Firm Liability When Third Parties and Consumers Incur Cumulative Harm

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Abstract

This paper analyzes liability rules when consumers and third parties/the environment incur harm. Expected harm is convex in the level of output and modeled as a power function. We show that the social ranking of liability rules previously established for the case in which only consumers suffer harm (strict liability dominates no liability and negligence) may be reversed if harm to third parties or the environment is sufficiently important.

Keywords: Liability; Cumulative harm; Environmental harm

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1 Introduction

1.1 Motivation and Main Results

Product-related accidents may harm consumers as well as third parties/the environment. Third-party effects can result from the widespread usage of the product in a neighborhood, through leakages, emissions, disseminating effects, etc., as well as from accidental events that induce consumers' harm (e.g., via flying debris). Consider, for example, the use of glyphosate by farmers for agricultural weed control. Glyphosate is currently the most widely used herbicide in the world and supposedly harms both human health and the environment (Dias et al. 2019). In this context, third-party effects may stem from, for example, exposure from the spraying of fields or water contamination (e.g., Sanchis et al. 2012).[1] Another example is pharmaceuticals. For example, Heberer (2002) and Li (2014) report that sewage treatment plants remove pharmaceuticals incompletely even in developed countries, which means that they are ultimately discharged into the environment. With respect to consumer harm from pharmaceuticals, there exists evidence that increases in acetaminophen usage can raise the probability and extent of liver damage, that increases in the usage of aspirin and other nonsteroidal anti-inflammatory drugs, which can raise the probability and extent of internal bleeding, and so on (e.g., Daughety and Reinganum 2014). The microplastic used, for instance, in personal care products and clothing represents just another example with potential harm to consumers and third parties/the environment (e.g., Prata et al. 2020).[2]

This paper analyzes liability rules when both consumers and third parties/the environment incur harm. Previous analyses of firm liability assumed that either consumers or third parties suffer harm. In our framework, when considering how different liability regimes influence privately optimal care and output choices by a monopolistic firm, we consider a weighting scheme that allows us to express the importance of consumer harm relative to third-party harm. We analyze a model in which the harm develops as a strictly convex function in the product's quantity, an

[1] See, for example, Dias et al. (2019) for a study of the potential effects on birth outcomes.

[2] Examples where products may cause harm to consumers and other people (as third parties) include smoke from tobacco products, potentially exploding smartphones (Samsung Galaxy Note 7), and soft drinks in bottles (e.g., Escola v. Coca-Cola Bottling Co.).

important and realistic assumption. For example, the environmental harm from antibiotics in the groundwater will presumably be non-linear (e.g., Martinez 2009). More generally, given that the environment is a complex system potentially involving tipping points (e.g., Mäler et al. 2003), environmental harm increasing disproportionally appears very reasonable. To focus on the role of the simultaneous presence of consumer and third party harm and follow previous literature on environmental liability law (e.g., van Egteren and Smith 2002), we use a simplistic representation of the compensation for environmental harm, for example, by abstracting from measurement issues and the distinction between the level of harm on the one hand and the level of clean-up costs on the other.[3]

Liability rules are an important instrument in the policymaker's toolbox (e.g., van Egteren and Smith 2002, Endres 2011). The determination of liability for harm in tort cases is based on two main liability schemes: either strict liability or negligence. Strict liability means that an injurer is liable regardless of how the activity that caused the harm was undertaken. Under negligence, the determination of liability hinges upon how the activity that caused the harm was undertaken. In real-world legislation, it often depends on the activity, whether strict liability or negligence applies. For instance, the Environmental Liability Directive of the European Union lists activities that are subject to strict liability, while other activities are subject to negligence. Much of the literature about liability rules is devoted to delineating under which circumstances one liability rule outperforms the other (e.g., Shavell 2007).

