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This paper considers the case that potential victims affect each other by taking care. Analyzing standard liability rules, we show that strict liability with a defense of contributory negligence is in the best position to induce the efficient outcome, i.e., this liability rule ensures efficiency if victims affect each other negatively - care by one victim increases the accident exposure of other victims - and makes the attainment likely if victims affect each other positively - if care by one victim decreases the accident exposure of other victims. In contrast, the other standard liability rules fail to induce first-best care.

Keywords: Victim interdependence, care incentives, liability rules, tort law

JEL-Classification: K 13, H 23

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1 Introduction

1.1 Motivation and Main Results

Numerous activities by an individual can have an effect on the well-being of several other individuals although possibly only one individual determines the extent of the activity and the way in which the activity is undertaken. For instance, vehicle drivers determine the care taken while driving and the number of miles driven, while others may be affected by becoming the victim in a possible accident with the driver. Liability rules are an instrument to reflect this interdependence between the potential injurer and the potential victim in the individual calculus of parties with an effect on the outcome. A wide range of literature discusses the merits of liability rules. Indeed, it has been established that different liability rules induce efficient care choices in the standard accident model (e.g., Shavell 1987). Consequently, liability law is a method that effectively allows for the internalization of the interdependence between the potential injurer and the potential victim, at least under certain circumstances.

Realistically, accident contexts are characterized by more complexity than what is captured by the standard accident model. For example, in many accident situations, there is not only one potential injurer or only one potential victim to the accident. This fact may introduce further interdepencies which need to be taken into account, in one way or another, by parties with an effect on the outcome, in order to achieve efficiency. The context with multiple tortfeasors and one victim has received some attention in the literature.[1] Liability rules can induce the efficient care choices in this more complex setting. In contrast, the complementary case in which there are multiple potential victims and only one potential injurer has obtained scant attention. The following analysis sets out to remedy this.

This paper analyzes the case in which the care-taking by one potential victim affects other potential victims. Consequently, victim interdependency in the accident setting is at the core of this work. In our setup, victim care has an effect on both the accident probability of the victim taking care, and the accident probability of other victims. Two different scenarios need to be distinguished. Beside the standard case with no interdependence, it is principally possible that additional care-taking by one victim decreases or increases the accident probability of other

[1] Two recent contributions concerning multiple tortfeasors are Jain and Kundu (2006) and Young et al. (2007). Further important analyses in this respect include Landes and Posner (1980), Kornhauser and Revesz (1989), and Miceli and Segerson (1991).

victims. This is contingent on the circumstances in which the accident potential unfolds. This study comprises both possible manifestations of the interdependence between victims. Despite this inclusive approach, our interest resides in particular with the case in which victims affect each other adversely. Care implies positive consequences for the victim taking care - a decrease in expected harm - and, simultaneously, negative consequences for other victims - an increase in expected harm. There are in all likelihood more settings in which the interdependence among victims is best described in this way.

Let us briefly outline the interdependency we focus on in particular: the case of victims affecting each other adversely. We will state three examples. First, consider a residential neighborhood in which one individual keeps doves. The other residents are disadvantaged by these doves due to noise and feces. Now, suppose that neighbor A of the dove-keeper applies coloring to his property, the drastic nature of which deters doves. This does not ameliorate the domesticized doves' need to pass through the residential area. Consequently, individual A's care-taking implies that other neighbors are affected to an increased extent by the doves. Doves avoid individual A's property but still pass through the neighborhood, where the dove-related drawbacks are concentrated on fewer properties. To that extent, care by individual A has decreased the expected harm of individual A but increased the expected harm of other neighbors. Second, the context we intend to analyze can also be motivated by a traffic example.[2] There are studies which establish that car drivers decrease their expected harm resulting from traffic accidents by having their lights running during daytime (e.g. Elvik et al. 2003). This results as road users can better and earlier detect, recognize and identify vehicles. However, it is argued by some that this may come at the cost of a greater exposure of motorcyclists. If formerly only motorcyclists used their lights during daylight, then the simultaneous use of daytime running light by cars can put motorcyclists at a disadvantage.[3] Consequently, the increase in care-taking by one potential victim, the car driver who uses light during daytime, reduces his expected harm, but simultaneously may increase the expected harm of another potential victim, the motorcyclist. Finally, consider an example from an environmental context. Assume that there is an oil spill close to the coast. If one of the potentially affected areas has

[2]Traffic accidents are important not only because they are often cited as an example but also because of their empirical significance (Shavell 2007, 153).

[3]There is a public consultation ongoing in the European Union, which tries to distill the size of advantages and disadvantages of mandating daytime running lights. For instance, the Federation of European Motorcyclists Associations highlights the possibility of adverse effects for motorcyclists (FEMA 2006).

erected shoreline protection systems, this may very well increase the expected harm resulting from the oil spill to other regions. Once again, the care-taking by one party exposed to the harm potential increases the expected harm of other parties exposed to the harm potential. Note that, under different circumstances, this setting can represent an example for victims affecting each other positively. If the protection system keeps the oil in check for a sufficient amount of time so that it starts to sink, the expected harm of other regions might decrease as a consequence of the care-taking by this region. In summary, there are numerous practical settings in which victim interdependence is a central feature of the context.

The consideration of victim interdependence yields strong conclusions with regards to the performance of standard liability rules. In particular, we show that one of the liability rules considered is uniquely equipped to deal with the additional complication of victim interdependence. This outstanding rule is strict liability with a defense of contributory negligence. In the case in which victims affect each other adversely when taking care, strict liability with a defense of contributory negligence cuts off victim care incentives once standard care is attained. This proves to be the central feature in this context. Given that victims take due care, the injurer is the residual risk bearer and chooses the efficient level of care as all effects at the margin are taken into account. In the case in which victims affect each other positively by decreasing each others' accident probabilities when increasing care, strict liability with a defense of contributory negligence is uniquely positioned to incentivize the taking of socially optimal care. Socially optimal care is individually perceived as too high due to the fact that the individual neglects the interdependence when choosing care. Strict liability with a defense of contributory negligence performs well because the expected harm burden is reliably shifted to the injurer as even standard injurer care cannot change this allocation given due victim care.

1.2 Relation to the Literature

In our setup, one injurer may impose harm on several victims. Such a context has not obtained much study yet. Jain (forthcoming) studies situations characterized by one injurer and multiple victims. However, the study mainly focuses on the case in which victims are independent. For that case, conclusions principally follow the standard model with only one injurer and one victim. In the section allowing for victim interdependence, Jain considers only the case in which victims affect each other positively and only provides the result that there is no standard liability rule which ensures the efficient outcome. This result re-emerges in Section 3.2, in which we suppose that victims affect each other positively. However, we add to Jain's finding that strict liability with a defense of contributory negligence is uniquely positioned to induce the efficient equilibrium. The fact that victims might have the capacity to divert the accident potential is to our knowledge nouveau to the literature.

