for individual harm provides incentives for efficient precaution and activity level. Consequently, the rule of strict total liability also provides incentives for efficient precaution and activity level.

We will restate this argument using our notation. Individual  $i$  causes harm  $h^i$  that is part of total harm  $H$ . Thus liability for  $H$  makes each factory  $i$  internalize the benefit from reducing its part of harm  $h^i$ . In addition, injurer  $i$  also bears the cost of harm caused by others. Injurer  $i$  cannot influence the harm caused by others except through collusion. By assumption, Proposition 4 rules out collusion. Since injurer  $i$  cannot influence the harm caused by others, these costs do not effect  $i$ 's incentives for precaution and activity level.

Having discussed incentives under strict total liability, we next consider incentives under the rule of total liability for excessive harm. When this rule is applied to Example 2, each factory that abates at a cost of 25 reduces its liability by 50.

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<sup>9</sup> We later discuss this assumption.

<sup>10</sup> See Devra L. Golbe and Lawrence J. White "Market Share Liability and its Alternatives" *Center for Law and Business Working Paper #CLB-99-014* (September 17, 1999).

Consequently, each factory has an incentive to abate at the efficient level, as expressed in this generalization.

Proposition 5. Total liability for excessive harm. Assume that  $m$  actors participate in an activity with unverifiable activity levels, unverifiable precautions and unverifiable individual harm  $h^i$ . Assume that actual total harm  $H$  and optimal total harm  $H^*$  are verifiable. Also assume that transaction costs prevent collusion among participants. Liability for excessive harm  $H-H^*$  gives each injurer efficient incentives with respect to precautions and activity level.

As with Proposition 4, Proposition 5 is true because injurer's marginal costs of precaution and activity level are the same under the rule of total liability for excessive harm as under the rule of strict liability for individual harm. In spite of this advantage, the rule may seem unfair because individual injurers are threatened with liability for harm caused by others. When individual injurers are rational and make no errors, however, the incentives created by the rule causes actors to behave optimally, so actual total harm is not excessive and the threat of liability is not carried out.

One important advantage of the rule of total liability for excessive harm over the rule of total strict liability concerns incentives to collude. The rule of total strict liability provides incentives to collude and reduce social harm beyond the optimum. To understand why, apply a rule of total strict liability to Example 2. Under such a rule, the  $m$  participants would gain *together*  $m$  times the value of any harm they prevent. If they can collude they would over-invest in precautions and inefficiently reduce activity levels. However, under a rule of total excessive harm, each participant gains nothing if actual total harm  $H$  falls below optimal total harm  $H^*$ . Colluding to reduce  $H$  below  $H^*$  gains nothing for them, so they have no incentive to do it.<sup>11</sup>

Unlike strict total liability and total liability for excessive harm, a rule of proportionate liability does not create incentives for optimal precaution and activity level. When a rule of proportionate liability is applied to Example 2, each factory that abates at a cost of 25 reduces its liability by  $50/m$ . If  $m$  is larger than 2 in Example 2, then abating costs each factory more than it saves in liability costs, so the factories will not abate. So a

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<sup>11</sup> Even under a rule of total liability for excessive harm, errors or irrationalities might cause the parties to gain from collusion. We discuss errors and irrationalities later in the paper.

rule of proportionate liability does not create incentives for optimal precaution and activity level.<sup>12</sup> This conclusion can be formalized as follows.

Proposition 6. Proportionate liability. Assume that  $m$  actors participate in an activity with unverifiable activity levels, unverifiable precautions and unverifiable individual harm  $h^i$ . Assume that actual total harm  $H$  is verifiable. Also assume that transaction costs prevent collusion among participants. Liability for proportionate harm ( $H/m$ ) gives each injurer deficient incentives with respect to precautions and activity level.

### III. Participation

Comparing Propositions 4, 5, and 6, we see that the rule of strict total liability and the rule of total liability for excessive harm provide incentives for efficient precaution and activity level, whereas the rule of proportionate liability does not. Between the two efficient rules, why prefer total liability for excessive harm rather than strict total liability? The rule of strict total liability has a decisive objection. Although the rule induces efficient precaution and activity level by participants, it over-burdens participation in the industry and reduces the number of participants below the efficient level. Specifically, strict total liability causes each of the  $m$  participants in the industry to pay damages of  $H$ , whereas the harm that each one causes is only  $h^i$ . To illustrate numerically by Example 2, if  $m$  equals 5, then strict total liability causes each of the 5 participants in the industry to pay damage of 500, whereas the harm that each one causes is only 100. A rule of strict total liability allocates much more infra-marginal cost to each injurer than he actually causes, which results in far too little participation. This fact makes a rule of strict total liability impractical.

For the rule of total liability for excessive harm, the analysis of participation reaches a different result. As we have explained, total liability for excessive harm gives each participant in an industry incentives to abate optimally, so total harm  $H$  equals  $H^*$  and liability is zero. Instead of being zero, the harm that each one causes is  $h^i$ . To illustrate by 2, total liability for excessive harm causes each of the  $m$  participants in the industry to pay damage of 0, whereas the harm that each one causes is 100. Under these

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<sup>12</sup> Notice however, that when individual precautions and activity level is verifiable, a rule of proportionate liability may be optimal. See Ariel Porat and Alex Stein, *Tort Liability under Uncertainty* (Oxford University press, 2001) 101-59.

circumstances, injurers cause somewhat more harm than they pay in damages, which results in somewhat too much participation.

Whereas the rule of strict total liability grossly over-burdens participation, the rule of total liability for excessive harm modestly under-burdens participation. As we will explain, modest over-participation is tolerable or correctable, so the rule of total liability for excessive harm is preferable to the rule of strict total liability. First, however, we need to develop the general analysis of participation levels.

When participating in an industry requires a fixed investment, such as buying a car or building a factory, participants are all the decision makers who make the fixed investment. In these circumstances, verifying participation is relatively easy, whereas verifying activity level is often difficult. Since participation can be verified, it can be taxed or subsidized, whereas activity level cannot be taxed or subsidized. A participation tax will decrease it, and a participation subsidy will increase it.

We exclusively discuss a *lump sum* tax or subsidy, which, by definition, does not vary with the participant's activity level. Thus a lump sum tax on cars requires each owner of a given type of car to pay the same amount, regardless of how much he drives. Similarly, a lump sum tax on factories requires each owner of a certain type of factory to pay the same amount, regardless of how much he produces. A lump sum tax or subsidy on participation will not affect the precaution or activity level of participants. Consequently, we can use the lump sum tax or subsidy to adjust the level of participation, without changing the participants' incentives for precaution and activity level. And we can use the liability rule, such as strict total liability or total liability for excessive harm, to control precaution and activity level.