We find that the explicit consideration of harm to third parties or the environment is consequential to the relative performance of liability rules. Our results show that the ranking of liability rules previously established by Daughety and Reinganum (2014) for the case in which only consumers suffer harm – strict liability dominates the other two liability regimes – may be reversed in our setting. First, we show that no liability can, in specific circumstances, produce the outcome that occurs under strict liability. To obtain this finding in our framework, harm to consumers must stand in an intuitive relationship to third-party or environmental harm (in a way made more

[3] In contrast, Endres and Friehe (2015) focus on the role of the compensation regime in environmental liability law, distinguishing the cases (i) compensation for the level of harm, (ii) compensation for clean-up costs, and (iii) compensation for a combination of the level of harm and the level of clean-up costs.

precise below). Relative to strict liability, no liability implies two distortions, which perfectly offset each other when the relative importance of second-party harm to third-party harm is of a well-defined magnitude. Within limited parameter bounds, no liability outperforms strict liability because it can induce greater output. Second, and more importantly, we delineate circumstances in which negligence yields higher welfare than strict liability. For negligence to possibly dominate strict liability, third-party harm must be sufficiently important relative to consumer harm (in a way made more precise below). In these circumstances, the firm strictly prefers being not liable to being liable, and the social planner can utilize this firm preference to implement a preferred social outcome. More specifically, the firm's strict preference for being not liable creates a willingness to pay in terms of greater product safety on behalf of the firm, and the social planner can exploit this reality to achieve higher welfare.

1.2 Related Literature

Our paper considers different liability regimes when *both* consumers and third parties incur cumulative harm. There is a vast literature on *product liability* (see, e.g., the surveys by Daughety and Reinganum 2013b, and Geistfeld 2009). The traditional setup considers perfectly competitive firms, identical risk-neutral consumers, common knowledge about expected harm, costless trials, and that both care costs and expected harm are proportional to output. The traditional framework delivers the key finding that strict liability, negligence, and no liability are all *equally efficient* when consumers are perfectly informed about care and do not misperceive risk (e.g., Shavell 1980). The rationale is that the consumers' willingness to pay introduces the concern for minimizing of the expected harm when it would otherwise be missing from the firm's profit maximization. In that standard framework, when third parties incur harm instead of consumers, strict liability and negligence are equally efficient, whereas no liability produces an inefficient outcome (e.g., Shavell 1987).

The irrelevance result for the scenario in which only consumers are harmed depends on the traditional setup's far-reaching assumptions. This reality is well-documented in the literature. For example, Daughety and Reinganum (2006) consider a scenario in which product safety is chosen in a preliminary R&D stage, which implies a fixed cost, introducing a strategic "business-stealing" effect of product safety. Other examples of departures from the standard framework include Daughety and Reinganum (1995), who analyze product liability when the level of product safety is the firm's private information, and Friehe et al. (2018), who focus on the influence of litigation costs and the implication of a probability of suit strictly below one. We will abstract from all of these complications and instead focus on the implications from a novel specification of expected harm that includes harm to consumers and third parties/the environment.

In our paper, the firm may be liable for both harm to consumers and harm to *third parties/the environment*. In the previous literature, firm liability for harm to third parties or the environment was *separated* from the liability of firms for harm to consumers. The former has been studied in relation to various issues, including liability sharing (Hansen and Thomas 1999; Watabe 1999), or extended liability and the judgment proof problem (Boyer and Laffont 1997, Evans and Gilpatric 2017); other work has focused on the incentives to adopt green innovations (Endres and Friehe 2011, Endres et al. 2007), or the interplay with competitive distortions (Charreire and Langlais 2020).

For our analysis and results, it is important that we consider *cumulative* harm, thereby building on Marino (1988) and Daughety and Reinganum (2013a, 2014). Our contribution to this branch of literature considers the scenario in which harm is incurred not only by consumers but also third parties/the environment. This is particularly interesting because the driving force in this context, namely that the marginal expected harm exceeds the average expected harm per unit of output, is only relevant to the extent that it affects consumers, but not third parties.