Besides, there are three different points of contact to the literature other than that to the literature on the setting of multiple tortfeasors mentioned above. First, we can refer to the diversion topic in the literature on the economics of crime (see, e.g., Shavell 1991, Hui-Wen and Png 1994, and Hylton 1996). There, the taking of private precautions by one potential victim to theft lowers the attractiveness of this specific theft opportunity, i.e., the house of the victim taking the precaution. This may divert thieves to neighbours' houses as theft opportunities which are relatively more attractive after the change in private precaution. In our tort setting, these effects can re-emerge. The former effect takes shape in the reduction of the accident probability of the potential victim taking the precaution, whereas the latter effect manifests in the increase of the accident probability of other potential victims. Second, there is an analysis by Dharmapala and Hoffmann (2005) in which there also is an interdependence in addition to the traditional one being that between the potential injurer and the potential victim resulting from the potential imposition of harm. In contrast to our setting, the nouveau interdependence introduced by the authors also relates the single potential injurer to the single potential victim. They extend the standard accident model by interdependent costs of precaution. Thus, in their model, the precaution costs of the injurer are affected by the magnitude of precaution taken by the victim and vice versa. This introduces a cost externality which cannot adequately be internalized by standard liability rules in the unilateral-harm setting. The final link of our paper to the existent literature regards Finsinger (1991). He considers the introduction of new activities as a consequence of which the appropriate care expected from potential victims under the liability rule strict liability with a defense of contributory negligence changes. For instance, the introduction of a new technology may demand higher victim care, so that standard-adherent behavior becomes more expensive for victims as a consequence of the technology introduction. It is shown that the missing internalization of this precaution cost change distorts the decision of whether to introduce a new activity, relative to the social optimum.

The rest of the paper is structured as follows. In the next section, we present the model. In Section 3, we lay out the analysis for the liability rules considered in detail. The central results are presented for the case in which victims affect each other adversely first, whereas results for the complementary case follow. Concluding remarks end this study.

2 The Model

We consider risk-neutral individuals of type X, Y, and Z. In the event of an accident, X will turn out as the injurer, whereas Y or (and) Z is (are) harmed as victim(s).[4] For simplicity, we consider homogeneous victims. This allows us to expect outcomes which are symmetric in victim care, which makes the analysis more straightforward. Both the care level and precaution costs are denoted by the respective lower case letter, x, y, and z. Precaution by X and J lower the accident probability of the potential injurer X with potential victim J, which is denoted by π^{XJ}, $J = Y, Z$. As is standard, we assume that individuals simultaneously choose care. The magnitude of harm in the event of an accident is exogenous at the level D, which is the same for both victims. The accident probability function is assumed to be $\pi^{XJ} = p(x)q^J(j,i)$, i, $j = y, z$, $j \neq i$, where $p_x, q^J_j < 0$ and $p_{xx}, q^J_{jj} > 0$, as usual.[5] To ensure that interior solutions are obtained for all care variables, we make the following assumptions: (i) $\lim_{x\to 0} p_x(x) = \lim_{j\to 0} q^J_j(j,i) = -\infty$ for any level of i. (ii) $|\lim_{i\to 0} q^J_i(j,i)| < \infty$ for any level of j. Finally, we assume that the diminishing productivity of care effects that $q^J_j(j,i) = 0$ for any i given a j sufficiently large, and likewise $p_x(x) = 0$ for x sufficiently large. This reasonable assumption ensures the existence of a Nash equilibrium below.

We choose to set up the model in a way that is most immediately interpretable as one of exclusive harm, i.e., harm is either suffered by Y or Z. The examples provided in the introduction are predominantly of this kind. However, another interpretation is possible as we can give the following meaning to the probability functions. The function p denotes the probability that a dangerous condition occurs, which is a precondition for an accident. The function q^Y denotes the probability that an accident with individual Y results, given that a dangerous condition has occurred. Finally, the function q^Z gives the probability that individual Z will suffer losses, given that Y suffers harm, i.e., the probability of Z suffering harm is contingent on there being an accident involving X and Y.

Our central interest is the consideration of an interdependency among victims. In fact, our model is, except for the added victim interdependency, rather standard. We intentionally abstract from further complications such as litigation costs or uncertainty over due care, in

[4]We concentrate on the simplest structure which displays the central features of our interest. However, the qualitative results are transferable to more general environments.

[5]The analysis can alternatively be presented using expected harm functions $h^{XJ}(x, j, i)$ without consequence for the conclusions.

order to highlight the effects of this sole variation. The interdependence is reflected in the following way. Given that there is a threat of an accident occurring, the increase of care by one potential victim tends to change the exposure of the other victim. The interdependence shows in $q_i^J \neq 0$, where the sign may be positive or negative.[6] The case in which victims affect each other positively (adversely) is described by the derivative being negative (positive) as this depicts the fact that the increase in care by victim I decreases (increases) the accident exposure of victim J.

It is assumed, as usual, that the social objective can be described by the minimization of total social costs associated with the accident potential, i.e. the sum of precaution costs and expected harm. Consequently, the policy maker minimizes

$$SC = x + y + z + p(x)[q^Y(y, z)D + q^Z(z, y)D] \tag{1}$$

and would choose interior solutions (x^*, y^*, z^*), where

$$1 + p_x(x^*)[q^Y(y^*, z^*)D + q^Z(z^*, y^*)D] = 0 \tag{2}$$

$$1 + p(x^*)[q_y^Y(y^*, z^*)D + q_y^Z(z^*, y^*)D] = 0 \tag{3}$$

$$1 + p(x^*)[q_z^Y(y^*, z^*)D + q_z^Z(z^*, y^*)D] = 0 \tag{4}$$

The level of the social cost function evaluated at (x^*, y^*, z^*) is SC^*.

We assume that the second-order conditions for (x^*, y^*, z^*) being a minimum are fulfilled. The first-order conditions reflect the incorporation of the victim interdependence by the policy maker. For instance, if $q_i^J < 0$ holds, the policy maker would like to implement a larger i in relation to a setting where this effect is missing, all else left unchanged. This is intuitive. If the additional unit of care achieves a larger reduction in total expected harm with marginal costs being constant, this care is optimally chosen somewhat larger.

Individuals pursue the minimization of individual costs, which comprise precaution costs and expected liability. The latter depends on the liability rule. Earlier literature (e.g, Shavell 1987) has shown that for liability rules to induce efficient care in bilateral-care settings, they

[6] Concerning our function q^J, one way to make the problem more concrete for the exclusive harm case is as follows. Suppose that $q^Y(y, z)$ and $q^Z(z, y) = K(y, z) - q^Y(y, z)$ represent probability functions, with $0 < q^Y < K \leq 1$. Per assumption, it always holds that $q_z^Z = K_z - q_z^Y < 0$ and $q_y^Y = K_y - q_y^Z < 0$. This is compatible with q_i^J being larger or smaller than zero.

need to utilize at least one due care level. We will consider simple negligence, strict liability with a defense of contributory negligence, as well as negligence with a defense of contributory negligence, and assume throughout the analysis that due care standards are equal to the efficient care level. We do not explicitly deal with comparative negligence in our analysis but comment on it in the conclusion.

