NEGLIGENCE, STRICT LIABILITY AND COLLECTIVE ACTION

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Conventional wisdom in law and economics has long been that negligence-based regimes induce optimal care but encourage excessive activity. This paper demonstrates that when behavior involves multiple victims or injurers, negligence-based regimes can create a collective action problem which results in sub-optimal care and insufficient activity. As we show, investments in effective precaution often become cost-justified only when multiple parties engage in high activity levels. If parties are not coordinated, however, each may choose a low activity level to minimize her risk of harm. This collective action problem provides several insights regarding the design of optimal liability rules. It sheds new light on the efficiency of applying negligence, strict liability, or a combination of these two regimes; presents an overlooked virtue of damage caps and negligence per-se rules; and justifies doctrines that limit joint tortfeasors' exposure to liability.

1. Introduction

Law and economics, exploring the desirability of negligence rules, has conventionally predicted two results. On the positive side, scholars have shown that negligence-based regimes incentivize parties to invest efficiently in care. On the negative side, they have shown that these regimes often encourage parties to over-engage in harmful behaviors (Shavell 1980; Landes & Posner 1987, pp. 66-73). Excessive activity therefore has traditionally been a main concern when applying negligence-based standards (Cooter & Ulen 2007, pp 348-349).

Against this background, this Article demonstrates that once conduct involves more than a single injurer or victim, negligence may induce behavior that deviates from both conventional predictions. Specifically, we argue that where the efficiency of precautions is affected by activity levels, negligence-based regimes can give rise to an overlooked collective action problem. In these cases, when welfare maximization requires a high level of activity and investment in care, the application of negligence can induce parties to insufficiently engage in their activity and to avoid desirable investments in precaution.

The intuition for this result is that investments in effective care are often cost-justified only if multiple parties engage in a high activity level. If parties are not coordinated, however, each of them may choose a low activity level to minimize her risk of harm. For example, suppose that the installation of guardrails on a certain road can substantially reduce the risk of accidents, but is cost-effective only if all the drivers in the area use the road on a regular basis. The local municipality, subject to a negligence standard, would

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thus be required to install the railings only if drivers' activity level is high. From each driver's perspective, using the road frequently when guardrails are in place provides a large benefit. Yet the drivers face a collective action problem that may cause all of them to use the road infrequently. Unless a driver expects the remaining drivers to use the road often, she is better off avoiding the road, since no guardrails would be installed.

As this example illustrates, victims' activity level has two opposite effects on expected harm. First, when victims raise their activity level, expected harm is likely to increase. Second, with a high level of activity, investment in care becomes more cost-justified. When such precaution can significantly reduce harm, a high activity level is often socially desirable. However, if the investment in care requires multiple victims to engage in a high level of activity, a collective action problem may occur. This paper shows that parties' collective action problem can arise under a wide range of circumstances. It may occur when care is lumpy (e.g., only one type of guardrail) or continuous (e.g., a multitude of guardrail types), may involve multiple victims or multiple injurers, and can develop under the various negligence-based standards.

Previous scholarship has suggested the possible interdependence between the cost-effectiveness of care and parties' activity levels, proposing that it may undermine efficiency in two ways. First, the literature has emphasized that when such interdependence exists, courts, lacking knowledge of parties' actual activity levels, may fail to determine the socially desirable level of care (Donohue 1989, Nussim & Tabbach 2009). Second, it has demonstrated that parties in such cases may strategically restrict their activity in order to avoid spending on socially desirable precaution (Gilo & Guttel 2009). What previous literature has overlooked, however, is the collective action problem that occurs when activity involves multiple victims or injurers. As we show, this problem may arise even when courts possess full information concerning parties' activity levels, and even if parties do not benefit from manipulating their level of activity.

The collective action problem we identify provides several insights regarding the design of optimal liability rules. First, the risk that parties would fail to act collectively and thus behave inefficiently sheds new light on the choice between negligence and strict liability. As we show, strict liability would often remove the risk of insufficient care and activity levels in the context of multiple victims, whereas the application of negligence would prevent the risk of such inefficiency in the context of multiple injurers. Second, our analysis highlights the potential spillover effect of liability in cases involving multiple parties. Making an injurer strictly liable only to some of his victims, or subjecting only some injurers to negligence, can be sufficient to induce optimal behavior by all victims or all injurers. Third, we demonstrate the virtue of using damage caps and negligence per-se rules in cases in which parties may engage not only in insufficient activity but also in excessive activity. Finally, we introduce an overlooked advantage of regimes that allow joint tortfeasors to externalize the cost of their behavior. By reducing each tortfeasor's exposure to liability, such regimes can make high activity levels attractive even when injurers may fail to act collectively.

2. Basic Illustration

This Section illustrates the collective action problem parties may face when activities are subject to negligence-based regimes. We first demonstrate how negligence can cause a collective action problem among victims. Next we demonstrate the risk of a collective action problem among injurers under strict liability. Both examples show that imposition of liability may induce parties to set their activity below the socially desirable level and to avoid investments in efficient care.

2.1. Collective Action by Victims

> <u>Example 1: Restaurants</u>
>
> Abe and Bob each own a local restaurant. A large carpentry shop, located nearby, is spreading a significant amount of dust. The cost of cleaning the dust from each restaurant's storefront window is 20 per day. Abe and Bob each consider whether to keep their restaurants open only on Sundays (when demand is highest) or on a daily basis (Sunday through Thursday). The following table summarizes the expected weekly payoff, per party, for each possibility:
>
> Table 1: Weekly Payoff per Party

	Benefit	Cost of cleaning
Sunday only	30	20
Five days	105	100

> The manager of the carpentry shop can activate a system to reduce the amount of dust at a weekly cost of 70. With this system in place, the risk of dust being spread is reduced from 100% to 50%.