Hay and Spier (2005) consider a model in which the products that consumers purchase from firms may cause harm to third parties, where the expected harm is influenced by product safety and consumer care. A realistic case-in-point for a product in their setup is guns. The authors show that full consumer liability induces the first-best outcome in a benchmark model, but also that shifting liability from the consumer to the firm may be desirable in some circumstances (e.g., when the consumer is potentially judgment-proof, that is, unable to pay the compensation due in the event of an accident). In contrast, we focus on the firm's efforts to address expected harm and include circumstances in which the harm to third parties is not directly due to consumers. Suppose, for example, that a manufacturer produces output using chemicals, where the types and volume of chemicals influence the expected harm to consumers (e.g., toxic chemicals in apparel) and the expected harm to the environment (e.g., from planned or accidental emissions during the production process).

1.3 Plan of the Paper

In Section 2, we present the framework used for our analysis. In Section 3, we first describe and compare the firm's decision-making under strict liability and no liability in terms of welfare. Next, we analyze how the firm behaves when subject to negligence and address the relative performance of negligence. We conclude in Section 4.

2 Model

Our model builds on Daughety and Reinganum (2014), who use a representative consumer framework. Specifically, we consider a risk-neutral monopolist serving a market described by a linear (inverted) market demand *gross of any harm* $P(q) = a - bq$, where q denotes output, and a and b are positive parameters. This (inverted) demand results from maximizing a quasi-linear utility *gross of any harm*, $U = aq - bq^2/2 + r$, subject to the budget constraint, $y = r + Pq$ where r represents a numeraire good and y exogenous income. The firm incurs a cost $C(q, x) = c(x)q$, where x denotes product safety and $c'(0) = 0 = c(0)$, $c' > 0$, and $c'' > 0$ for all $x > 0$. To provide an analysis focused on incorporating third-party harm, we abstract from the possibility that liability induces firm insolvency.

Observable product safety influences the expected harm caused to the representative consumer and/or a third party. Similar to Daughety and Reinganum (2014), we assume that the total expected harm can be described by the convex function $H(q, x) = \gamma h(x)q^\theta$, where $\theta > 1$, $h(0) > 0$ and, for any x, $h'(x) < 0 < h''(x)$. Importantly, we assume that $\gamma = \alpha + \beta$ where $\alpha \geq 0$ scales up consumer harm and where $\beta \geq 0$ is the multiplier for third-party/environmental harm.[4] The

[4]We abstain from incorporating mitigation incentives discussed in Endres and Friehe (2015) and Friehe and

framework considered by Daughety and Reinganum (2014) in their main analysis results for $\theta = 2$, $\alpha = 1$, and $\beta = 0$. Needless to say, our assumptions about how expected harm depends on firm output and how it can be separated into consumer and third-party harm will imprint on the exact results presented below.

The timing is such that, in Stage 1, the firm determines the level of observable product safety and the level of output in view of the consumer's decision-making in Stage 2, as represented by the market demand function. In Stage 3, after an accident, the firm is made to compensate for any harm when judged liable in (socially and privately) costless litigation.

3 Analysis

In Sections 3.1 and 3.2, we will describe market outcomes when the firm faces no liability or is subject to strict liability. In Section 3.3, we compare the privately optimal choices under the respective regimes from a welfare perspective. Section 3 concludes with an analysis of firm behavior under a negligence rule with a well-defined product safety standard and how welfare under negligence compares to that under other liability rules (Section 3.4).[5]

Before we start our analysis of decentralized decision-making, as a benchmark, the socially optimal levels of output and safety, $(\hat{q}^W, \hat{x}^W)$, maximize

$$W(q,x) = \left(a - \frac{b}{2}q - c(x)\right)q - \gamma h(x) q^{\theta} \tag{1}$$

and are characterized by the first-order conditions for an interior solution[6]

$$W_q = a - bq - c(x) - \gamma\theta h(x) q^{\theta-1} = 0 \tag{2}$$

$$W_x = -c'(x)q - h'(x)\gamma q^{\theta} = 0, \tag{3}$$

where we use subscripts to denote partial derivatives. We denote with $q^W(x)$ the function that yields the first-best output for the given product safety level, derived from condition (2). Similarly,

Langlais (2017), for example.