3 The Analysis

Liability rules perform superbly regarding the inducement of optimal care in the standard accident model. The following analysis considers an important additional complexity which has been neglected in the literature so far. We will now embark upon our analysis of the performance of different standard liability rules when there is victim interdependence. There are two cases which need to be distinguished, the one in which victims affect each other positively, and the one in which victims affect each other adversely. The latter scenario is particularly interesting as there are presumably more settings in which the interdependence among victims is best described as accident diversion. Consequently, we will treat the case that victim care can increase the accident probability of other victims extensively in the following ($q_i^J > 0$), whereas the other case is briefly analyzed subsequently ($q_i^J < 0$).

3.1 Victims Affect Each Other Adversely

Simple Negligence (SN)

Under simple negligence, the injurer is obliged to compensate the victim if injurer care fails to meet due care. This implies the following individual cost functions. Injurer costs XC can be stated as

$$XC_{SN} = \begin{cases} x + p(x)[q^Y(y,z)D + q^Z(z,y)D] & \text{if } x < x^* \\ x & \text{if } x \geq x^* \end{cases} \tag{5}$$

Victims of type J have costs JC, where

$$JC_{SN} = \begin{cases} j & \text{if } x < x^* \\ j + p(x)q^J(j,i)D & \text{if } x \geq x^* \end{cases} \tag{6}$$

The minimization of total social costs yields that (x^*, y^*, z^*) is the most desirable outcome from a social stance. It is now of central interest whether this behavior can be decentralized by the use of simple negligence. Thus, we will now test whether simple negligence induces this care vector as an equilibrium.

Suppose that victims behave in accordance with the social optimum by choosing y^* and z^*. In that case, injurers choose x^* since it not only minimizes the first line of (5), which can be seen from returning to (2), but also allows to become free of expected harm. Thus, to obtain the efficient care vector as equilibrium, victims need to find it optimal to respond to x^* with efficient care.

Assume accordingly that the injurer chooses x^*. In that case, victim type J minimizes the second line in (6) for a given i and $x = x^*$ and would therefore like to choose $\hat{j}$ as a best response to i, where

$$1 + p(x^*)q_j^J(\hat{j}, i)D = 0 \tag{7}$$

Importantly, note that $\hat{j} > j^*$ if $i = i^*$ holds. This deviation from the social optimum occurs because victims do not internalize the effect their care entails on the expected harm of other victims. A negative externality results. Given a certain level of injurer care, care by potential victim J changes with increases in i according to

$$\frac{d\hat{j}}{di} = -\frac{q_{ji}^J}{q_{jj}^J} \tag{8}$$

If care by potential victim Y and potential victim Z are strategic substitutes (complements), any increase in care by Y provokes a reduction (an increase) in care by Z. In graphical terms, best response functions have a negative (positive) slope if care levels are strategic substitutes (complements). It depends upon the cross partial q_{ji}^J whether care by respective victims are strategic substitutes or complements. The interpretation is that the marginal benefit of care for J is increasing (decreasing) in i if $q_{ji}^J < (>) 0$, while the marginal costs of care are unaffected.

Figure 1 depicts the case of complementary victim care and shows that for $x = x^*$ any equilibrium in victim care will be such that both victims choose supraoptimal care.[7] For this assertion, we combine that $\hat{j}(i^*) > j^*$, that $\hat{j}(0)$ is larger than zero, and that best response functions are positively sloped. The figure also contains a stylized isocost-line for both victims, the slope of which is given by $\frac{-p(x^*)q_i^J(j,i)D}{1+p(x^*)q_j^J(j,i)D}$, which is positive (negative) as long as care is less (larger) than the individually optimal response for the respective i.

[7] The figures use linear best response functions for illustrative purposes only. The set of assumptions set out in Section 2 allows for other curvatures as well.

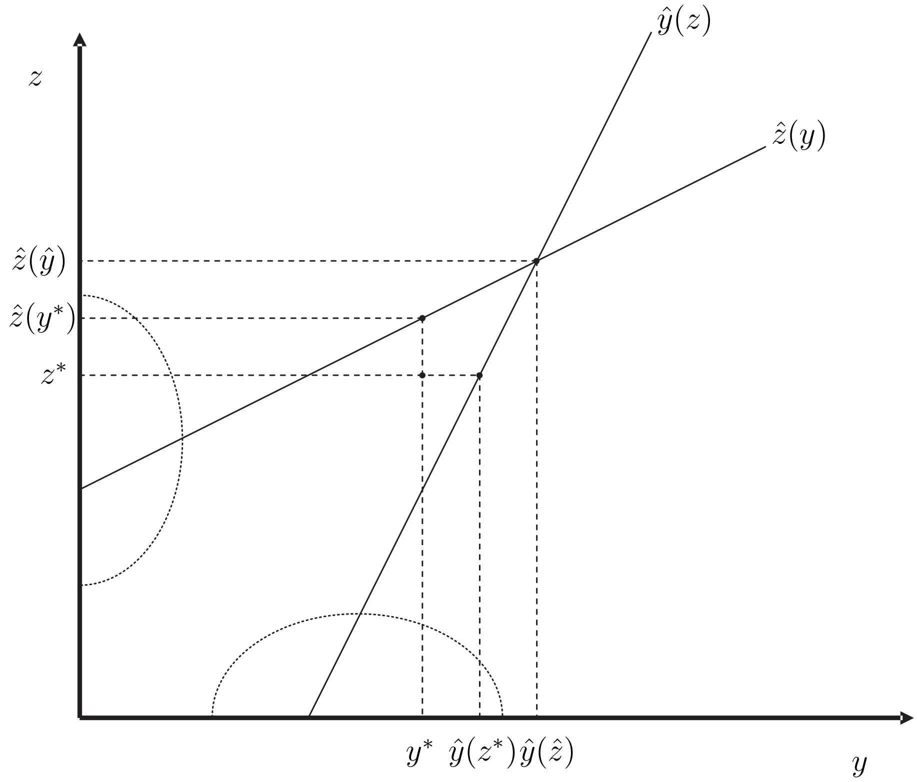

Figure 1: Best response functions if victim care is strategically complementary

Figure 2 illustrates the case in which respective victim care are substitutes. We know $\hat{j} > j^*$ if $i \leq i^*$, for $x = x^*$. Consequently, again, any intersection of best response functions must lie to the northeast of (y^*, z^*), i.e. be such that both victims choose supraoptimal care.