Optimal incentives for participation require the injurer to internalize the cost that his participation imposes on others. The liability rule causes the participant to internalize some of these costs. Consequently, the participation tax should equal the social costs of participation that optimal liability does *not* impose. Under the rule of strict total liability, each participant has optimal incentives for precaution and activity level, so injurer *i* imposes social costs  $h^{*i}$  on others. Under the rule of strict total liability, each participant faces liability  $H^*$ . Thus the social costs of participation that optimal liability does not impose, which is the optimal participation tax, equals  $h^{*i} - H^*$ . This is typically a large

negative number, so each participant receives a large participation subsidy. To illustrate by Example 2, the optimal participation subsidy under a rule of strict total liability equals  $100(m-1)$ . Given 5 participants, the optimal participation subsidy equals 400.

Similarly, under the rule of total liability for excessive harm, each participating injurer  $i$  imposes social costs  $h^{*i}$  on others. Under the rule of total liability for excessive harm, each participating injurer faces liability 0. Thus the social costs of participation that optimal liability does not impose, which is the optimal participation tax, equals  $h^{*i}$ . To illustrate by Example 2, the optimal participation tax under a rule of total liability for excessive harm equals 100.

The following generalization formalizes this result.

Proposition 7: Optimal participation. Assume that  $n$  actors potentially participate in an activity. Assume that participants face liability  $l^{*i}$  that induces socially optimal precaution and activity level. Assume that external harm  $H$  increases with more participation. Incentives for an optimal number of the  $n$  actors to participate are achieved if each actor  $i$  who participates pays a lump sum tax equal to the harm  $h^{*i}$  caused by participating at optimal level of activity and precaution, minus the liability  $l^{*i}$ .

Now we summarize our conclusions about participation. A rule of strict liability for individual harm causes each injurer to internalize the harm caused by his participation, as required for efficient participation. A participation tax is unnecessary. In contrast, a rule of strict total liability causes each injurer to internalize  $H^*-h^{*i}$  *more* harm than he actually causes. Consequently, inducing optimal participation under a rule of strict total liability requires a participation subsidy equal to  $H^*-h^{*i}$ , which can be a very large number.<sup>13</sup> Without the participation subsidy, a rule of strict total liability causes deficient participation. In contrast, a rule of total liability for excessive harm provides incentives for injurers to meet the target  $H^*$  for optimal harm, in which case their liability equals zero. When liability is zero, Proposition 7 indicates that optimal incentives for

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<sup>13</sup> Notice that the subsidy depends on optimal values  $H^*-h^{*i}$ , not on actual values  $H-h^i$ . If actual values determine the subsidy, injurers will recognize that the subsidy will increase as the total harm  $H$  increases, which distorts their incentives. If ideal values determine the subsidy, then actual precautions and actual activity level does not affect the subsidy, so the existence of the subsidy does not change injurer's incentives for precautions and activity level.

participation requires each injurer to pay a lump sum tax equal to the harm  $h^{*i}$  caused by participating at optimal precaution and activity level.<sup>14</sup>

We have shown that optimal participation can be achieved by a rule of total liability for excessive harm, combined with a participation tax equal to the harm that the injurer causes when his behavior is optimal. To illustrate by Example 2, assume that the environmental agency imposes a rule of total liability for excessive harm. In addition, the environmental agency examines the designs for factory  $i$  and determines that its pollution will cause harm of 100 when it abates optimally. To give the industrialist efficient incentives to build or not build the factory, the environmental agency should assess a participation tax of 100 for building the factory.

We summarize the main conclusions of our paper in two tables. Table 1 shows the variables that must be verifiable in order to implement each of the liability rules. Table 2 assumes that participation subsidy or tax is unavailable and compares the efficiency of the most important liability rules.

**Table 1: Verifiability and Liability**

Legal rule	Total Harm $H$	Ideal Harm $H^*$	actual individual harm $h$	ideal individual harm $h^*$	actual individual precaution $x$	ideal individual precaution $x^*$
total strict liability	√					
total excessive harm	√	√				
individual strict liability			√			
individual excessive harm			√	√		
Negligence			√		√	√

<sup>14</sup> Notice that the tax depends on optimal values  $h^{*i}$ , not on actual values  $h^i$ . See *supra* note.



**Table 2: Efficiency of Injurer's Behavior**

Legal Rule	Precaution?	Activity Level?	Participation?
total strict liability	√	√	far too low
total excessive harm	√	√	moderately too high
individual strict liability	√	√	√
individual excessive harm	√	√	moderately too high
Negligence	√	too high	moderately too high

#### IV. Errors and Irrationality

We have explained that the rule of total liability for excessive harm creates incentives for efficient precaution and activity level, so actual harm is not excessive and actual liability is nil. This result, however, requires the authorities to make no errors in assessing liability. Implementing the rule requires setting the target  $H^*$  and then observing total harm  $H$ . We will explain the consequences of errors by the authorities in setting the target  $H^*$  and observing the total harm  $H$ . We will also consider the consequences of irrationality or errors by injurers in responding to the liability rule. Irrationalities and errors come in many types and we will only consider the main ones.

Total liability for excessive harm requires each injurer to pay the difference between actual harm  $H$  and socially optimal harm  $H^*$ . One type of error consists in the authorities overestimating or underestimating the actual harm by error  $\varepsilon$ . We call  $H+\varepsilon$  the harm *observed* by the authorities, when  $\varepsilon>0$  implies an overestimation and  $\varepsilon<0$  implies an underestimation. Under the rule of total liability for excessive harm, each injurer is liable when the total *observed* harm exceeds the social optimum,  $H+\varepsilon> H^*$ , in which case liability equals the total observed excess  $H+\varepsilon- H^*$ . Otherwise the injurer is not liable.

Another type of error occurs when the authorities observe the social optimum  $H^*$  with error  $\varepsilon$ , which we write  $H^*+\varepsilon$ . The authorities over-estimate the socially optimal

harm when  $\varepsilon > 0$ , and the authorities under-estimate the socially optimal harm when  $\varepsilon < 0$ . Under the rule of total liability for excessive harm, each injurer is liable when the total harm exceeds the observed social optimum,  $H > H^* + \varepsilon$ , in which case liability equals the total observed excess  $H - H^* - \varepsilon$ . Otherwise the injurer is not liable.

Obviously the situation described in the preceding paragraph where the authorities make an error in observing the target  $H^*$ , is mathematically identical to the previous situation where authorities make an error in observing the actual harm  $H$ . To be more precise, over-estimating actual harm  $H$  and attributing more harm to injurers than they actually caused is mathematically equivalent to under-estimating the socially optimal harm  $H^*$  and setting the target too low. In either case, the error causes injurers who set actual harm equal to social optimal harm to be held liable by mistake.