[5]The close analogy of no liability and strict liability, when compared to negligence, justifies this sequence. Note that we assume throughout that firms are legally constrained by the respective regime (i.e., cannot contractually circumvent it using a voluntary offer to compensate consumers' losses, for example).

[6]See Appendix A for the description of sufficient conditions.

the function that yields the first-best product safety level for a given output level is denoted $x^W(q)$ and results from condition (3). The socially optimal levels of output and product safety result as $(\hat{q}^W, \hat{x}^W) = (q^W(\hat{x}^W), x^W(\hat{q}^W))$.

3.1 Care and Output Under No Liability

Under no liability, total harm remains with the consumer and/or the third party. This influences the consumer's willingness to pay derived in Stage 2. Considering the marginal effects flowing from the maximization of $\tilde{U} = aq - bq^2/2 + y - Pq - \alpha h(x)q^\theta$, that is, expected payoffs taking account of the budget constraint and the expected harm, we can assert that

$$P(q) = a - bq - \alpha\theta h(x)q^{\theta-1}$$

is the relevant (inverted) market demand for the firm to consider in the first stage.

In Stage 1, the monopolist chooses output and product safety in order to maximize

$$\Pi^{NL}(q, x) = (a - bq - c(x))q - \alpha\theta h(x)q^\theta. \tag{4}$$

Under no liability, the privately optimal level of product safety conditional on output, $x^{NL}(q)$, and the privately optimal level of output conditional on product safety, $q^{NL}(x)$, satisfy

$$\Pi_q^{NL} = a - 2bq - c(x) - \alpha\theta^2 h(x)q^{\theta-1} = 0 \tag{5}$$

$$\Pi_x^{NL} = -c'(x)q - h'(x)\alpha\theta q^\theta = 0. \tag{6}$$

The profit-maximizing levels of output and product safety result as $(\hat{q}^{NL}, \hat{x}^{NL}) = (q^{NL}(\hat{x}^{NL}), x^{NL}(\hat{q}^{NL}))$. As is clear from the last term in condition (5), under no liability, the firm internalizes the marginal output costs besides $c(x)$ to the extent that the higher expected harm reduces the consumer's willingness to pay, $\alpha\theta^2 h(x)q^{\theta-1}$. In contrast, marginal expected social harm amounts to $\gamma\theta h(x)q^{\theta-1}$. Under no liability, the firm is concerned only about harm incurred by the consumer and *not at all* about harm incurred by the third party/the environment, suggesting that output under no liability will be excessive. However, it is important to note that the firm internalizes how its output increase changes the consumer's marginal harm instead of how its output variation influences the consumer's average harm, making suboptimal output possible under no liability. Similarly, with respect to product safety, the information about the marginal benefit from product safety is transmitted to the firm via the change in the consumer's willingness to pay which only reflects the repercussions for the consumer's marginal harm.

3.2 Care and Output Under Strict Liability

Under strict liability, total harm is shifted from both the consumer and the third party to the firm. Since we assume full compensation of harm, under strict liability, the consumer's willingness to pay derived in Stage 2 does not depend on product safety and can be stated as

$$P(q) = a - bq.$$

In Stage 1, the monopolist chooses output and product safety in order to maximize

$$\Pi^{SL}(q,x) = \big(a - bq - c(x)\big)q - \gamma h(x)q^{\theta}. \tag{7}$$

The firm bears the average of the *total* expected harm per unit of output. This contrasts with the case of no liability in two ways. First, the consumer's expected harm enters the firm's maximization problem as the average consumer harm per unit of output. Second, under strict liability, the firm internalizes not only consumer harm but also third-party harm.