In this example, three scenarios are possible:
(a) Both Abe and Bob operate their restaurants only on Sundays
(b) One of them operates his restaurant on Sundays, while the other operates his restaurant on a daily basis
(c) Both operate their restaurants on a daily basis

A comparison of the net payoff under each possibility shows that option (c) is socially optimal. In option (a), activating the anti-dust system is not cost-justified, and thus Abe and Bob each incur a cost of 20 with certainty. Consequently, the net social benefit equals 20 (60 – 40). Activating the system remains inefficient in option (b), and thus the parties incur a cost, respectively, of 20 and 100 with certainty. Consequently, the net social benefit equals 15 (135 – 120). In option (c), activating the system becomes cost-justified, and thus the parties each incur a cost of 100 with 50%. Consequently, the net social benefit, comprised of the parties' benefit minus the cost of care and the residual harm, equals 40 (210 – 70 – 100).

Let us now analyze Abe and Bob's incentives under a negligence regime. Because care (activating the anti-dust system) becomes cost-justified only when both parties engage in the higher activity level (operating the restaurants on a daily basis), the parties' payoff matrix, as described in table 2, is that of a stag hunt game.[1]

Table 2: Parties' Payoff under Negligence

	Sundays only	Daily
Sundays only	10, 10	10, 5
Daily	5, 10	55, 55

If Bob expects Abe to operate his restaurant on a daily basis, his strategy should be to operate his own restaurant on a daily basis as well. Given the manager of the carpentry shop's duty to take care, operating daily provides Bob with a net benefit of 55 (105 – 50). If Bob would operate only on Sundays, the manger would have no duty to invest in care and thus Bob's payoff would only be 10 (30 – 20). In contrast, if Bob expects Abe to operate only on Sundays, Bob is better off operating only on Sundays as well. Since the manger is not required to take care, Bob's net benefit when operating daily would be 5 (105 – 100), compared to 10 (30 – 20) if he operates only on Sundays.

As table 2 indicates, negligence can result in insufficient activity levels on the part of victims, leading the injurer to invest in sub-optimal precaution. Although operating the restaurants on a daily basis and the activation of the anti-dust system are both socially desirable, Abe and Bob may end up operating only on Sundays while the manger takes no care. Unless Abe and Bob are able to act collectively, they may set their activity at the low level, rendering dust-prevention inefficient.

Consider now parties' incentives under a regime of strict liability. As table 3 shows, once the manager must compensate the restaurants' owners for their harm, the game involves only one Nash equilibrium. As opposed to negligence, parties' gains are now uncorrelated. Operating daily provides the highest payoff, irrespective of whether the other party operates daily or only on Sundays:

Table 3: Parties' Payoff under Strict Liability

	Sundays only	Daily
Sundays only	30, 30	30, 105
Daily	105, 30	105, 105

Because both Abe and Bob operate their restaurants on a daily basis, the manager will activate the anti-dust system. A strict liability regime thus incentivizes the parties to choose efficient levels of care and activity.

[1] We focus on pure-strategy equilibria since any mixed-strategy equilibrium involves some combination of high and low activity levels and is therefore inferior to the socially optimal result. As shown, social welfare is maximized when both parties engage in high activity levels.

2.2 Collective Action by Injurers

A similar problem of collective action may arise amongst multiple injurers. Specifically, the problem will occur in cases when the victim may efficiently reduce the harm by taking care. If the cost-effectiveness of the victim's precaution is affected by the injurers' level of activity, the injurers may face the same type of collective action problem under a regime of strict liability with a contributory negligence defense.

To illustrate, consider the following example:

> <u>Example 2: Polluting Factories</u>
>
> A and B are polluting factories in the same area. Their benefits and the harm they inflict on the victim, a nearby facility, correspond to the payoffs described in table 1. Thus, each factory benefits 30 and inflicts a harm of 20 when it engages in the low activity level. In the high activity level, each factory's benefit is 105 and the harm it inflicts is 100. The victim may reduce the likelihood of harm from 100% to 50% by taking care (using pollution resistant paint) at a cost of 70.

As already demonstrated, under these circumstances it is socially optimal that the injurers will both operate at the high activity level and the victim invest in care. However, since the cost-effectiveness of the victim's precaution is contingent on the expected harm, the factories' payoffs correspond to the matrix described in table 2. Factory A will set its activity at the high level only if it anticipates that factory B will also engage in a high level of activity. If factory A expects factory B to produce at the low level, it would similarly produce at the low level.

The interdependence of the factories' payoffs does not exist, however, when the applicable regime is negligence. Since the benefit from operating at the high activity level is greater than the ensuing harm (105 > 100), and since both factories have no cost effective precautions in which they may invest, producing at this level will not be considered negligence. This result holds whether the other factory's activity level is high or low. As such, the factories' payoff matrix corresponds to table 3. For both factories, the dominant strategy is to operate at the high activity level, and the victim will be incentivized to take care. Negligence thus induces the parties to choose efficient levels of both care and activity.

2.3 Equilibrium Selection

The preceding examples demonstrate that in cases involving multiple victims or multiple injurers, the application of negligence-based standards can result in a stag hunt game involving two possible equilibria. One of them, the Pareto-dominant equilibrium, is socially optimal. The other, the risk-dominant equilibrium, is socially sub-optimal, as it involves inefficient levels of care and activity. It is thus worthwhile to examine what factors may affect equilibrium selection in such cases (Carlsson & van Damme 1993).