When the kind of error that we are discussing occurs, it is usually a random variable. Random errors can be unbiased, in which case their expected value is zero: ( $E(\varepsilon) = 0$ ). In the presence of random, unbiased errors in observing total harm  $H$  or setting ideal harm  $H^*$ , the rule of total liability for excessive harm induces socially optimal precaution and activity levels among risk-neutral injurers. This is a specific form of the proposition that random, unbiased errors do not change the behavior of risk-neutral actors.

Alternatively, random errors can be biased, in which case their expected value is not zero: ( $E(\varepsilon) \neq 0$ ). For errors biased towards lower liability (errors of under-estimation of actual harm  $H$  or over-estimation of socially optimal harm  $H^*$ ), we can show that the rule of total liability for excessive harm induces too little precaution and too much activity. Errors biased towards lower liability result in too much harm because injurers escape liability at a level of actual harm that is excessive. Having escaped liability, injurers have no incentive to reduce social harm any further. This conclusion is robust.

Conversely, for errors biased towards higher liability (errors of over-estimation of actual harm  $H$  or under-estimation of socially optimal harm  $H^*$ ), the rule of total liability for excessive harm induces socially optimal precaution and activity level. To see why, consider the situation of an injurer whose behavior is socially optimal. By assumption the authorities mistakenly set the target too low, or they mistakenly observe more total harm than actually occurs. Consequently, even though all of the injurers behave optimally, they

still face liability. A small increase in precaution or a small decrease in activity level by any injurer will reduce his liability. The injurer thus internalizes the benefits and costs of reducing the total harm. Since his behavior is already socially optimal, a small increase in precaution or decrease in activity costs him more than the resulting reduction in liability. The injurer, consequently, prefers to continue behaving optimally with respect to precaution and activity level. (We discuss participation level later.) Thus the error biased towards higher liability does not cause injurers who behave optimally to stop doing so.

With respect to errors biased towards higher liability, however, the incentives for optimal behavior are not robust. Injurers have a strong incentive to collude with each other in order to reduce the level of actual harm  $H$  below the socially optimal level  $H^*$ . By colluding to reduce actual harm  $H$ , the injurers can eliminate the excessive harm mistakenly observed by the authorities. Since each injurer is liable for the total excessive harm mistakenly observed by the authorities, the groups of injurers saves a lot by escaping liability. In sum, an error by the authorities that increases liability under a rule of total liability for excessive harm provides socially optimal incentives to injurers who act strictly individually, but strong incentives also exist to collude and over-perform relative to the social optimum.<sup>15</sup>

To illustrate, assume that each of 5 polluters cause harm of 100, optimal harm  $H^*$  is 500, and the authorities mistakenly set the target at 400. Under the rule of total liability for excessive harm observed by the authorities, if the polluters continue at the socially optimal level of pollution, each one pays 100 in mistaken liability and the total liability paid by all of them equal 500. By colluding and reducing pollution from 500 to 400, the 5 polluters reduce their total liability from 500 to 0.

Proposition 8 formulates these conclusions, which the appendix proves.

Proposition 8. Total liability for excessive harm with random additive error. Assume that  $m$  risk-neutral actors participate in an activity with unverifiable activity levels and unverifiable precautions. Assume that actual total harm  $H$  and optimal total harm  $H^*$  are verifiable with additive error  $\varepsilon$ . When  $H + \varepsilon > H^*$ , each injurer is totally liable for  $H - H^* + \varepsilon$ . Otherwise each injurer is not liable.

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<sup>15</sup> Another reason the result is not robust, which we do not discuss, is that a discontinuity in social costs creates an incentive to over-perform in order to escape liability. The problem of discontinuity is discussed extensively in the literature on negligence. For a summary, see Cooter and Ulen, *supra* note 1, Chapter 8.

- (i). If the expected error is unbiased ( $E(\varepsilon)=0$ ), then the injurer has socially efficient incentives with respect to precautions and activity level.
- (ii). If the expected error is biased towards a legal standard that is too low ( $E(\varepsilon)<0$ ), then the injurer has incentives for too little precaution and too much activity.
- (iii). If the expected error is biased towards a legal standard that is too high ( $E(\varepsilon)>0$ ), then the injurer has incentives to take optimal precaution and activity (but optimal incentives are vulnerable to collusion).

We have discussed the consequences of random error on precaution and activity level. We also note briefly the consequences of random error on participation. Unbiased error does not change the expected payoffs for risk neutral injurers, so unbiased error does not change their incentives for participation. Error biased towards a legal standard that is too low increases the payoffs from participation. Consequently, participation will increase, assuming the participation tax remains constant. Conversely, error biased towards a legal standard that is too high decreases the payoffs from participation. Consequently, participation will decrease, assuming the participation tax remains constant.

We have analyzed the consequences of simple, additive errors by authorities in observing actual or optimal harm.<sup>16</sup> Now we turn to the consequences of irrationality or errors by some actors. We will explain how rational actors respond to the presence of irrationality by some other actors. We will not discuss how to influence irrational actors, which, would require a psychological theory of behavior that we have not developed in this paper.

We can model irrationality as an error that causes actual behavior to deviate from rational behavior. We have explained that rational actors respond to a rule of total liability for excessive harm by causing total harm  $H$  to equal the target  $H^*$ . We can analyze irrationality as a situation where actors respond to a rule of total liability for excessive harm by causing total harm  $H$  *not* to equal the target  $H^*$ . From the viewpoint of

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<sup>16</sup> Proposition 8 and the discussion leading up to it assumes the error in observation by authorities adds to, or subtracts from, the actual harm  $H$  or the optimal harm  $H^*$ . Our conclusions would be quite different if the error multiplied the actual harm  $H$  or optimal harm  $H^*$ . To illustrate multiplicative error, the authorities may underestimate actual harm by 10%, or the authorities may overestimate the socially optimal harm by 15%. With a multiplicative error, the extent of liability under the rule of total liability for excessive harm can be written  $H(1+\varepsilon)-H^*$ , or  $H-H^*(1-\varepsilon)$ . Multiplicative error affects marginal values, whereas additive error often does not affect marginal values. The effect of multiplicative errors on marginal values change incentives of injurers in situations where additive errors cause no change.

rational actors, irrational behavior by others can be modeled as a random error  $\varepsilon$  such that  $H=H^*+\varepsilon$ . Proposition 8 already describes the effects of such a random error on the behavior of rational actors. Thus we can reinterpret Proposition 8 as an account of the incentive effects that irrational actors impose on rational actors.

For example, assume that irrational over-performance by some actors tends to offset irrational under-performance by others, so the expected error from irrational actors is nil:  $E(\varepsilon)=0$ . In these circumstances, Proposition 8 asserts that *rational* actors will choose the socially efficient precaution and activity level. (The irrational actors are wasting resources by taking too much or too little precaution, but we offer no theory for how to influence their behavior.)