The first-order conditions give the privately optimal level of product safety conditional on output, $x^{SL}(q)$, and the privately optimal level of output conditional on product safety, $q^{SL}(x)$ when the firm is strictly liable by solving the system:

$$\Pi_q^{SL} = a - 2bq - c(x) - \gamma\theta h(x)q^{\theta-1} = 0 \tag{8}$$

$$\Pi_x^{SL} = -c'(x)q - h'(x)\gamma q^{\theta} = 0 \tag{9}$$

The profit-maximizing levels result as $(\hat{q}^{SL}, \hat{x}^{SL}) = (q^{SL}(\hat{x}^{SL}), x^{SL}(\hat{q}^{SL}))$. The per-unit marginal expected liability cost that the firm takes into account under strict liability is equal to the marginal expected social harm. However, the marginal private benefits of output fall short of the marginal social benefit, signifying that the privately optimal output under strict liability will tend to be socially suboptimal. It results from our assumptions about both the level of compensation being equal to the level of harm and the free litigation – which basically means that the firm internalizes the full expected social harm – that strict liability induces socially adequate product safety for the given level of output.

3.3 Comparing No Liability to Strict Liability

While strict liability induces the firm to take into account the socially adequate marginal expected harm from greater output and the correct marginal benefits from greater product safety for the given output, the monopolistic firm's output is too small. Under no liability, the marginal effects that the firm internalizes usually differ from their social counterparts. Because the firm creates artificial scarcity to raise the product's price in both regimes, it is unclear whether strict liability outperforms no liability. This section clarifies how the two regimes compare in terms of welfare.

In order to determine whether no liability or strict liability yields greater welfare, we state firm profits as

$$\Pi(q,x) = \big(a - bq - c(x)\big)q - \alpha\kappa h(x)q^{\theta}, \tag{10}$$

with the first-order conditions

$$\Pi_q(q,x) = a - 2bq - c(x) - \alpha\kappa\theta h(x)q^{\theta-1} = 0 \tag{11}$$

$$\Pi_x(q,x) = -c'(x)q - \alpha\kappa h'(x)q^{\theta} = 0. \tag{12}$$

where $\kappa^{SL} = 1 + \beta/\alpha$ when the firm is subject to strict liability and $\kappa^{NL} = \theta$ when no liability applies. Both liability regimes produce *exactly the same* incentives when $\kappa^{NL} = \kappa^{SL}$, that is, when $1 + \beta/\alpha = \theta$ holds. This equality results if

$$\beta = \hat{\beta}(\alpha) \equiv (\theta - 1)\alpha, \tag{13}$$

where $\hat{\beta} \leq \alpha$ if $\theta \leq 2$ and $\hat{\beta} > \alpha$ otherwise.[7] This means that for any α (i.e., consumer harm), there exists a level of β (i.e., third-party harm) such that the institutional choice between strict liability and no liability is irrelevant. This produces a stark contrast to the analysis by Daughety and Reinganum (2014). Whereas the firm under no liability considers terms including $\alpha\theta$

[7] We will sometimes suppress the argument of the function $\hat{\beta}(\alpha)$ to ease on notation.

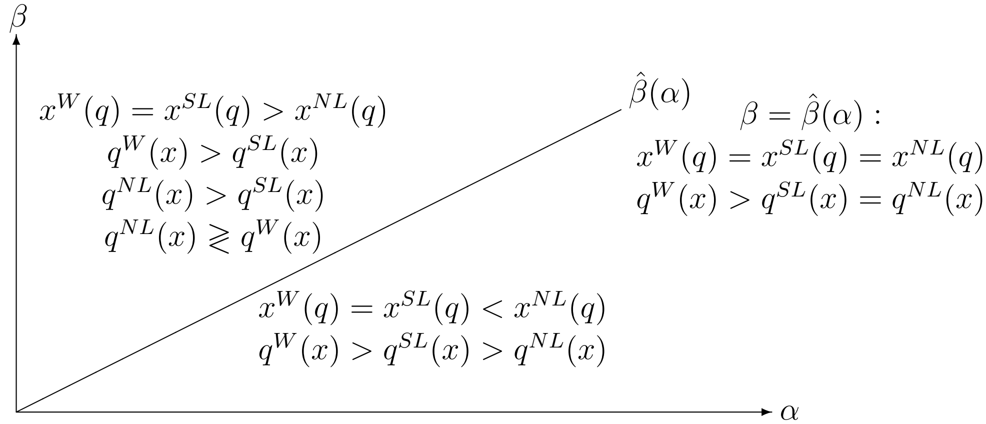

Figure 1: Comparison of output and safety levels under no liability (superscript NL), strict liability (SL) and in the first best (W).