Consequently, we deduce from the figures that, for $x = x^*$, there cannot be an equilibrium with victim care levels less than the efficient levels, irrespective of victim care being substitutes or complements. In the following, we provide a more formal argumentation for this fact. Given $x = x^*$, the fact that JC_{SN} is strictly convex in j and that care ceases to be productive for sufficiently large care levels assures the existence of a Nash equilibrium in victim care. In the face of this abstract statement, it is of interest whether victim care levels in that equilibrium can fall below the socially desired levels. We denote $(\hat{y}, \hat{z})$ as the victims' best responses, given $x = x^*$. For $(\hat{y}, \hat{z}) << (y^*, z^*)$ to be the equilibrium given $x = x^*$, it needs to hold that a unilateral increase of care to the socially optimal level implies higher individual costs for both victims. Since the individual victim cost function JC_{SN} is strictly convex given $x = x^*$ and a certain i, increasing j beyond $\hat{j}$ until j^* is attained necessarily implies an increase in the cost

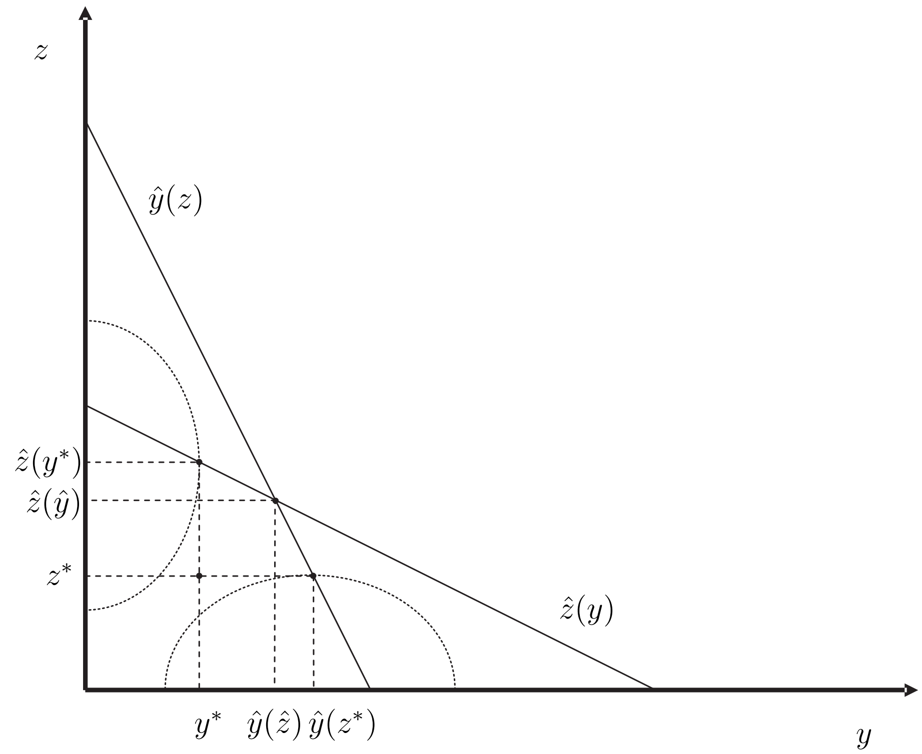

Figure 2: Best response functions if victim care is strategically substitutionary

level if $\hat{j} < j^*$. Expressing this fact for Y and Z, we obtain

$$\hat{y} + p(x^*)q^Y(\hat{y}, \hat{z})D < y^* + p(x^*)q^Y(y^*, \hat{z})D$$

$$\hat{z} + p(x^*)q^Z(\hat{z}, \hat{y})D < z^* + p(x^*)q^Z(z^*, \hat{y})D \quad (9)$$

The summation of these inequalities gives

$$\hat{y} + \hat{z} + p(x^*)[q^Y(\hat{y}, \hat{z})D + q^Z(\hat{z}, \hat{y})D]$$

$$< y^* + z^* + p(x^*)[q^Y(y^*, \hat{z})D + q^Z(z^*, \hat{y})D] \quad (10)$$

We add x^* to both sides and obtain

$$x^* + \hat{y} + \hat{z} + p(x^*)[q^Y(\hat{y}, \hat{z})D + q^Z(\hat{z}, \hat{y})D]$$

$$< x^* + y^* + z^* + p(x^*)[q^Y(y^*, \hat{z})D + q^Z(z^*, \hat{y})D] \quad (11)$$

Note that $q^J(j^*, \hat{i}) < q^J(j^*, i^*)$ due to the assumption of $q_i^J > 0$ and that $\hat{y}$ as well as $\hat{z}$ are assumed to be smaller than y^* and z^*, respectively. Consequently, the right-hand side of the above inequality is less than SC^*. The difference to SC^* is only that the level of y (z) in q^Z (q^Y) is less than y^* (z^*), which reduces q^Y (q^Y). Unaffected by this, q^Y (q^Z) is evaluated using y^* (z^*). In contrast to the right-hand side, the left-hand side of the inequality must be larger than SC^* because this represents an evaluation of social costs at $(x^*, \hat{y}, \hat{z})$ and otherwise (x^*, y^*, z^*) would not be social cost-minimizing.

From this reasoning follows that the actual ordering is

$$x^* + \hat{y} + \hat{z} + p(x^*)[q^Y(\hat{y}, \hat{z})D + q^Z(\hat{z}, \hat{y})D]$$

$$> SC^* > x^* + y^* + z^* + p(x^*)[q^Y(y^*, \hat{z})D + q^Z(z^*, \hat{y})D] \tag{12}$$

which excludes an equilibrium in $(\hat{y}, \hat{z}) << (y^*, z^*)$ with $x = x^*$.

Given that victims exert more than the socially optimal level of care in response to injurer care being equal to due care, it needs to be tested whether the injurer takes x^* in response to these victim care levels. It is very well possible that the supraoptimal victim care decreases the threat of the expected liability to such an extent that the injurer minimizes individual costs by a care level less than due care. In consequence, to establish $x = x^*$ as the best response to $(\hat{y}, \hat{z})$, we need to argue that

$$x^* < \bar{x} + p(\bar{x})[q^Y(\hat{y}, \hat{z})D + q^Z(\hat{z}, \hat{y})D] \tag{13}$$

holds, where $\bar{x} = \arg\min_{x<x^*}\{x + p(x)[q^Y(\hat{y}, \hat{z})D + q^Z(\hat{z}, \hat{y})D]\}$. This obviously is certainly true if $[q^Y(\hat{y}, \hat{z}) + q^Z(\hat{z}, \hat{y})] \geq [q^Y(y^*, z^*) + q^Z(z^*, y^*)]$ holds, i.e. if the total accident probability for given x is actually increased by victim care being larger than the socially optimal levels. The reverse case is presumably more relevant and occurs if the direct effect on the accident probability q^J of $\hat{j} > j^*$ dominates the indirect effect of $\hat{i} > i^*$. Under these circumstances, the inequality (13) does not necessarily hold and it is no longer certain that the injurer takes x^* in response to $(\hat{y}, \hat{z})$. Consequently, an ambiguity remains without further restrictions. The injurer prefers to take standard care only if the effect of suprastandard care by victims on total expected harm is not too strong.[8] Figure 3 illustrates the case in which the supraoptimal victim care argues for taking less injurer care than is prescribed by the standard care level, i.e. depicts the case in which (13) does not hold.