In contrast, if irrational over-performance by some actors exceeds irrational under-performance by other actors, so that  $(E(\varepsilon)<0)$ , then Proposition 8 asserts that rational actors will abate too little. Finally, if irrational under-performance by some actors exceeds irrational over-performance by other actors, so that  $(E(\varepsilon)>0)$ , then Proposition 8 asserts that rational actors who do not collude will abate efficiently, but rational actors have an incentive to collude.

We have been discussing irrationality that takes the form of calculation errors by some actors. Under a rule of total liability for excessive harm, irrational actors who take too little precaution and too much activity reduce their own payoffs. That is why their behavior is irrational. However, they also reduce the payoffs of all the other injurers. Consequently, the other injurers have a strong incentive to help irrational actors correct their errors and start behaving rationally.

Conversely, when an irrational actor takes too much precaution and too little activity, the rational actors benefit from this mistake and they have no incentive to help the irrational actors correct their errors and start behaving rationally.<sup>17</sup>

A more sinister possibility is that an actor threatens to take too little precaution and too much activity in order to intimidate others. In other words, an actor threatens that he will impose liability on himself and everyone else unless the others do something to benefit him. Acting on a threat lowers the actor's payoff. Consequently, economists say

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<sup>17</sup> We implicitly assume that the authorities do not respond to irrational actors by adjusting the target. If the legal target adjusts to irrational actors, the analysis becomes more complicated.

that such a threat is not credible. In reality, incredible threats are sometimes effective. Special circumstances might arise where the rule of total liability for excessive harm enables someone to make incredible threats that intimidate others.<sup>18</sup> This possibility, however, is insufficient to justify rejecting the rule of total liability for excessive harm.

## V. Victims Incentives

We have been assuming that injurers can reduce social harm  $H$  and victims cannot reduce it. Now we relax the assumption that victims cannot influence the extent of social harm and we discuss briefly the incentives of alternative liability rules on victims. In general, when victims do not receive compensation, they internalize the benefits as well as the costs of their actions, so victims' incentives are socially efficient.<sup>19</sup> Consequently, if injurers are liable to the state and not liable to the victims, as with a pollution tax, then victim's incentives are efficient.

In terms of our notation, assume that injurers can reduce harm  $H$  by restraining their activity levels  $y$  and taking precaution  $x$ , and victims who suffer harm  $H$  can reduce it by acts  $z$ , so  $H=H(y,x,z)$ . The acts  $z$  may encompass precaution and activity level. If injurers are liable to the state and not to victims, then victims have incentives to chose  $z$  to equal the social optimum  $z^*$ .<sup>20</sup>

Instead of being liable to the state, injurers may be liable to the victims. If the extent of compensation received by victims depends on their actual behavior  $z$ , then they will have an incentive to increase their compensation by manipulating  $z$  and departing from the optimum  $z^*$ . For example, victims will manipulate  $z$  if their compensation equals the difference between actual harm  $H(y,x,z)$  and optimal harm  $H(y^*,x^*,z^*)$ . To avoid this problem, the state should set liability equal to the difference between the harm that would result given the actual behavior of injurers and ideal behavior of victims

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<sup>18</sup> For example, an actor might make such a threat to stop potential competitors from entering the industry. In this case, the threat to impose liability costs on oneself in order to impose them on some else resembles predatory pricing. With predatory pricing, a monopolist threatens to price below the cost of production in order to prevent a competitor from entering the industry.

<sup>19</sup> Similarly, a rule of negligence in simple economic models induces non-negligent behavior by injurers, so victims face the same incentives as under a rule of no liability. This proposition is proved in many places, including Cooter and Ulen, *supra* note 1, Chapter 8.

<sup>20</sup> If liability equals  $H-H(y^*,x^*,z)$ , and if  $z=z^*$  when  $y=y^*$  and  $x=x^*$ , then  $(y,x,z)=(y^*,x^*,z^*)$  is an equilibrium.

$H(y,x,z^*)$ , and the harm that would result given the ideal behavior of both injurers and victims  $H(y^*,x^*,z^*)$ . When liability follows this formula, victims receive compensation  $H(y,x,z^*) - H(y^*,x^*,z^*)$ , which they cannot influence by their actual behavior  $z$ . Note, however, that implementing requires the ability to verify  $H(y,x,z^*)$  and  $H(y^*,x^*,z^*)$ , which may be difficult or impractical.

## VI. Additional Examples and Applications

Having explained the theory of total liability for excessive harm, we discuss some applications.

Example 3: Provision of services -- hospitals. When Hospital A diagnoses melanoma, it refers the patient to Hospital B for treatment. The rate of death among patients diagnosed in hospital A and treated in hospital B is 20%. Experts using statistics determine that when diagnosis and treatment follow the best medical practices, the rate of death in the relevant population is 15%. The divergence between the optimal and actual death rate could result from tardy diagnosis by hospital A or deficient treatment by hospital B.

In Example 3, the hospital authority can impose a rule of total liability for excessive harm on hospital A and hospital B. Under such a rule, if the two hospitals continue to have a death rate of 20% and the optimal rate remains 15%, then each will pay for the excessive harm of 5%. Consequently, each hospital will have a strong incentive to adopt the optimal practices and lower the death rate to 15%. Also hospitals A and B will have a strong incentive, individually and collectively, to cooperate and help each other to lower their death rates. Once the death rate falls to the optimum, the hospitals are no longer liable for the death of melanoma patients.

A potential problem with this liability rule is that the two hospitals might attempt to improve their performance by refusing to take patients whose survival prospects are below average. For example, hospital A might not admit patients who delay too long and come to the hospital with an advanced stage of melanoma. This is the same problem of adverse selection that occurs currently in private medical insurance markets. This problem diminishes or disappears in so far as hospitals must accept all patients in need of care.

In our earlier analysis of pollution, we explained that when factories abate optimally, their participation in the market causes pollution. A participation tax can make them internalize these costs. This problem of participation, however, does not arise in the preceding case of hospitals. When hospitals diagnose and cure melanoma at the optimal rate, their participation in the medical market does not cause the remaining melanoma deaths. Unlike polluting factories, there is no need for a participation tax on hospitals. If hospitals are held liable for harm that they did not cause, their profitability will fall, which will discourage participation.<sup>21</sup> The rule of total liability for excessive harm avoids this problem by exempting hospitals that perform optimally from liability.

Example 4 applies the rule of liability for excessive harm to accidents.

Example 4: Product defects—exploding bottles. Company A supplies bottles to Company B who fills them with soda. Defective bottles supplied by A or defective filling of bottles by B can cause explosions that injure consumers.