First, if parties can communicate with each other, the Pareto-dominant equilibrium becomes more probable. In example 1, if Abe and Bob know one another and are able to plan ahead, they may coordinate their actions. They can reassure each other that they will both operate daily, thus making it less risky for each one to choose a high level of activity over a low activity level. Similarly, factories A and B in example 2 could agree to both produce at the high activity level so that the nearby facility's precaution would be cost-effective.

Second, the smaller the number of parties involved, the more likely they are to select the Pareto-dominant strategy. Consider again example 1. Under a negligence regime, for Abe to choose to operate daily it is only required that he anticipate that Bob engage in similar behavior. Suppose, however, that the number of restaurants owners is greater, and that the carpentry-shop manager would be required to invest in care only if all of them operate on a daily basis. In this case, for Abe to choose a high level of activity, he would have to anticipate similar behavior by all of the remaining restaurants owners. The more owners there are, the less likely this condition is to hold.

Third, parties' conduct is likely to be affected by the divergence between their net benefit from low and high activity levels. Depending on other parties' behavior, choosing a high activity level can either increase or decrease the expected payoff. Parties will be more inclined to choose a high activity level the greater their potential gain from the activity, and the smaller the possible loss it might cause them. In our examples, weighed against the payoff from a low activity level (10), choosing a high activity level could increase a party's payoff by 45 (when the other party elects a high activity level as well), or possibly decrease it by 5 (when the other party elects a low level of activity). A greater possible increase, as well as a lower possible decrease, will make high activity more attractive, and thus enhance the likelihood of efficient behavior.

Finally, parties' own attitudes toward risk as well as their perception of other parties' attitudes will influence their choice of strategy. All things being equal, Abe is more likely to operate daily if he is a risk-seeker and he perceives Bob to be a risk-seeker as well. In contrast, Abe is more likely to operate only on Sundays if he is risk-averse and he assumes Bob's attitude is the same. If Abe's own preference differs from his perception of Bob's preference, the effects then run in opposite directions. For example, imagine that Abe is a risk-seeker but assumes that Bob is risk-averse. Abe's own disposition would be to choose the higher activity level. His perception of Bob, however, may induce Abe to choose the lower activity level.

3. The Continuous Case

The examples in the previous sections were characterized by discrete levels of activity and care. There were only two possible levels of activity (e.g., operating on Sunday only or daily) and one possible level of care (e.g., activation of an anti-dust system). The current section shows that a collective action problem may yield insufficient activity and care also when the levels of activity and care are continuous. By continuous levels of activity we mean that parties can engage in any level of activity, at least within a certain range. For example, the two plants in example 2 can choose their level of production, rather than merely choosing between low and high activity. By continuous levels of care we refer to the case where a party can choose how much to invest in care, and any increase in such expenditure continuously reduces the level of harm.

As our model shows, unlike the discrete case explored above, the continuous case need not involve a stag hunt game. Victims could end up in an equilibrium in which welfare is lower than it could have been at higher levels of activity, while these higher activity levels need not be an equilibrium.

Consider the following model. There are two victims that could suffer harm from an injurer.[2]

Each victim's harm is $H(x,z_i)$, where z_i is victim i's activity level ($i=1,2$) and x is the injurer's level of care.

$\frac{\partial c}{\partial x} > 0$, $\frac{\partial H}{\partial x} < 0$, $\frac{\partial H}{\partial z} > 0$ and $\frac{\partial^2 H}{\partial x \partial z} < 0$.

At the first stage of the game, victims simultaneously choose their activity levels z_1 and z_2. At the second stage, the injurer chooses his level of care, x, given the activity levels chosen by the victims. The negligence standard imposed on the injurer given the victims' activity levels requires him to minimize the sum of his costs of care and victims' harm levels: $H_1(z_1,x)+H_2(z_2,x)+c(x)$. We will assume this sum to be twice differentiable and convex for each z_1, z_2, having a unique minimum $x^*(z_1,z_2)$. Hence, the injurer's choice of x, x^*, given the victims' activity levels z_1 and z_2, is derived by the following first order condition:

$$\frac{\partial H_1(z_1,x)}{\partial x} + \frac{\partial H_2(z_2,x)}{\partial x} = -\frac{\partial c(x)}{\partial x} \qquad (1)$$

Accordingly, the injurer will spend $x^*(z_1, z_2)$ on care and will not be found negligent.[3]

Implicitly differentiating (1) gives

$$-\frac{\partial x^*(z_1,z_2)}{\partial z_1} \equiv D(z_1,z_2) = \frac{\frac{\partial^2 H}{\partial x \partial z}(x^*(z_1,z_2),z_1)}{\frac{\partial^2 H}{\partial x^2}(x^*(z_1,z_2),z_1) + \frac{\partial^2 H}{\partial x^2}(x^*(z_1,z_2),z_2) + \frac{d^2 c}{dx^2}(x^*(z_1,z_2))}.$$

Given our assumption that $\frac{\partial^2 H}{\partial x \partial z} < 0$, this implies that an increase in a victim's activity level z_i ($i=1,2$) causes an increase in the injurer's level of care x.

[2] An analogous analysis would follow for multiple injurers strictly liable toward a single victim, who is subject to a contributory negligence standard.

[3] To see why, note that for any levels of z_1 and z_2, the injurer can earn more profits by taking due care and spending c(x) than by taking less than due care and spending $c(x)+h_1(z_1)+h_2(z_2)$. Any cost savings the injurer could make by taking less care would be more than offset by the additional harm that would result, since by definition, $x^*(z_1,z_2)$ minimizes $c(x)+h_1(z_1)+h_2(z_2)$.