when assessing output and safety, the firm under strict liability considers the same terms with γ substituting the $\alpha\theta$. Given any arrangement (α, β) in our framework, the firm under no liability will thus consider harm implications from its output and safety choices that are too small (large) relative to the true expected social harm implications when $\beta >$ $(<)$ $\hat{\beta}$. We summarize in Figure 1 and the next result.

Lemma 1 *(i) If $\beta = \hat{\beta}$, the conditional product safety under no liability is equal to the one under strict liability, and both concur with the socially optimal level. The profit-maximizing conditional output levels under no liability and strict liability match but fall short of the socially optimal one. (ii) If $\beta < \hat{\beta}$, the conditional product safety level under strict liability is equal to the socially optimal one and short of that under no liability. Socially optimal conditional output exceeds output under strict liability, which in turn exceeds output under no liability. (iii) If $\beta > \hat{\beta}$, the conditional product safety level under strict liability is equal to the socially optimal one and in excess of the one under no liability. In terms of conditional output, the socially optimal level exceeds the privately optimal level under strict liability, which is also smaller than output under no liability.*

Proof. See Appendix B for the derivation of this result. ■

Because strict liability induces socially optimal product safety conditional on output, no liability may yield higher welfare only if it produces a socially more desirable output level than strict liability. Starting at $\beta = \hat{\beta}$ where both regimes produce equal welfare, an increase in β such that $\kappa^{SL} > \kappa^{NL}$ means that the firm subject to no liability perceives implications falling short of the social harm consequences and thus will implement a larger level of output and a smaller level of safety when compared to what is obtained when the firm is subject to strict liability. When β is similar to $\hat{\beta}$, the deviation in terms of product safety will be marginal, but the improvement in terms of output will be discrete. In contrast, a decrease in β starting at $\hat{\beta}$ such that $\kappa^{SL} < \kappa^{NL}$ means that the firm subject to no liability perceives implications greater than social harm consequences and thus will implement a smaller level of output and a higher level of safety when compared to what is obtained under strict liability. As a result, strict liability produces a welfare level closer to the welfare maximum.

Proposition 1 *(i) Strict liability and no liability produce the same welfare when $\beta = \hat{\beta}(\alpha)$. (ii) Strict liability is welfare superior to no liability when $\beta < \hat{\beta}(\alpha)$. (iii) No liability is welfare superior to strict liability when β is greater but close to $\hat{\beta}(\alpha)$, whereas it is ambiguous when β is much larger than $\hat{\beta}(\alpha)$.*

Proof. Part (i) results directly from Lemma 1(i). With respect to parts (ii) and (iii), consider how social welfare changes with the level of κ for a fixed combination of (α, β) by using how both the output and the product safety level respond to a change in κ. When we derive

$$\widetilde{W}(\kappa) = \left(a - \frac{b}{2}q(\kappa) - c(x(\kappa))\right) q(\kappa) - \gamma h(x(\kappa))q(\kappa)^{\theta} \tag{14}$$

with respect to the value of κ to represent a change that pertains only to the firm's internalization of social marginal effects, we obtain

$$\frac{d\widetilde{W}}{d\kappa} = \left(a - bq(\kappa) - c(x(\kappa)) - \gamma\theta h(x(\kappa))q(\kappa)^{\theta-1}\right) \frac{dq}{d\kappa} + \left(-c'(x)q - h'(x)\gamma q^{\theta}\right) \frac{dx}{d\kappa} \tag{15}$$