So far, we have first looked at the victim response to $x = x^*$ and then whether $x = x^*$ is the best response to the way victims respond to $x = x^*$. Now, we consider what victim

[8]Note that, for instance, Dharmapala and Hoffmann (2005) assume that an analogue to (13) always holds for $\bar{x} < x^*$ and any (y, z).

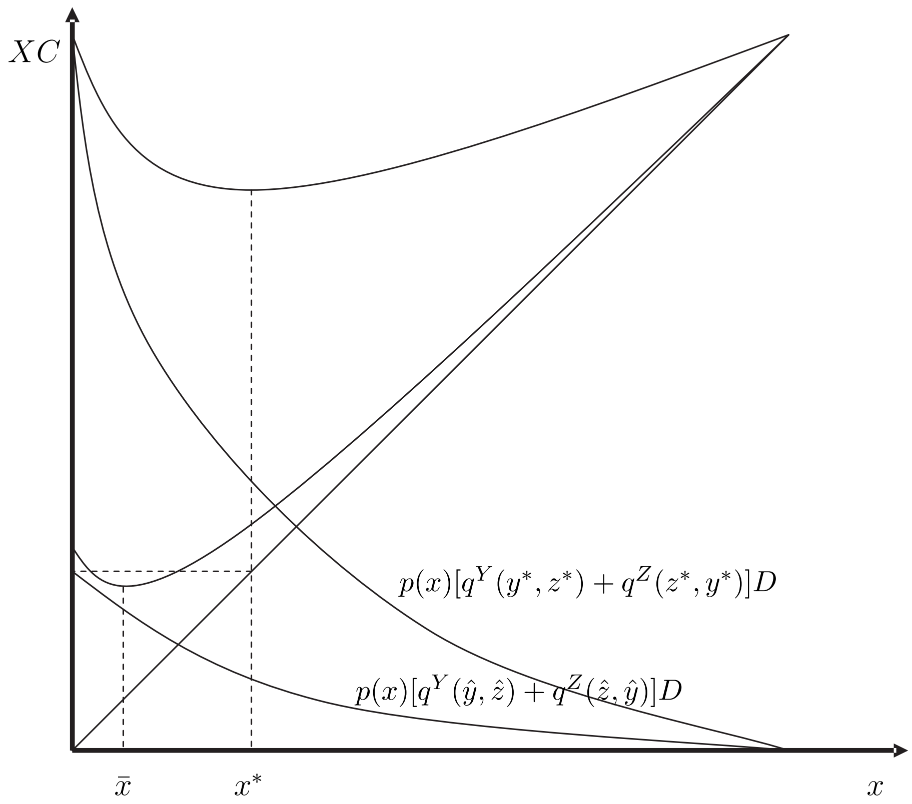

Figure 3: Injurer cost comparison

behavior results in response to $x < x^*$, that is if (13) does not hold. Since the first line in (6) is relevant in that case and will be minimized by the potential victim J, the victims' response to any $x < x^*$ is not exerting any care. If such an outcome were an equilibrium, the injurer would bear

$$XC = x_0 + p(x_0)[q^Y(0,0)D + q^Z(0,0)D] \tag{14}$$

where accordingly $x_0 = \arg\min_{x<x^*}\{x + p(x)[q^Y(0,0)D + q^Z(0,0)D]\}$.

From the social optimality of (x^*, y^*, z^*), we know that

$$\begin{aligned} x^* <& x^* + y^* + z^* + p(x^*)[q^Y(y^*, z^*)D + q^Z(z^*, y^*)D] \\ <& x + y + z + p(x)[q^Y(y, z)D + q^Z(z, y)D] \end{aligned} \tag{15}$$

holds for any $(x, y, z) \neq (x^*, y^*, z^*)$ and, thus, will also hold for $(x_0, 0, 0)$. Consequently, injurers prefer to deviate unilaterally to $x = x^*$ if $(x_0, 0, 0)$ is the constellation faced by the injurer. In consequence, if (13) does not hold, then there is a circle which allows only for a mixed-strategy equilibrium. Given $x = x^*$, we obtain $(\hat{y}, \hat{z})$ as best responses by Y and Z. Given $(\hat{y}, \hat{z})$ and (13) failing to hold, the injurer responds by taking $x < x^*$. Given $x < x^*$, victims do not take care. Given $(y, z) = (0, 0)$, the injurer deviates to $x = x^*$ and we return to the beginning. Similar circles will emerge below and are described in, for instance, Endres and Querner (1995).

The above allows deducing the following result.

Proposition 1 *Assume that* $q_i^J > 0$. *Given simple negligence, (i) if* (13) *holds, the outcome with respect to care is* $(x^*, \hat{y}, \hat{z})$, *where* $(\hat{y}, \hat{z}) >> (y^*, z^*)$, *whereas (ii) if* (13) *does not hold, the equilibrium is in mixed strategies where care levels different from the socially optimal levels are played with positive probability.*

Proof. See the above. ∎

In the setting considered in this section, victim care has an upside and a downside, since it lowers the accident probability for the victim exerting care but also increases the probability of being involved in an accident for other victims. The fact that the latter does not enter the individual calculus causes a tendency of victims investing too much in care from a social perspective. Simple negligence directs a standard at the injurer who complies (if (13) holds). As a consequence, victims are residual risk bearers. However, they are residual risk bearers who do not internalize all consequences flowing from their choices. Consequently, simple negligence proves unable to deal with the complexity of victims adversely affecting each other by taking care.

Negligence with a Defense of Contributory Negligence

Negligence with a defense of contributory negligence directs behavioral standards at both parties to the accident. The injurer will be free from expected liability if either she fulfills due care or if she is negligent but excused from liability due to victim negligence. This is expressed in the following individual cost functions. The injurer expects to bear costs according to

$$XC_{NCN} = \begin{cases} x + p(x)D[q^Y(y,z) + q^Z(z,y)] & \text{if } x < x^* \text{ and } y \geq y^*,\ z \geq z^* \\ x + p(x)q^Y(y,z)D & \text{if } x < x^* \text{ and } y \geq y^*,\ z < z^* \\ x + p(x)q^Z(z,y)D & \text{if } x < x^* \text{ and } y < y^*,\ z \geq z^* \\ x & \text{if } x < x^* \text{ and } y < y^*,\ z < z^* \text{ or } x \geq x^*\ \forall y, z. \end{cases} \tag{16}$$

Victim J has costs JC, where

$$JC_{NCN} = \begin{cases} j & \text{if } x < x^* \text{ and } j \geq j^* \\ j + p(x)q^J(j,i)D & \text{if } x < x^* \text{ and } j < j^* \text{ or } x \geq x^* \ \forall y, z \end{cases} \tag{17}$$

The central difference between simple negligence and negligence with a defense of contributory negligence is the fact that negligent injurers are freed from expected liability if the victim is negligent as well. Given the analysis presented for simple negligence, we may conjecture that the efficient outcome is not attainable under negligence with a defense of contributory negligence either. The reasoning goes as follows. Given that injurers take due care, victims bear full expected individual harm and therefore have excessive incentives to take care. In other terms, having standards directed at victims, which are effective only if the injurer is negligent, cannot curtail excessive incentives. This intuition will now be supported more formally.