Let $u(z_i)$ be victim i's utility (before subtracting the harm victim i bears) with $\frac{\partial u}{\partial z} > 0$
The two victims' payoff functions are:

$$\pi^1(z_1, z_2) = u(z_1) - H(x^*(z_1, z_2), z_1)$$
$$\pi^2(z_1, z_2) = u(z_2) - H(x^*(z_1, z_2), z_2)$$

Social welfare is:

$$W(z_1, z_2) = \pi^1(z_1, z_2) + \pi^2(z_2, z_2) - c(x^*(z_1, z_2))$$

Let (z^*, z^*) be an equilibrium of victims' activity levels.

The collective action problem will arise when there exists a point (y,y) for some $y>z^*$ with higher welfare than the equilibrium.

Let $y>z^*$, then

$$\begin{aligned} W(y,y) - W(z^*, z^*) &= 2u(y) - 2H(x^*(y,y),y) - c(x^*(y,y)) \\ &\quad - (2u(z^*) - 2H(x^*(z^*,z^*),z^*) - c(x^*(z^*,z^*))) \\ &= 2[u(y) - u(z)] - 2[H(x^*(y,z^*),y) - H(x^*(z^*,z^*),z^*)] \\ &\quad - 2[H(x^*(y,y),y) - H(x^*(y,z^*),y)] - [c(x^*(y,y)) - c(x^*(z^*,z^*))]. \end{aligned}$$

(2)

Thus, the change in welfare between (z^*, z^*) and (y,y) can be divided into 4 parts:

Part 1: $u(y) - u(z^*) > 0$: Each victim's own utility increases when he moves from z^* to y.

Part 2: $H(x^*(y,z^*),y) - H(x^*(z^*,z^*),z^*) > 0$: Each victim's own harm increases when he moves from z^* to y (assuming the other victim remains at z^*).

Part 3: $H(x^*(y,y),y) - H(x^*(y,z^*),y) < 0$: Assuming a victim moves from z^* to y, his own harm decreases when the other victim also moves from z^* to y, because this raises the injurer's level of care.

Part 4: $c(x^*(y,y)) - c(x^*(z^*,z^*)) > 0$: When the two victims move from z^* to y, the injurer needs to spend more on care.

Parts 1 and 2 above represent a victim's own gain and loss in moving from z^* to y given that the other victim stays at z^*. Parts 3 and 4 represent the positive and negative externalities involved in a victim moving from z^* to y given that the other victim's activity level is y. The positive externality, exhibited by part 3, stems from the fact that a move by a victim from z^* to y reduces the other victim's harm. The negative externality, exhibited by part 4, stems from the fact that as both victims move from z^* to y, they externalize expenses on the injurer, who, due to the negligence standard, needs to invest more in care.

To have higher welfare at (y,y), parts 1 and 3 need to be greater than parts 2 and 4.

To maintain (z^*,z^*) as an equilibrium, for all y we must have that the first part (a victim's increased utility from moving to y) is weakly outweighed by the second part (a victim's increased harm from such a move):

$$u(y) - u(z^*) \leq H(x^*(y,z^*),y) - H(x^*(z^*,z^*),z^*). \tag{3}$$

That is, (z^*,z^*) is an equilibrium because given that the other victim's activity level is z^*, a victim is reluctant to move on her own to activity level y, as the increase in harm is not outweighed by the increase in utility.

Nevertheless, social welfare could be increased by having both victims raise their level of activity to (y,y) instead of (z^*,z^*).

For (y,y) $(y>z^*)$ to involve higher welfare than (z^*,z^*) (while maintaining (z^*,z^*) as an equilibrium) it must be that the positive externality (part 3) outweighs the negative externality (part 4).[4] The reason victims do not individually choose (y,y) is that each victim disregards the positive externality he causes the other victim in doing so.

Let us derive the condition for the positive externality (part 3) to outweigh the negative externality (part 4), thereby mapping the set of cases in which the collective action problem may arise.

Proposition 1: Let (z^*,z^*) be an equilibrium of victims' activity levels. A necessary condition for the collective action problem to arise (i.e., for the existence of a point (y,y), for some $y>z^*$, in which $W(y,y)>W(z^*,z^*)$ is that the positive externality (part 3) outweigh the negative externality (part 4), or, equivalently:

$$2\int_{z^*}^{y} \frac{\partial H}{\partial x}(x^*(s,s),s)D(s,s)ds < \int_{z^*}^{y} \frac{\partial H}{\partial x}(x^*(s,y),y)D(s,y)ds, \tag{4}$$

Proof:
First note that for each z_1 and z_2 we have

$$\frac{dc}{dx}(x^*(z_1,z_1)) = -2\frac{\partial H}{\partial x}(z_1,x^*(z_1,z_1)), \text{ and } \quad \frac{\partial x^*}{\partial z_1}(z_1,z_2) = -D(z_1,z_2).$$

To see why, let $\varphi(z_1,z_2,x) = \frac{\partial H}{\partial x}(z_1,x) + \frac{\partial H}{\partial x}(z_2,x) + \frac{dc}{dx}(x)$. By the definition of x^* we have $\varphi(z_1,z_2,x^*(z_1,z_2)) = 0$, or

[4] If the negative externality is greater than the positive externality, point (y,y) would involve excessive activity from a welfare perspective.

$$\frac{dc}{dx}(x^*(z_1,z_1)) = -\frac{\partial H}{\partial x}(z_1,x^*(z_1,z_1)) - \frac{\partial H}{\partial x}(z_1,x^*(z_1,z_1))$$
$$= -2\frac{\partial H}{\partial x}(z_1,x^*(z_1,z_1)),$$