In Example 4, the consumer protection agency could apply the rule of total liability for excessive harm. Under such a rule, the agency would collect statistics on the frequency of injuries to consumer of soda and determine the expected rate of injury for companies following the best practices. If the actual rate for company A and B exceeded the ideal rate, then the consumer protection agency could collect a fine from both companies. Thus the two firms would have a strong incentive to work together to reduce defects to the ideal level.

Now we consider pollution from moving sources.

Example 5: Pollution by buses. A city has three large bus companies. The fleet of buses varies in age, design, and state of repair. City officials can determine with reasonable accuracy the amount of total pollution caused by buses, but not the amount of pollution caused by each of the three companies. Before remedial action, the buses emit 100 units of pollution. The City sets a target of reducing total pollution to 90 units.

To achieve the City's goal in Example 5, the City could impose a rule of total liability for excessive harm, which would hold each of the three bus companies liable for

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<sup>21</sup> Sometimes there is a difference between optimal practices, and over-optimal practices, that can reduce harm even below the optimal level of harm. Still, one cannot argue that hospitals "caused" social harm when they took optimal practices (instead of over-optimal practices). To understand why, apply the "but for" causation test to hospital which takes the optimal level of care, and ask what would have been the social harm but for the participation of the hospital.



actual pollution exceeding the target of 90 units. This rule would give each of the three companies a strong incentive to reduce its own pollution and to collaborate with the other companies to help them reduce their pollution. The great advantage of the rule is that it creates efficient incentives for the three companies without requiring the City officials to inspect buses or enforce rules on their operation.

The preceding examples concern several injurers who caused separate, unverifiable harms. In addition, nature can contribute to the harm, without changing our conclusion about the efficiency of the rule of total liability for excessive harm. To illustrate, nature may create part of the pollution in Example 1. Furthermore, nature's contribution to total pollution in Example 1 may be unverifiable. Even so, the rule of total liability for excessive harm provides efficient incentives for the factories to pollute. (The participation tax is more complicated.<sup>22</sup>)

The last example that we give relates to mass tort cases, when human behavior and nature inflict injuries, and it is impossible to determine who caused each injury.

Example 6: The Radiation Case.<sup>23</sup> A factory negligently emits carcinogenic radiation. In the area affected by the radiation, the incidence of cancer rises by 25%: while prior to the factory's operation, only 80 people contracted cancer each year, 100 people now become afflicted each year. There is, however, no evidence that could preponderantly identify those people who actually contracted cancer as a result of exposure to the radiation, as opposed to those who are simply victims of misfortune.<sup>24</sup>

Applying our new rule of total liability for excessive harm to Example 6 would yield factory's liability equal to the harm suffered by 20 cancer victims. Damages could be paid to the state or to the 100 victims of cancer. The rule creates efficient incentives for the factory to reduce deaths from radiation.

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<sup>22</sup> If nature's contribution is unverifiable, then the authorities lack the information to calculate the ideal tax on participation. The ideal participation tax equals the pollution caused by a factory operating optimally, not the pollution caused by nature.

<sup>23</sup> See Porat & Stein, *supra* note, at p. 70.

<sup>24</sup> For a well-known case belonging to this category of cases and in which a settlement was reached, see *In re "Agent Orange" Product Liability Litigation*, 597 F. Supp. 740 (E.D.N.Y. 1984), *aff'd*, 818 F. 2d 145 (2d Cir. 1987).

## Conclusion

We conclude with some retrospective and prospective remarks about the idea of total liability for excessive harm. This idea combines “total liability” and “liability for excessive harm.” We found some history of the idea of total liability and no history for the idea of total liability for excessive harm.

Although its mathematical foundations are old,<sup>25</sup> the economic analysis of liability is relatively recent. The economic analysis of torts apparently began in the late 1960s and early 1970s.<sup>26</sup> Once the foundation was in place, many papers extended the economic analysis of liability law, some in ways that come close to the idea of total liability.<sup>27</sup> For example, some previous papers analyze the incentive effects of different liability rules when several injurers cause the same harm. To illustrate, when two cars collide and damage each other, the accident would have been avoided if either driver had

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<sup>25</sup> For a mathematician, much of the economic analysis of liability and taxation, including the idea of total liability, is implicitly present in the “marginalist revolution” of the late 19th century. This phrase refers to the reworking of economic theory by absorbing calculus into utilitarian reasoning. The marginalist revolution made economists appreciate the importance of marginal costs, as opposed to average costs or total costs. The derivative of a function does not change when a constant value is added to it. So the inputs that maximize a utility function or minimize a cost function do not change when a constant is added to the function. The fact that the optimum depends on marginal values, not infra-marginal values, is the germ of the idea that total liability creates efficient incentives.

<sup>26</sup> Vickery (1968) is a powerful paper that was not absorbed into the legal literature, whereas Calabresi’s book *The Costs of Accidents* (*supra* note), was foundational. See W. Vickery, “Automobile Accidents, Tort Law, Externalities, and Insurance: An Economist’s Critique” 33 *Law and Contemporary Problems* 465-487 (1968). Calabresi does not discuss the possibility that liability should rest on more than one actor. Clearly, he does not suggest that efficient incentives would be achieved if the injurer and victim each bear 100% of the accident’s costs. The developing subject was anticipated and described in Richard Posner’s *Economic Analysis of Law* (1972). The most relevant discussion concerns the rule of negligence with a defense of contributory negligence, which occurs in Chapter 4, circa page 70. Posner asks whether efficiency requires the injurer or victim to bear the cost of an accident, but he shows no awareness that imposing the cost on both of them would provide efficient incentives. The most important break-through in mathematical modeling of tort liability was made by Brown, who also does not consider the possibility of total liability: J. Brown, “Toward an Economic Theory of Liability” 2 *J. Legal Studies* 323-349 (1973).

<sup>27</sup> Green extended the mathematics. Shavell’s influential paper in 1980 on the distinction between precaution and activity level clarified the nature of the problem of incentives for injurer and victim (Calabresi discussed it earlier in his book: Calabresi, *ibid.*, pp....). These ideas were subsequently developed in a variety of papers where more than one actor influences the probability or magnitude of an accident. These papers mostly assumed that injurer’s damages would be paid to the victim as compensation. Subsequently a discussion developed as to whether injurer’s liability might be “decoupled” from damages plaintiff’s recovery. For all that, See J. R. Green, “On the Optimal Structure of Liability Laws” 7 *The Bell Journal of Economics* 553-574 (1976); Stephen Shavell, “An Analysis of Causation and the Scope of Liability in the Law of Torts” 9 *J. Legal Studies* 463-516 (1980); A. Leong, “Liability Rules When Injurers as Well As Victims Suffer Losses” 9 *International Review of Law and Economics* 105 (1989); J. H. Arlen, “Re-Examining Liability Rules When Injurers as Well as Victims Suffer Losses” 10 *International Review of Law and Economics* 233-239 (1990); A. M. Polinsky and Y. K. Che, “Decoupling Liability: Optimal Incentives for Care and Litigation” 22 *Rand J. Economics* 562-570 (1991).

stayed home. The drivers have efficient incentives if each of them must pay 100% of the cost of the harm suffered by both cars.<sup>28</sup> In addition, some previous papers analyze the incentive effects of different liability rules when several injurers harm several victims, but no one can verify which injurer caused which victim's harm. To illustrate, several companies manufacture the same drug that causes harm to several users, but the victims cannot prove who manufactured the drug that they took.<sup>29</sup> The literature on the economic analysis of tort liability contains some discussions that come close to, or explicitly mention, what we call "total liability",<sup>30</sup> although we know of no formal analysis.