Proposition 2 *Assume that* $q_i^J > 0$. *Given negligence with a defense of contributory negligence, (i) if* (13) *holds, the outcome under negligence with a defense of contributory negligence with respect to care is* $(x^*, \hat{y}, \hat{z})$, *where* $(\hat{y}, \hat{z}) >> (y^*, z^*)$, *whereas (ii) if* (13) *does not hold, the equilibrium is in mixed strategies where care levels different from the socially optimal levels are played with positive probability.*

Proof. Given that $x = x^*$, incentives are the same as under simple negligence as long as there are no incentives for substandard victim care. However, it can be ruled out that $(\hat{y}, \hat{z})$ are substandard care levels (the argumentation undertaken for simple negligence applies analogously). Then, x^* is a best response to $(\hat{y}, \hat{z})$ if (13) holds, which establishes the equilibrium in $(x^*, \hat{y}, \hat{z})$.

If (13) does not hold so that X chooses $x < x^*$ as best response to $(\hat{y}, \hat{z})$, it is then vital how victims will respond to this. Given that $\bar{x} < x^*$, victim J knows that taking due care means being free of expected harm, whereas a care level below standard care leaves expected harm with the victim. Suppose there is an equilibrium in substandard victim care given $\bar{x} < x^*$, denoted $(\bar{x}, y_s, z_s)$. In such a case, we would have to be in the position to rule out that a unilateral deviation by victims to due care is individually desired, i.e., it needs to hold that

$$y_s + p(\bar{x})q^Y(y_s, z_s)D < y^* \tag{18}$$

$$z_s + p(\bar{x})q^Z(z_s, y_s)D < z^* \tag{19}$$

Summing up and adding x^* leads to

$$x^* + y_s + z_s + p(\bar{x})[q^Y(y_s, z_s)D + q^Z(z_s, y_s)D] < x^* + y^* + z^* \tag{20}$$

This ranking is contradicted by (x^*, y^*, z^*) being the unique minimizer of SC.[9]

Consequently, victims would not opt for a care level less than the care standard in equilibrium. With victims being standard-adherent if $x < x^*$, injurers prefer to choose due care themselves as this minimizes individual costs which is obvious in reference to the social first-order condition with respect to injurer care, (2). Due care by injurers is best responded to from the victims' perspective by $(\hat{y}, \hat{z})$, as established above. As a consequence, in the case that (13) does not hold, we once again obtain circular reasoning of the following sort. Given $x < x^*$, victims choose to adhere to due care. Given victim due care, the injurer rather adheres to standard care. If injurer care equals standard care, victims choose $(\hat{y}, \hat{z})$ to which the injurer optimally responds with $x < x^*$. ■

Victims are once again destined to be residual risk bearers (if (13) holds), which cannot lead to the efficient care vector as marginal effects from the social problem are missing in the victim cost minimization. This is the same reasoning as laid out for simple negligence. The standards directed at victims under negligence with a defense of contributory negligence have an effect if the inequality which reasons for taking due care by the injurer, (13), does not hold. In that circumstance, victims include care levels in their mixed strategy different from those under simple negligence.

Strict Liability with a Defense of Contributory Negligence (SLCN)

This liability rule obliges injurers to compensate non-negligent victims, whereas victims whose care falls short of due care obtain no transfer irrespective of injurer behavior. This implies the following individual cost functions. Injurer costs XC can be stated as

$$XC_{SLCN} = \begin{cases} x + p(x)[q^Y(y,z)D + q^Z(z,y)D] & \text{if } y \geq y^* \text{and } z \geq z^* \\ x + p(x)q^Y(y,z)D & \text{if } y \geq y^* \text{and } z < z^* \\ x + p(x)q^Z(z,y)D & \text{if } y < y^* \text{and } z \geq z^* \\ x & \text{if } y < y^* \text{and } z < z^*. \end{cases} \tag{21}$$

[9]The LHS is larger than the usual reference $\bar{x} + y_s + z_s + p(\bar{x})[q^Y(y_s, z_s)D + q^Z(z_s, y_s)D]$ due to $x^* - \bar{x} > 0$.

Victim J has costs JC, where

$$JC_{SLCN} = \begin{cases} j & \text{if } j \geq j^* \\ j + p(x)q^J(j,i)D & \text{if } j < j^* \end{cases} \tag{22}$$

Suppose that victims exactly comply with care standards. Then injurers choose x^* since it minimizes individual costs. This follows from the first-order condition of the social problem with respect to injurer care, (2).

In turn, suppose that the injurer chooses x^*, then victims may either comply with due care or take care that falls short of due care. In any case, victims will never exert more care than due care since these alternative actions are clearly dominated by due care. This feature will prove to be fundamental for the efficiency characteristics of strict liability with a defense of contributory negligence. In effect, the liability rule removes the concern for expected harm from the cost function of victims as long as care does not fall short of due care. This removal proves sufficient to attain efficiency in the present setting. The reason for why this proves advantageous is that victims do not consider total social expected harm but only private expected harm, which creates higher care incentives for the individual victim than desirable from the social point of view. In other terms, if strict liability with a defense of contributory negligence succeeds in inducing victims to take standard care, the injurer is the residual risk bearer who internalizes all marginal effects. Therefore, the efficient outcome is attained if victims take due care.

Now, we will argue that victims indeed find it optimal to take due care as a response to $x = x^*$. Note that the cost function relevant for substandard victim care levels has been shown to be minimized by $(\hat{y}, \hat{z}) >> (y^*, z^*)$. Consequently, the option of being freed from expected harm by complying with standard care is unambiguously better than taking any care lower than what is required by the legal standard.

Suppose instead that $x < x^*$ is chosen by the injurer. This only reinforces the incentive to comply with due care for victims as injurer care and victim care are substitutes with respect to the accident probability π^{XJ}. For very high $x > x^*$, it might become optimal for victims to choose less than due care. However, this cannot be part of a pure-strategy equilibrium. The injurer would adapt by taking no care, to which victims respond by deviating to standard care. Given victim standard care, injurers optimize by taking x^*.

Proposition 3 *Assume that $q_i^J > 0$. The outcome under strict liability with a defense of contributory negligence with regard to care is (x^*, y^*, z^*).*

Proof. See the above. ■

This analysis incorporates that victims affect each other when taking care. We have established that this challenges the efficiency properties of simple negligence and negligence with a defense of contributory negligence. Under simple negligence, victims optimize continuously with respect to care since injurers choose standard care. The resultant care levels differ from the efficient care levels due to the missing internalization of the effect victim care entails on other victims. Negligence with a defense of contributory negligence directs standards at both parties. However, if the injurer always complies with the standard, the effects are unchanged in comparison to simple negligence. If the injurer does not always comply, then negligence with a defense of contributory negligence yields an outcome different from that resultant under simple negligence because of the standards directed at victims. Yet, under that circumstance, both liability rules obtain an equilibrium in mixed strategies which is characterized by care levels different from socially optimal care being played with positive probability.