Since $\varphi(z_1,z_2,x^*(z_1,z_2)) = 0$ for all z_1 and z_2, we have

$$\frac{\partial x^*}{\partial z_1}(z_1,z_2) = -\frac{\varphi'_{z_1}}{\varphi'_x} = -D(z_1,z_2).$$

The difference between the positive externality (part 3) and the negative externality (part 4) is:

$$-2[H(y,x^*(y,y)) - H(y,x^*(y,z^*))] - [c(x^*(y,y)) - c(x^*(z^*,z^*))].$$

Using the above derivations, we get:

$$-2[H(y,x^*(y,y)) - H(y,x^*(y,z^*))] = -2\int_{z^*}^{y} \frac{\partial H(y,x^*(y,s))}{\partial s} ds$$
$$= -2\int_{z^*}^{y} \frac{\partial H}{\partial x}(y,x^*(s,y)) \cdot \frac{\partial x^*}{\partial z_1}(s,y) ds$$
$$= 2\int_{z^*}^{y} \frac{\partial H}{\partial x}(y,x^*(s,y)) \cdot D(s,y) ds,$$

and

$$-[c(x^*(y,y)) - c(x^*(z^*,z^*))] = -\int_{z^*}^{y} \frac{dc(x^*(s,s))}{ds} ds$$
$$= -\int_{z^*}^{y} \frac{dc}{dx}(x^*(s,s)) \cdot \left[\frac{\partial x^*}{\partial z_1}(s,s) + \frac{\partial x^*}{\partial z_2}(s,s) \right] ds$$
$$= -\int_{z^*}^{y} -2\frac{\partial H}{\partial x}(s,x^*(s,s)) \cdot 2\frac{\partial x^*}{\partial z_1}(s,s) ds = -4\int_{z^*}^{y} \frac{\partial H}{\partial x}(s,x^*(s,s)) D(s,s) ds.$$

Therefore, the positive externality (part 3) outweighs the negative externality (part 4) if and only if (4) holds.
Given (2) and (3), (4) constitutes a necessary condition for the commitment problem to arise.
Q.E.D

In cases where the above-mentioned *necessary condition* for the collective problem to arise holds (that is, the positive externality in part 3 outweighs the negative externality in part 4), a *sufficient condition* for it to arise is that the difference between parts 3 and 4 outweighs the difference between parts 1 and 2. That is, inequation (3) must not be as strong as inequation (4).

As noted, and unlike the discrete case analyzed in section 2, the continuous case does not always involve a stag hunt game. In the following example, the equilibrium involves victims engaging in one activity level, whereas welfare would be enhanced had they engaged at a higher activity level.

Example-an equilibrium with socially insufficient activity:
Consider:

$$c(x) = 20x,$$

$$H(z,x) = \frac{2}{x} - (z-1)x + 5z, \text{ and}$$

$$u(z) = \sqrt{21-z} - \frac{2(z-1)}{\sqrt{21-z}} + 5z - \frac{(z-1)^2}{1000} + 5,$$

for $0 < x \leq 5$, $1 - 2/25 \leq z \leq 12$ and $z_1 + z_2 < 21$.

In the range considered we have $c' > 0$, $\frac{\partial H}{\partial z} = 5 - x > 0$, $\frac{\partial H}{\partial x} = -2/x^2 - (z-1) < 0$, and

$$u' = -\frac{5}{2\sqrt{21-z}} - \frac{z-1}{(21-z)\sqrt{21-z}} + 5 - 2\frac{z-1}{1000}$$

$$> -\frac{5}{6} - \frac{11}{27} + 5 - \frac{22}{1000} > 0.$$

Let $\varphi(z_1, z_2, x) = H(z_1, x) + H(z_2, x) + c(x)$, then $\varphi(z_1, z_2, x)$ is a convex function and

$$\frac{\partial \varphi(z_1,z_2,x)}{\partial x}(z_1, z_2, x) = -\frac{4}{x^2} - (z_1 + z_2 - 2) + 20$$

And solving $\varphi' = 0$ yields $-\frac{4}{x^2} = 20 - (z_1 + z_2 - 2)$ or

$$x^*(z_1, z_2) = \frac{2}{\sqrt{22 - z_1 - z_2}}$$

It can be shown that for all z_1 and z_2 in the range we have $0 < x^* \leq 2$.

As shown in the appendix, (1,1) is an equilibrium, while welfare at (10.8,10.8) yields higher welfare.

In particular,

$W(1,1) \approx 1.055$, while
$W(10.8,10.8) \approx 1.39 > W(1,1)$

Indeed, the necessary and sufficient conditions developed above are shown in the appendix to hold.

However, as shown in the appendix, (10.8,10.8) is not an equilibrium. Against an activity level of 10.8 engaged in by victim 2, the payoff function of victim 1 is strictly increasing with her activity level. That is, if victim 2 engages in 10.8, victim 1 would want to engage in an even higher activity level.

While a stag hunt game is not a necessary characteristic of the continuous case, it is certainly possible. Consider the following revision of our example, in which the harm function is:

$$H(z,x) = \frac{2}{x} - (z-1)x + 5z + \begin{cases} 0 & \text{if } z \leq 10.8, \\ e^{\alpha(z-10.8)} - \alpha(z-10.8) - 1 & \text{if } z > 10.8. \end{cases}$$

With such a harm function, for α large enough, a victim's increase in harm for z>10.8 will be higher than the increase in her utility, and (10.8,10.8) is an equilibrium, along side (1,1), which remains an equilibrium as well.