Unlike tort liability, the literature on externality taxes contains at least one explicit analysis of the rule of total liability. An innovative paper by Segerson analyzes the consequences of taxing each polluter for total pollution that exceeds the social optimum, while also offering a subsidy to each polluter for total pollution that falls short of the social optimum.<sup>31</sup> In addition to literature on pollution, a largely independent literature on

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<sup>28</sup> Each driver is a "but-for" cause of the harm, so under prevalent law they are joint tortfeasors who are jointly and severally liable toward the victim for the full harm, and have contribution claims against each other. Some authors have discussed the possibility of a rule that holds each of the joint tortfeasors liable for full harm with no contribution claims among them. For example, when two automobiles collide, the drivers have efficient incentives if each of them must pay 100% of the cost of the harm suffered by both cars. Instead, prevalent liability law causes each of them pay 50% on average (given the contribution claims among tortfeasors). In intriguing research on automobile accidents, Edlin attempted to measure the extent of this externality. A motorist who drives more miles increases the risk of an accident. Part of this risk translates into higher insurance premiums for others, which Edlin calls the "insurance externality." Part of the external risk, however, does not translate into higher insurance premiums. For example, automobile deaths impose some losses of a kind that are uninsurable. Edlin considers market and tax mechanisms to make drivers internalize the insurance externality and non-insurance externalities that they impose on others. He shows that the revenue capacity for this kind of Pigouvian tax is very high in states where roads are congested. Edlin, however, does not discuss the rule of total liability for excessive harm and there is no reason why he should, since our rule is impractical when applied to automobile accidents.

<sup>29</sup> This is the case of separate tortfeasors who are responsible for separate, non-verifiable harms. For a discussion of the consequences of a rule of strict total liability, see Golbe and White, *supra* note.

<sup>30</sup> Posner and Landes (1987) and Shavell (1987) published comprehensive books on tort liability, but we cannot find in them the suggestion that several actors who caused separate non-verifiable harms should be held liable for the total harm (or excessive total harm) caused by all actors. See W. M. Landes, and R. Posner, *The Economic Structure of Tort Law* (Harvard University Press, 1987). Especially see *ibid.*, Chapter 7: "Joint and Multiple Torts", at pp. 190-227. See also S. Shavell, *Economic Analysis of Accident Law* (Harvard University Press, 1987). Especially see *ibid.*, Chapter 2: "Liability and Deterrence: Basic Theory", at pp. 5-46. Unfortunately, there are no comprehensive treatments that are more recent.

<sup>31</sup> K. Segerson, "Uncertainty and Incentives for Nonpoint Pollution Control" 15 *Journal of Environmental Economics and Management* 87-98 (1988). Also see T. J. Miceli and K. Segerson, "Joint Liability in Torts: Marginal and Infra-Marginal Efficiency" 11 *International Review of Law and Economics* 235-249 (1991). Miceli & Segerson proposed a form of total liability for ambient pollution, according to which under-achievement of a group's abatement goal results in a tax and over-achievement results in a subsidy. For under-achievement, Miceli & Segerson's tax has the same consequences as our rule of total liability for excessive harm. For over-achievement, however, Miceli & Segerson's subsidy creates a potentially fatal

the principal-agent problem offers some valuable insights into possibilities resembling total liability.<sup>32</sup> Unlike past work, this paper proposes and analyzes the rule of liability for excessive harm.

Having discussed its origins, we turn to the future prospects of the idea of total liability for excessive harm. The negligence rule for consumer product injuries was eventually replaced by a rule of strict liability. Problems of proof compelled the change. In our view, the same consideration must eventually lead to replacing individual liability with total liability for certain kinds of harm. The best form of such a rule is total liability for excessive harm. Perhaps the largest obstacle to gaining acceptance for this rule is that its consequences are counter-intuitive and, therefore, difficult for the public to understand. The fact that a rule of total liability for excessive harm induces socially optimal precautions and activity levels is a reason for everyone who understands this fact to favor the rule. The fact that each injurer's liability equals zero in equilibrium should make the rule especially attractive to injurers who understand this fact. The fact that no one actually pays for the equilibrium harm caused by another should allay the fear among those who understand it that the rule is unfair.<sup>33</sup>

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incentive problem. A group that reduces total pollution below the target receives a subsidy equal to a multiple of the total benefit created by their over-achievement. Consequently, by over-achieving they realize a private gain and cause a social loss. Over-achieving is privately profitably and socially costly. The rule of total liability for excessive harm avoids this problem by not paying subsidies for over-achieving relative to the target.

<sup>32</sup> Like the victim and injurer, efficient incentives for the principal and agent are achieved by double liability at the margin. This is true if the principal and agent can both influence outcomes, or if there are several agents. A classical paper that explores the equivalent of total liability for multiple agents is B. Holmstrom, "Moral Hazard in Teams" 13 *The Bell Journal of Economics* 324-340 (1982). The idea takes a somewhat different form in contracts in our theory of "anti-insurance": Robert Cooter and Ariel Porat, "Anti Insurance" 31 *J. of Legal Studies* 203 (2002). Both papers did not discuss however the case of actors liable for outcomes, part of them caused by other actors, which is the gist of this present paper.

<sup>33</sup> The argument for the rule's fairness resembles the utilitarian justification of an effective deterrent: An "effective" deterrent is fair because it does not have to be used. Utilitarian and deontological traditions disagree about whether a very harsh penalty that perfectly deters and never require use should be praised for its good consequences or condemned for its excessive threat. For a recent contribution to this debate that favors the utilitarian tradition, see L. Kaplow and S. Shavell, "Fairness versus Welfare" 114 *Harvard L. Rev.* 961-1388 (2001).