Strict liability with a defense of contributory negligence differs in that there is no standard directed at injurers. Victims can free themselves of expected harm by complying with due care. In response, injurers optimize continuously with respect to care, which does not question the attainability of efficient care since this individual optimization takes all marginal effects of care into account. Stated alternatively, the removal of expected harm from the individual victim cost functions, once victim due care is taken irrespective of injurer care, proves to be the critical ingredient for the attainment of efficiency. This holds due to the fact that the consideration of expected harm in the victim cost function leads them astray from the social problem as it comprises only a part of total expected harm.

3.2 Victims Affect Each Other Positively

In this section, we consider the case that care-taking by one victim lowers the accident probability of other victims, i.e. the case in which $q_i^J < 0$ holds. The consequence is that since victims only take individual costs into account, taking victim care is associated with a positive externality. We will now establish how the liability rules considered perform under these circumstances.

Simple Negligence

The individual cost functions relevant in this case are (5) and (6). The injurer avoids expected harm by taking due care. Victims respond by taking $(y^+, z^+) << (y^*, z^*)$ due to the effect on the accident probability of other victims, which is considered in the social but neglected in the individual optimization. This also states that there is no equilibrium in which, given $x = x^*$, both victims take care above the socially optimal level. The reasoning very much follows that from above. For $(y^+, z^+) >> (y^*, z^*)$ to be the equilibrium given $x = x^*$, it needs to hold that a unilateral decrease of care to the socially optimal level implies higher individual costs for both victims. Consequently, it must simultaneously hold that

$$y^+ + p(x^*)q^Y(y^+, z^+)D < y^* + p(x^*)q^Y(y^*, z^+)D$$

$$z^+ + p(x^*)q^Z(z^+, y^+)D < z^* + p(x^*)q^Z(z^*, y^+)D \tag{23}$$

The summation of these inequalities and x^* to both sides gives

$$x^* + y^+ + z^+ + p(x^*)[q^Y(y^+, z^+)D + q^Z(z^+, y^+)D]$$

$$< x^* + y^* + z^* + p(x^*)[q^Y(y^*, z^+)D + q^Z(z^*, y^+)D] \tag{24}$$

Now, $q^J(j^*, i^+) < q^J(j^*, i^*)$ due to the assumption of $q_i^J < 0$ and the assumption that $(y^+, z^+) >> (y^*, z^*)$. Consequently, the right-hand side of the above inequality is less than SC^*. In contrast, the left-hand side of the inequality must be larger than SC^* because this represents an evaluation of social costs at (x^*, y^+, z^+) and otherwise (x^*, y^*, z^*) would not minimize social costs. Therefore it holds that

$$x^* + \hat{y} + \hat{z} + p(x^*)[q^Y(\hat{y}, \hat{z})D + q^Z(\hat{z}, \hat{y})D]$$

$$> SC^* > x^* + y^* + z^* + p(x^*)[q^Y(y^*, \hat{z})D + q^Z(z^*, \hat{y})D] \tag{25}$$

which excludes an equilibrium $(y^+, z^+) >> (y^*, z^*)$ for $x = x^*$.

As in Section 3.1, the intuition for this finding can be illustrated by the use of figures analogous to Figure 1 and 2. Figure 4 (5) depicts the case in which care by victim Y and by Z are strategic complements (substitutes). Once again, figures comprise the best response function and one iso-cost curve for each victim. The illustration shows that there is no intersection of respective best response functions to the northeast of (y^*, z^*).

Given (y^+, z^+), the injurer chooses due care since the substandard victim care only reinforces the incentive to comply with due care due to the fact that injurer and victim care are substitutes with respect to the accident probability function. In fact, there is no other pure-strategy equilibrium under simple negligence. Taking $x > x^*$ is dominated by taking $x = x^*$ and any

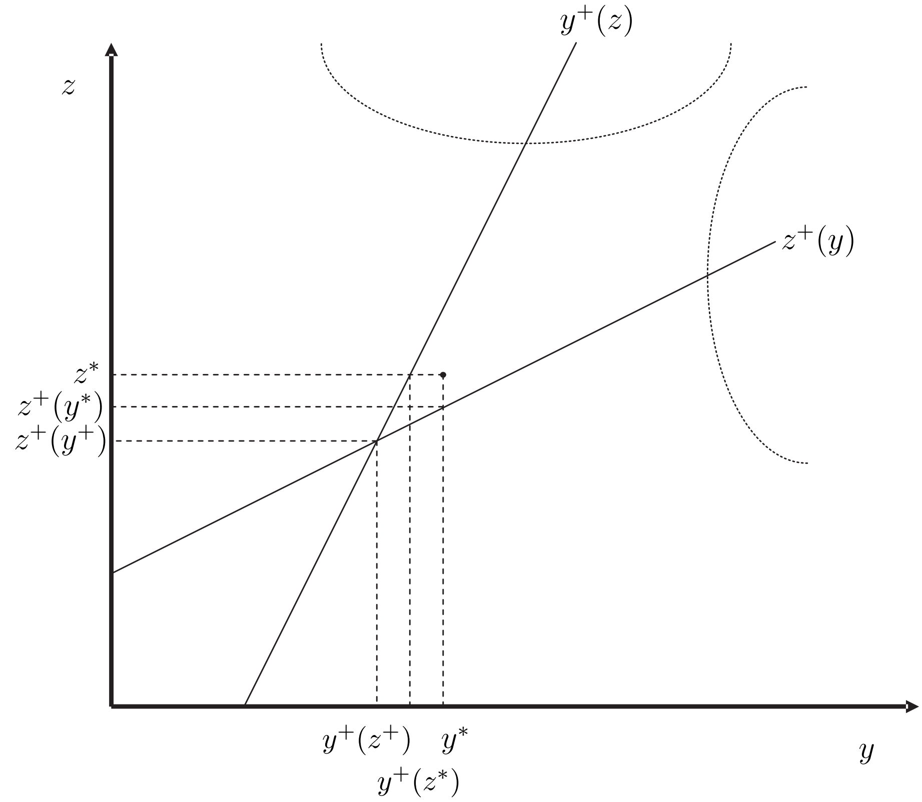

Figure 4: Best response functions if victim care is strategically complementary

constellation with $x < x^*$ would also entail $(y, z) = (0, 0)$ to which the injurer always responds by taking due care.

Note that we argued in the previous section that there cannot be an equilibrium in which both victim care levels are less than first-best care and injurer care is equal to first-best care. The above seems to be in contradiction to this assertion. However, there is a key difference due to the reversed direction of victim care on the accident probability of other victims.