4. Normative Implications

This Section presents the implications of our analysis for the design of optimal liability rules. We begin by revisiting the conventional wisdom concerning the choice between negligence and strict liability. Next, we discuss the advantage of damage caps and negligence per-se rules in contexts that may involve both insufficient and excessive activity. Finally, we demonstrate the efficiency of regimes which allow tortfeasors to externalize the costs of their conduct.

4.1. Negligence and Strict Liability Reconsidered

Victims or injurers' collective action problem provides a new consideration regarding the choice between negligence and strict liability. Under conventional law and economics theory, which focuses on the risk of excessive levels of activity, when parties lack incentives to set their activity beyond the socially desirable level, the selection of either form of liability is assumed to induce optimal behavior. As examples 1 and 2 illustrate, however, when more than a single victim or injurer is involved, even if parties do not have incentives for excessive activity, the selection between negligence and strict liability can have important efficiency-related implications. In example 1, to avoid the risk of victims' insufficient activity, strict liability should be favored over negligence. In example 2, to avoid the risk of injurers' insufficient activity, negligence should be favored over strict liability.

The preceding analysis also highlights the possible "spillover effect" of liability. When harmful activities involve more than a single victim or injurer, the legal system can apply more than one liability standard when regulating behavior. For example, an injurer whose conduct harms two victims can be strictly liable toward victim A, but only liable for harm caused by negligence to victim B. Compared to a system that applies negligence with respect to both victims, at first blush the hybrid regime seems to only make victim A better off. However, because the application of strict liability may induce victim A to choose a high level of activity, the hybrid system can also benefit victim B.

Consider the application of such a hybrid regime in example 2. Suppose that the carpentry shop is strictly liable to Bob, but must only compensate Abe if it is negligent. Recall that if negligence is applied indiscriminately with respect to both Abe and Bob, they may end up operating only on Sundays. However, if the carpentry shop is strictly liable to Bob, operating daily becomes Bob's dominant strategy as he is now always entitled to compensation. Given Bob's excepted behavior, Abe can predict with certainty that if he also operates daily, the carpentry shop will be required to invest in care. Rendering the carpentry shop strictly liable toward Bob thus makes high activity the dominant strategy for *both* parties and increases each of the parties' payoffs.

Similar reasoning suggests the advantage of limiting the application of strict liability in cases involving multiple injurers. As shown above, when strict liability is applied uniformly, injurers may engage insufficiently in their activities. Applying a negligence standard, even with respect to only some of the injurers, can induce *all* of them to set their activity at an efficient level and incentivize victims to invest in cost-effective precaution. This result can be achieved by narrowing the definition of "abnormally dangerous" activities, which renders injurers strictly liable to victims. A narrow definition would increase the likelihood that some of the injurers would be subject to negligence rather than strict liability, which would prevent the risk of an inefficient equilibrium. This spillover effect may provide another justification for Judge Posner's controversial decision in *Indiana Harbor*, holding that transportation of toxic material should not be considered an abnormally dangerous activity. Judge Posner's narrow approach benefits not only the injurers who are consequently subject to negligence, but also those who fall within the definition of "abnormally dangerous" and are thus subject to strict liability.

4.2 Caps on Damages and Negligence Per-Se

While choosing appropriately between negligence and strict liability can prevent the collective action problem, in some cases both regimes (as well as a hybrid one) may nevertheless fail to provide optimal incentives. As the following example shows, when parties may engage not only in too little activity but also in too much activity, both negligence and strict liability may induce sub-optimal behavior. Parties will either be incentivized to act excessively, or end up choosing to engage in insufficient activity.

<u>Example 4: Restaurants – Extended</u>

Suppose that Abe and Bob consider extending their business hours. Keeping each restaurant open for longer hours requires cleaning the windows twice a day. Both parties can thus choose from three different activity levels: operating only on Sundays, operating five days a week during regular business hours, and operating five days a week with extended hours. The following table summarizes the expected weekly payoff, per party, for each possibility:

Table 4: Weekly Payoff per Party

	Benefit	Cost of Cleaning
Sunday only	30	20
Five days – regular business hours	105	100
Five days – extended business hours	109	200

Although it increases each party's benefit to 109, operating the restaurants on a daily basis for extended business hours is socially undesirable. Even if the manager of the carpentry shop invests in care, each party's net benefit from such a high activity level (109 – 100) is lower than their net benefit from operating on a daily basis during regular business hours (105 – 50). Nevertheless, under these circumstances the legal system cannot induce optimal behavior. As shown, under negligence, Abe and Bob may end up operating only on Sundays (insufficient activity).[5] Under strict liability—where they are always compensated—both parties will prefer extended business hours (excessive activity). Applying a hybrid regime, which combines negligence and strict liability, may reduce, but not eliminate, the social loss. While the victim that is protected by a negligence standard will choose the efficient activity level (regular business hours), the other victim—protected by strict liability— will choose an excessive level (extended business hours).

Similar analysis shows that neither negligence nor strict liability regimes can induce optimal behavior in cases in which multiple injurers may engage in both insufficient activity as well as excessive activity. The application of strict liability, as demonstrated in Example 2, may induce insufficient activity. On the other hand, the application of negligence—which relieves injurers from liability when taking due care—could induce excessive activity. Finally, the application of a hybrid regime will only reduce but not eliminate the risk of inefficient behavior. The injurer subject to strict liability may produce at the efficient level, yet the injurer subject to negligence will over-produce.

This deficiency of negligence and strict liability, however, can be resolved by imposing restrictions on victims' right to be compensated or injurers' right to inflict harm. By imposing caps on damages and negligence per-se rules, the legal system can simultaneously address the risks of insufficient and excessive activity. Parties subject to such liability regimes, if applied properly, will be induced to set their activity at the efficient level.