## Mathematical Appendix

### Definitions

$n$ =number of potential participants  
 $m$ =number of actual participants, where  $m \leq n$ .  
 $k^i$ =actor  $i$ 's fixed cost of participating  
 $K^m$ = total fixed cost of participating by actors  $1, 2, \dots, m$ .  
 $x_j^i$  = input  $j$  by actor  $i$   
 $\underline{x}^i$  = vector of inputs by actor  $i$ , one of which is precaution  $x_{\Pi}^i$   
 $\underline{x}$  = vector of inputs by all actors  $1, 2, \dots, n$   
 $p_j$ = price of input  $j$   
 $\underline{p}$ = vector of prices of inputs  
 $y^i$ = output by actor  $i$  (also called "activity level")  
 $\underline{y}$ = vector of outputs by all actors  
 $q_i$ = price of  $i$ 's output  
 $\underline{q}$ = vector of market prices of outputs  
 $h^i$ = harm caused by actor  $i$   
 $H$ =total social harm  
 $H^{i(}$ =total harm that would result if actor  $i$  were not participating  
 $l^i$ = $i$ 's liability  
 $t^i$ = $i$ 's lump sum participation tax  
 $V$ =social welfare  
 \* indicates a socially optimal value.

### Functions

$K^m = k^1 + k^2 + \dots + k^m$ =total cost of participating by  $m$  actors  
 $y^i = y^i(\underline{x}^i)$  production function of actor  $i$   
 $0 = y^i = \underline{x}^i$  for  $i \geq m+1$  no activity or precaution by non-participants  
 $H = H(\underline{y}; \underline{x})$  total harm  
 $H^{i(} = H(\underline{y}; \underline{x}) - H(y^1, y^2, \dots, y^{i-1}, 0, y^{i+1}, \dots, y^m; \underline{x}^1, \underline{x}^2, \dots, \underline{x}^{i-1}, 0, \underline{x}^{i+1}, \dots, \underline{x}^m)$   
 $h^i = H - H^{i(}$   
 $V = \underline{q}\underline{y} - \underline{p}\underline{x} - H(\underline{y}, \underline{x}) - K^m$  social welfare function.

Assume that potential participants  $1, 2, \dots, n$  are uniquely arranged in order from highest to lowest contributors to social welfare. Consequently, when all actors who participate do so at the socially optimal inputs, social welfare falls more when actor  $i$  stops participating than when actor  $i+1$  stops participating, for all  $i$ .

### Social optimum

Maximize social welfare:  
 $\max \quad \underline{q}\underline{y} - \underline{p}\underline{x} - H(\underline{y}; \underline{x}) - K^m$

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subject to

$$y^i = y^i(\underline{x}^i) \text{ all } i$$

$$0 = y^i = \underline{x}^i \text{ for } i \geq m+1 \text{ all } i.$$

First order conditions for optimal activity level and precaution by all m participants:

$$q_i - H_{y_i} + \lambda \leq 0 \quad \text{optimal activity level } y^{i*} \text{ for } i=1,2,\dots,m.$$

$$-p_j - H_{x_{ij}} - \lambda y_{x_{ij}}^i \leq 0 \quad \text{optimal precaution } \underline{x}_j^{i*} \text{ for } i=1,2,\dots,m \text{ and } j=1,2,\dots,m.$$

Combining the preceding conditions yields

$$q_i y_{x_{ij}}^i - p_j - H_{y_i} y_{x_{ij}}^i - H_{x_{ij}} \leq 0 \quad \text{for all } i,j \quad (1)$$

Conditions for number of participants m to be optimal:

$$q_i y^{i*} - \underline{p x}^{i*} - \Delta h^{*i} - k^i \geq 0 \text{ for } i=1,2,\dots,m \quad (2)$$

$$< 0 \text{ for } i=m+1, m+2,\dots,n.$$

### ***Individual Rationality***

Assume that each actor i responds to prices, liability, and taxes, but does not anticipate how his behavior might influence the behavior of others (zero conjectural variations). i maximizes his profits:

$$\max_{\underline{x}^i, y^i} q_i y^i - \underline{p x}^i - l^i + t^i$$

subject to

$$y^i = y^i(\underline{x}^i).$$

First order conditions:

$$q^i - l_{y_i}^i + \lambda^i \leq 0 \quad \text{optimal activity level } y^{i+}$$

$$-p_{x_{ij}} - l_{x_{ij}}^i - \lambda^i y_{x_{ij}}^i \leq 0 \quad \text{optimal precaution } \underline{x}_j^{i+} \text{ for all } j$$

Combining conditions yields

$$q^i y_{x_{ij}}^i - p_{x_{ij}} - l_{y_i}^i y_{x_{ij}}^i - l_{x_{ij}}^i \leq 0. \quad (1')$$

Condition for i's participation (non-negative average net revenues):

$$q_i y^{i+} - \underline{p x}^{i+} - l^{i+} - t^i - k^i \geq 0. \quad (2')$$

### ***Propositions – proofs are interpretations of the conditions for social and individual optima***

We prove the efficiency or inefficiency of equilibria that exist, but we do not prove the existence of equilibria. The propositions are interpretations of the conditions for social and individual optimization.

Proposition 1. Strict liability. Assume that m actors participate in an activity with unverifiable activity levels and unverifiable precautions that cause external harm H. Assume that individual harm  $h^i$  is verifiable for all m participants. Strict liability of

injurer  $i$  for the harm  $h^i$  creates socially optimal incentives with respect to  $i$ 's precaution and activity level.

Proof:

By assumption,  $i$ 's liability equals the harm  $i$  caused,  $l_i = h^i$ . By Definition,  $l_i = H - H_j$

Equation (1') for individual rationality thus reduces to the condition for socially optimal precaution and activity level:  $q_i y_{xij} - p_{xij} - H_i y_{xij} - H_j x_{ij} < 0$ .

Proposition 2. Negligence. Assume that  $m$  actors participate in an activity with unverifiable activity levels and verifiable precautions  $x_p^i$  that cause external harm  $H$ . Assume the individual harm  $h^i$  is verifiable. Assume that law imposes a legal standard of care at the social optimum,  $x_p^{i*}$ , and injurer  $i$  is liable for the harm  $h^i$  that occurs when his care falls below the legal standard, but not otherwise. His precaution will be efficient and his activity level will be inefficient.

Proof:

1. Assume that actual precaution  $x_{ij}$  is epsilon below the legal standard, which is the social optimum by assumption. Consequently, the individual is liable for the actual harm that he causes. His costs are the same as under strict liability, so, by Proposition 1, costs are minimized by setting precaution and activity level at the social optimum, and thus he increases his precaution by epsilon.

2. When precaution equals the social optimum, liability falls to zero. Now equation (1') for individual rationality reduces to the following for all variables except precaution:

$$q_i y_{xij} - p_j \leq 0 \text{ for all } j \text{ not equal to precaution } x_{ij}$$

This condition does not coincide with the social optimum except by chance.

Proposition 3. Excessive harm. Assume that  $m$  actors participate in an activity with unverifiable activity levels and unverifiable precautions that cause verifiable external harm  $H$ . Individual liability for excessive harm ( $h^i - h^{i*}$ ) gives the injurer socially optimal incentives with respect to his precaution and activity level.