Negligence with a Defense of Contributory Negligence

The injurer avoids expected harm by taking due care. Victims respond to $x = x^*$ by taking $(y^+, z^+) << (y^*, z^*)$. That level of victim care as given, injurers reduce care taken to zero as injurers only care about precaution costs in that circumstance (see (16)). Now, as it follows from (x^*, y^*, z^*) being the unique social cost minimizing care vector that

$$y_0 + p(0)q^Y(y_0, z_0)D < y^* \tag{26}$$

$$z_0 + p(0)q^Z(z_0, y_0)D < z^* \tag{27}$$

cannot hold simultaneously, where y_0 and z_0 are cost-minimizing victim care levels given $x = 0$

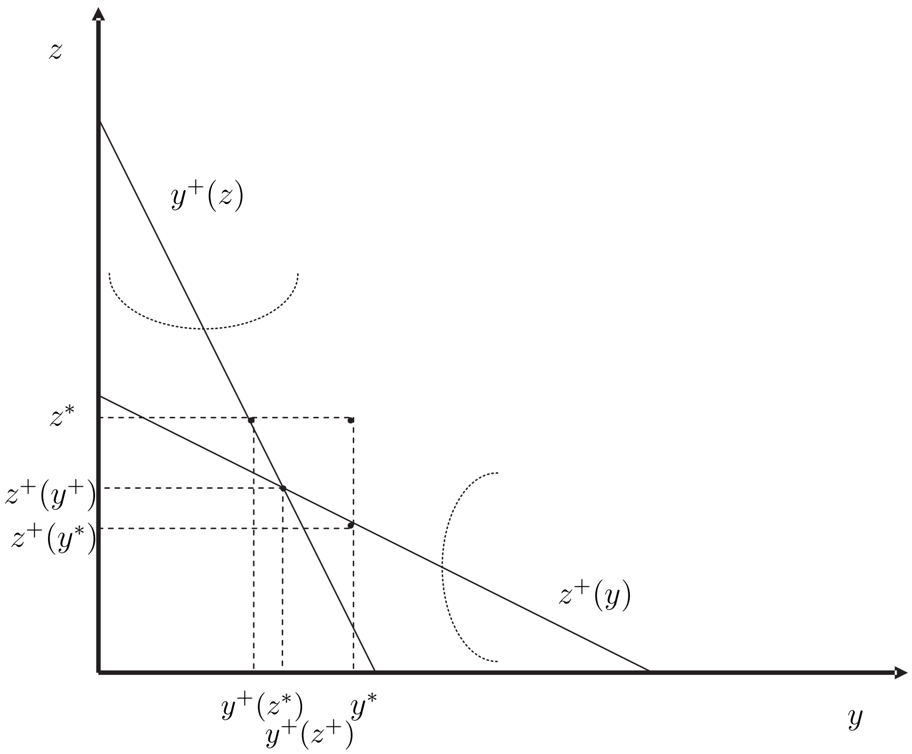

Figure 5: Best response functions if victim care is strategically substitutionary

with (y, z) restricted to be less than (y^*, z^*), we predict that victims divert to due care given no injurer care. As a consequence, there is no pure-strategy equilibrium under negligence with a defense of contributory negligence.

Strict Liability with a Defense of Contributory Negligence

The individual cost functions relevant in this case are (21) and (22). Suppose $x = x^*$, then victims may either comply with due care or choose less than due care. The victim payoffs are j^* and $\tilde{j}+p(x^*)q^J(\tilde{j}, i^*)D$ for J, where $\tilde{j}$ minimizes the individual cost function for $j < j^*$ given $x = x^*$ and $i = i^*$. For there to be an equilibrium in (x^*, y^*, z^*), we need to assure that there are no incentives for victim J to deviate to $\tilde{j}$ given x^* and i^*. This is not generally possible. The fact that there is a positive externality causes the individually optimal care level given (x^*, i^*) to be less than j^*. In cases in which the positive effect on the accident probability of others is huge, this may reason that $j^* > \tilde{j} + p(x^*)q^J(\tilde{j}, i^*)D$.

As stated above, Dharmapala and Hoffmann (2005) assume that the threat of expected harm is always sufficient for the individual to find it beneficial to increase care to standard care. Such an assumption takes the requisite

$$j^* < \tilde{j} + p(x^*)q^J(\tilde{j}, i^*)D \tag{28}$$

as fulfilled in all cases.

Although we cannot rule out incentives for a unilateral deviation, i.e., that (28) does not hold, we can rule out that there is an equilibrium in which both victims considered indeed choose care below due care. In such an equilibrium, injurers choose no care and consequently the reasoning involving (26) and (27) would apply.

Proposition 4 *Assume that $q_i^J < 0$. Given strict liability with a defense of contributory negligence, (i) if* (28) *holds, then the efficient care vector is attained, whereas (ii) if* (28) *does not hold, then there is no pure strategy equilibrium. Under simple negligence and negligence with a defense of contributory negligence, the efficient care vector is never attained.*

Proof. See the above. ■

4 Conclusion

Liability rules can under many circumstances deal with the interdependency of potential injurer and potential victim. However, since real accident contexts are very often quite complex, further interdependencies are likely to be at work. In our framework, victims are interdependent in the sense that care by one victim affects not only the accident probability of this victim but also that of other victims. Such an interrelation is likely to be present in many accident contexts. The interesting case in which care by one victim increases the exposure of other victims describes accident diversion, a phenomenon related to the diversion of crime.

This structure creates an externality, which implies that precaution choices may be inefficient. In the individual optimization, victims do not account for the effect on total expected harm but only for the effect on individual expected liability. This can effectuate that victims are willing to surpass (exert less than) efficient care in the case that victims affect one another detrimentally (positively). However, it is shown that strict liability with a defense of contributory negligence can induce optimal care. Interestingly, this holds for the case of a positive and a negative externality. For the case of a negative externality, the reason for the efficient outcome under strict liability with a defense of contributory negligence is that the liability rule cuts off further victim care-taking incentives once due care is achieved. For the case of a positive externality, the efficient outcome is possible under strict liability with a defense of contributory negligence since it can incentivize victims to take due care by freeing them from expected harm, whereas the first-best outcome proves unattainable under simple negligence or negligence with a defense of contributory negligence.

The analysis explicitly considered simple negligence, negligence with a defense of contributory negligence, and strict liability with a defense of contributory negligence and points out that the latter has the best properties when it comes to inducing efficient care. Comparative negligence directs standards at both parties and yields payoffs different from those resulting for negligence with a defense of contributory negligence only if injurer and victim choose care less than due care. Consequently, comparative negligence cannot outperform strict liability with a defense of contributory negligence in either of the cases considered since it lacks the features of the latter rule highlighted at the end of the last paragraph.

This study highlights the fact that victims' interdependence is not appropriately captured by liability rules. The optimal behavior of victims is orchestrated with that of other victims. The decentralization of care-taking behavior via liability rules is not successful in ensuring this orchestration. This shortcoming may be explained by the fact that liability rules do not consider that the concept of duty of care ideally needs to include the relationship among victims. For instance, if victim care lowers the accident probability of other victims, care ought to be higher from a social perspective than from the individual victim's stance due to victim interdependence. If a given victim takes individually optimal care which is less than socially optimal care, liability law offers other victims who are affected by the care of the given victim no means to correct incentives.

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