[5] Note that although Abe and Bob can now engage in three different activity levels, both may still end up choosing to engage in insufficient activity. As shown in example 1, when Abe operates only on Sundays, Bob is better off doing the same rather than operating on a daily basis. Operating only on Sundays remains Bob's best strategy even with the option of extended business hours. Although choosing extended business hours would require the injurer to take care, it provides Bob with a net benefit of 9 (109 – 100). In contrast, if Bob operates only on Sundays, his net benefit equals 10 (30 – 20).

Consider first the context of multiple victims. Applying a regime of strict liability with damage caps can induce the victims to set their activity at the socially optimal level. On the one hand, because under strict liability the victims can always collect compensation for their harm, they will have no incentive to engage in insufficient activity. On the other hand, a cap on victims' compensation, equal to the harm caused when activity levels are optimal, would remove their incentive to engage excessively in their activity. Since the marginal benefit from excessive activity is by definition lower than the marginal cost, requiring victims to assume the harm that exceeds the cap will discourage them from increasing their activity beyond the efficient level.[6]

Similar analysis shows that the application of negligence per-se rules can induce multiple injurers to set their activity at the optimal level. As shown, under negligence, injurers will have no incentive to engage in insufficient activity. While negligence may encourage too much activity, properly designed negligence per-se rules that render it unreasonable to inflict harm beyond a certain limit will remove the injurers' incentive to engage in excessive activity. As with damage caps, this limit should correspond to the harm at the socially optimal level of activity.

This analysis therefore provides a novel justification for using damage caps and negligence per se rules. In the contexts of multiple victims or injurers, these rules allow the legal system to address the risk of insufficient activity without simultaneously creating incentives for engaging in excessive activity.

4.3 Individual and Joint Liability

Our discussion thus far has assumed individual liability, under which parties bear the cost of their activity. Multiple injurers, however, can be jointly liable. In such cases, injurers might pay less than the harm they caused. This may occur, for example, if a defendant who compensated the victim in full is not allowed to seek contribution from other defendants, or if contribution follows the pro rata rule (Dobbs 2003). Under a no-contribution regime, an injurer escapes liability entirely when the victim sues other defendants. Under a pro rata regime, because damages are divided equally among the joint tortfeasors, an injurer's share can be less than the harm he actually inflicted.[7]

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[6] To illustrate, consider again example 3. Suppose that the applicable regime is strict liability, but that compensation to the restaurant owners is capped at 100 (the harm, per victim, when the activity level is optimal). By operating the restaurant only on Sundays (harm of 20) or on a daily basis during regular business hours (harm of 100) Abe's harm is within the cap's range. In contrast, when he operates daily at extended business hours (harm of 200) Abe's harm exceeds the cap, and thus he will only be compensated for 50% of his loss. Abe's expected payoff for each activity level is as follows: if he operates only on Sundays, his net benefit equals 30. If he operates daily during regular business hours, his net benefit equals 105. If he operates daily with extended hours, his net expected benefit equals 59 (while he gains 109, in 50% of the cases he suffers a harm of 200 for which he only receives compensation of 100). Since operating daily during regular business hours provides the highest possible payoff, the dominant strategy for both victims is to operate at the efficient level. Given Abe and Bob's expected behavior, the manger of the carpentry shop will invest efficiently in care (dust prevention).

[7] As Kornhauser and Revesz (1989) demonstrate, a similar externality may occur even when contribution shares are determined by reference to the injurers' comparative fault (e.g. the amount of waste dumped by

Law and economics scholarship has demonstrated that such regimes may induce injurers to take undesirable risks (Kornhauser and Revesz 1989). Because each injurer reaps the entire benefit from her activity but shares the possible cost with the others, she may engage in the activity even if it is socially inefficient. In contrast, as scholars have stressed, this disadvantage does not exist when injurers are required to bear the full costs of their conduct.

The preceding analysis, however, suggests that regimes which allow tortfeasors to pay less than the harm they caused may serve to reduce the risk of insufficient activity levels. Since such regimes enable injurers to externalize part of the costs of their behavior, they provide injurers with a greater net benefit from increasing their activity level. This upward shift in the payoff from a high activity level can change the game into one with a single equilibrium in which all injurers will prefer high activity levels.

This insight can be demonstrated by reconsidering example 2. Recall that when the factories are individually liable, under strict liability both may end up producing at the low level. Suppose, however, that the factories—still subject to strict liability—are now jointly liable for the harm, and that liability is allocated on a pro-rata basis, such that each factory must pay 50% of the total harm. In this case, the factories have no incentives to engage in low activity. On the benefit side, by choosing a high activity level over a low activity level, a factory increases its payoff by 75 (from 30 to 105). On the cost side, production at the high level also raises the factory's expected damages. The actual increase depends on the other factory's activity level, but in any case it is below 75. If the other factory also engages in high activity, thereby inducing the victim to invest in care, the expected harm is raised by 30 (from 20 to 50). If the other factory engages in low activity, since the victim does not invest in care, the expected harm is raised by 80 (from 20 to 100). Yet, given the pro-rata rule, the factory must compensate for only 50% of the harm it causes. Thus the maximum increase in a factory's expected damages as a result of a high activity level is 40. Consequently, under the pro-rata rule both factories will engage in a high level of activity.[8]

Therefore, in multiple-injurer cases in which the collective action problem may arise, rules that allow joint tortfeasors to avoid paying in full can be socially desirable. By making a high activity level more attractive, these rules allow injurers to behave efficiently even when coordination is unlikely.