Proof:

1. Assume that actual harm  $h^i$  is above the legal standard  $h^{i*}$ . Consequently, injurer's liability for excessive harm ( $h^i - h^{i*}$ ) is identical to injurer's liability under a rule of strict liability except for the constant  $h^{i*}$ . First order conditions are invariant with respect to changing the maximand by a constant. Consequently, the proof for Proposition 1 also that injurer will lower  $h^i$  to  $h^{i*}$ .

2. Assume that actual harm  $h^i$  is below the legal standard  $h^{i*}$ . Consequently, the injurer's liability is zero. Therefore the injurer will lower his costs by reducing precaution and increasing the activity level until he raises  $h^i$  to  $h^{i*}$ .

Proposition 4. Strict total liability. Assume that  $m$  actors participate in an activity with unverifiable activity levels and unverifiable precautions that

cause verifiable external harm H. Assume that transaction costs prevent collusion among participants. Liability for total harm H gives each participant socially optimal incentives with respect to precautions and activity level.

Proof: By assumption, individual i's liability equals total harm:  $l^i=H$ . Consequently, condition (1) for socially optimal activity level and precaution is the same as condition (1') for individual rationality.

Proposition 5. Total liability for excessive harm. Assume that m actors participate in an activity with unverifiable activity levels and unverifiable precautions. Assume that actual total harm H and optimal total harm  $H^*$  are verifiable. Liability for excessive harm  $H-H^*$  gives each injurer efficient incentives with respect to precautions and activity level.

Proof:

1. Assume that actual harm H is above the legal standard  $H^*$ . Consequently, injurer's liability for excessive harm  $(H-H^*)$  is identical to injurer's liability under a rule of strict total liability except for the constant  $H^*$ . First order conditions are invariant with respect to changing the maximand by a constant. Consequently, the proof for Proposition 1 also proves that injurer will increase his payoff by decreasing activity and increasing precaution until H equals  $H^*$ .
2. Assume that actual harm H is below the legal standard  $H^*$ . Consequently, the injurer's liability is zero. Therefore the injurer will increase his payoff by increasing activity and decreasing precaution until H equals  $H^*$ .

Proposition 6. Proportionate liability. Assume that m actors participate in an activity with unverifiable activity levels and unverifiable precautions that cause verifiable external harm H. Assume that transaction costs prevent collusion among participants. Liability for proportionate harm  $(H/m)$  gives each injurer deficient incentives with respect to precautions and activity level.

Proof:

1. The condition (1) for social optimal activity level and precaution reduces is  $q_i y_{xij} - p_j - H^i_{yi} y_{xij} - H^i_{xij} \leq 0$ .
2. The assumption that liability  $l^i$  equals  $H/m$  implies that equation (1') for individual rationality reduces to  $q^i_{y_{xij}} - p_{xij} - (H^i_{yi} y_{xij} - H^i_{xij})/m \leq 0$ .
3. Thus individual rationality results in sub-optimal precaution and activity level except by chance.



Proposition 7: Optimal participation. Assume that  $n$  actors potentially participate in an activity. Assume that participants face liability that induces socially optimal precaution and activity level. Assume that external harm  $H$  increases with more participation. Incentives for an optimal number of the  $n$  actors to participate are achieved if each actor  $i$  who participates pays a lump sum tax equal to the harm  $h^{*i}$  caused by participating at optimal level of activity and precaution minus the liability  $l^{*i}$ .

Proof:

1. Incentives for participation are socially optimal when equal (2') is identical to the condition for individual participation (2). Setting these equations equal to each other yields  $q_i y^{i*} - p x^{i*} - \Delta h^{*i} - k^i = q_i y^{i+} - p x^{i+} - l^{i+} - t^i - k^i$ .
2. By assumption, injurers face liability that induces socially optimal precaution and activity level, so  $x^{i*} = x^{i+}$  and  $y^{i*} = y^{i+}$ .
3. Inserting the conditions in step 2 into the condition in step 1 yields  $t^i = \Delta H^{*i} - l^i$ .

Proposition 8. Total liability for excessive harm with random additive error. Assume that  $m$  risk-neutral actors participate in an activity with unverifiable activity levels and unverifiable precautions. Assume that actual total harm  $H$  and optimal total harm  $H^*$  are verifiable with additive error  $\varepsilon$ . When  $H + \varepsilon > H^*$ , each injurer is totally liable for  $H - H^* + \varepsilon$ . Otherwise each injurer is not liable.

- (i). If the expected error is unbiased ( $E(\varepsilon) = 0$ ), then the injurer has socially efficient incentives with respect to precautions and activity level.
- (ii). If the expected error is biased towards a legal standard that is too low ( $E(\varepsilon) < 0$ ), then the injurer has incentives for too little precaution and too much activity.
- (iii). If the expected error is biased towards a legal standard that is too high ( $E(\varepsilon) > 0$ ), then the injurer has incentives to take optimal precaution and activity (but optimal incentives are vulnerable to collusion).

Proof:

1. Assume that  $H$  is less than  $H^* - E(\varepsilon)$ , so injurer expects to be not liable. Injurer will increase his payoff by increasing activity and decreasing precaution until he becomes liable, which occurs when  $H$  equals  $H^* - E(\varepsilon)$ . Thus injurer will set  $H$  equal to  $H^*$  if  $E(\varepsilon)$  is zero; injurer will set  $H$  higher than  $H^*$  if  $E(\varepsilon)$  is negative; injurer will set  $H$  lower than  $H^*$  if  $E(\varepsilon)$  positive.
2. Assume that  $H$  is greater than  $H^* - E(\varepsilon)$ , so injurer expects to be liable for  $H - H^* + E(\varepsilon)$ . Minimizing injurer's total costs with liability  $H - H^* + E(\varepsilon)$  is identical to minimizing total costs with liability  $H - H^*$  but for the constant  $E(\varepsilon)$ . First order conditions are invariant with respect to changing the maximand by a constant. Consequently, the proof for Proposition 5 also proves that injurer will set  $H$  equal to  $H^*$ .
3. If the expected error is unbiased ( $E(\varepsilon) = 0$ ), then step 1 and step 2 indicate that injurer will set  $H$  equal to  $H^*$ , which proves (i).
4. If the expected error is biased towards a legal standard that is too low ( $E(\varepsilon) < 0$ ), then injurer will set  $H$  above  $H^*$  and escape liability as indicated in step 1. Since injurer already expects not to be liable, injurer would gain nothing from lowering  $H$  to  $H^*$  as in step 2.

5. If the expected error is biased towards a legal standard that is too high ( $E(\varepsilon) > 0$ ), then injurer will set  $H$  equal to  $H^*$  as indicated in step 2.