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each polluter). When the damage function is convex, a joint tortfeasor subject to strict liability may pay less than the harm he actually caused.

[8] The analysis is generally similar under a no-contribution regime. Assuming the probability of being sued is equally divided, each injurer faces a 50% risk of bearing the total harm. Thus, while she reaps the full benefit from a higher activity level, she internalizes only 50% of the cost.

5. Conclusion

The basic premise underlying tort analysis has been that making a party bear the harm caused from tortious conduct will induce her to select a socially optimal level of activity. Accordingly, scholars have assumed that negligence and strict liability will incentivize either victims or injurers to engage efficiently in their activities. Under negligence, since victims are not compensated for loss caused by non-negligent injurers, they will set their activity at the optimal level. Similarly, under strict liability, because injurers must compensate non-negligent victims, they will choose an efficient activity level. As this paper shows, however, this basic premise may not hold when conduct involves multiple victims or injurers. When negligence is applied, multiple victims may face a collective action problem that causes them to engage in insufficient activity. When strict liability is applied, a similar collective action problem may induce insufficient activity by injurers.

In modern life, potentially harmful activities often involve many victims or injurers. As we have shown, it is in such cases where the collective action problem becomes most likely. Our analysis indentifies several legal tools that would eliminate the problem by inducing parties to engage in a high activity level regardless of other parties' conduct. Each of these tools reduces the possible loss a party may suffer as a result of choosing a high activity level over a low activity level. By applying these tools, the legal system can induce multiple victims or injurers to select optimal levels of both care and activity.

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Appendix

We will first show that $(1,1)$ is an equilibrium:

$$x^*(z,1)=\frac{2}{\sqrt{21-z}},$$

$$H(z,x^*(z,1))=H(z,\frac{2}{\sqrt{21-z}})=\sqrt{21-z}-\frac{2(z-1)}{\sqrt{21-z}}+5z, \text{ and}$$

$$\pi^1(z,1)=u(z)-H(z,x^*(z,1))$$
$$=\sqrt{21-z}-\frac{2(z-1)}{\sqrt{21-z}}+5z-\frac{(z-1)^2}{1000}+5$$
$$-\left(\sqrt{21-z}-\frac{2(z-1)}{\sqrt{21-z}}+5z\right)=5-\frac{(z-1)^2}{1000}.$$

Thus, $\pi^1(z,1)$ is maximized at z=1 and (1,1) is an equilibrium.

We will now show that welfare at (10.8,10.8) is higher than at the equilibrium.

$$W(1,1)=2u(1)-2H(1,x^*(1,1))-c(x^*(1,1))=10-c(x^*(1,1))$$
$$=10-\frac{40}{\sqrt{20}}\approx 1.055,$$

$$x^*(z,z)=\frac{2}{\sqrt{22-2z}},$$

$$H(z,x^*(z,z))=\sqrt{22-2z}-\frac{2(z-1)}{\sqrt{22-2z}}+5z, \text{ and}$$

$$W(z,z)=2u(z)-2H(z,x^*(z,z))-c(x^*(z,z))$$
$$=2\left(\sqrt{21-z}-\frac{2(z-1)}{\sqrt{21-z}}+5z-\frac{(z-1)^2}{1000}+5\right)$$
$$-2\left(\sqrt{22-2z}-\frac{2(z-1)}{\sqrt{22-2z}}+5z\right)-\frac{40}{\sqrt{22-2z}}$$
$$=2\sqrt{21-z}-\frac{4(z-1)}{\sqrt{21-z}}-\frac{(z-1)^2}{500}+10-2\sqrt{22-2z}$$
$$+\frac{4(z-1)}{\sqrt{22-2z}}-\frac{40}{\sqrt{22-2z}}.$$

It can similarly be shown that $W(10.8,10.8)\approx 1.39>W(1,1)$.

To see how the necessary and sufficient conditions hold, note that Part 3 equals:
$2(H(10.8,x^*(10.8,10.8)-H(10.8,x^*(10.8,1)))\approx -54.83$

Part 4 equals $c(x^*(10.8,10.8)-c(x^*(1,1))\approx 54.3$

Hence part 3 (the positive externality) outweighs part 4 (the negative externality) and the necessary condition is fulfilled.

Part 1 equals $2(u(10.8)-u(1)) \approx 82.98$ whereas
Part 2 equals $2(H(10.8, x^*(10.8,1)-H(1, x^*(1,1))) \approx 83.17$

Accordingly, the sufficient condition holds as well, since the difference between part 3 (in absolute value) and part 4 outweighs the difference between parts 1 and 2:
82.98-83.17+54.83-54.3=0.34>0

To see why (10.8,10.8) is not an equilibrium note that

$$x^*(z,10.8) = \frac{2}{\sqrt{11.2-z}},$$

$$H(z, x^*(z,10.8)) = \sqrt{11.2-z} - \frac{2(z-1)}{\sqrt{11.2-z}} + 5z, \text{ and}$$

$$\pi^1(z,10.8) = \sqrt{21-z} - \frac{2(z-1)}{\sqrt{21-z}} + 5z - \frac{(z-1)^2}{1000} + 5$$

$$-\sqrt{11.2-z} - \frac{2(z-1)}{\sqrt{11.2-z}} + 5z$$

$$= 5 - \frac{(z-1)^2}{1000} + \sqrt{21-z} - \frac{2(z-1)}{\sqrt{21-z}} - \sqrt{11.2-z} + \frac{2(z-1)}{\sqrt{11.2-z}}.$$

Hence, given that victim 2 engages in 10.8, victim 1’s payoff function is strictly increasing with her activity level, and (10.8,10.8) is not an equilibrium.