and after using the first-order conditions (11) and (12), we can state

$$\frac{d\widetilde{W}}{d\kappa} = \left(bq(\kappa) + \alpha(\kappa - \kappa^{SL})\theta h(x(\kappa))q(\kappa)^{\theta-1}\right) \frac{dq}{d\kappa} + \left(\alpha(\kappa - \kappa^{SL})h'(x)\gamma q^{\theta}\right) \frac{dx}{d\kappa}, \tag{16}$$

where $dq/d\kappa < 0$ and $dx/d\kappa > 0$ (see the proof in Appendix B). When $\beta = \hat{\beta}$, the level of κ is equal to κ^{SL} in both liability regimes. In this circumstance, the derivative of welfare with respect to κ is clearly negative, indicating that it is welfare-improving to implement a marginally smaller

κ in order to raise the firm's level of output. When the true β is smaller (larger) than $\hat{\beta}$, we have $\kappa^{NL} > (<) \kappa^{SL}$. This means that $\beta > \hat{\beta}$ but a value around $\hat{\beta}$ represents a scenario where no liability can outperform strict liability as it induces the smaller level of κ for the fixed combination of (α, β). This dominance results from the fact that the welfare effect of greater output is first order while the product safety effect is not. When β is no longer close to $\hat{\beta}$, the relatively greater output under no liability is associated with a product safety that is noticeably smaller than under strict liability. This is discussed in claim (iii). In contrast, if $\beta < \hat{\beta}$, strict liability induces the preferable outcome in terms of both product safety and output. ■

The two liability regimes can also be compared from the firm's standpoint. This comparison is an important input for the analysis of the negligence rule conducted in the next section. We find that there are circumstances in which the firm prefers strict liability over no liability and vice versa.

Lemma 2 *Strict liability dominates (is dominated by) no liability in terms of the firm's expected profits when* $\beta > (<) \hat{\beta}(\alpha)$.

Proof. By application of the envelope theorem, only the direct effect of κ matters, such that the firm prefers the regime that yields the smaller level of κ as

$$\frac{d\Pi}{d\kappa} = -\alpha h(x) q^{\theta} < 0.$$

As a result, the firm prefers no liability over strict liability when $\beta > \hat{\beta}$ and vice versa. ■

3.4 Care and Output under Negligence

Any negligence standard allows the firm to choose between the two previously discussed regimes: the firm is strictly liable when it chooses product safety below the due level $\bar{x}$, and the firm has payoffs identical to those as under no liability provided that product safety is weakly in excess of the product safety standard. Formally, this means that

$$\Pi^{N}(q, x) = \mathbf{1}_{\{x \geq \bar{x}\}} \Pi^{NL}(q, x) + (1 - \mathbf{1}_{\{x \geq \bar{x}\}}) \Pi^{SL}(q, x), \tag{17}$$

with $\mathbf{1}_{\{x \geq \bar{x}\}}$ as an indicator variable equal to one if product safety is at least as high as the standard. According to Proposition 1(i) in conjunction with Lemma 2, if $\beta < \hat{\beta}(\alpha)$, strict liability is the preferable regime from the firm's point of view and from a welfare perspective. Any due level for product safety in a negligence regime can at best lead to the same level of welfare as under strict liability. The firm will certainly not comply with a due level of product safety that is excessive from the firm's point of view.

In contrast, if $\beta > \hat{\beta}(\alpha)$, as illustrated in Figure 2 (which assumes the parameter constellation $a = 10$, $b = 1$, $c(x) = (1/2)x^2$, $h(x) = (1/2)x^{-2}$, $\theta = 2$, $\alpha = 1/4$ and $\beta = 3/4 > \hat{\beta} = 1/2$), the firm prefers to operate in a regime with no liability instead of strict liability. In particular,

$$\Pi^{SL}(q^{SL}, x^{SL}) < \Pi^{NL}(q^{SL}, x^{SL}) < \Pi^{NL}(q^{NL}(x^{SL}), x^{SL}), \tag{18}$$

such that in a negligence regime with a due level of product safety $\bar{x} = x^{SL}$, the firm will voluntarily adhere to the safety standard in order to avoid liability.

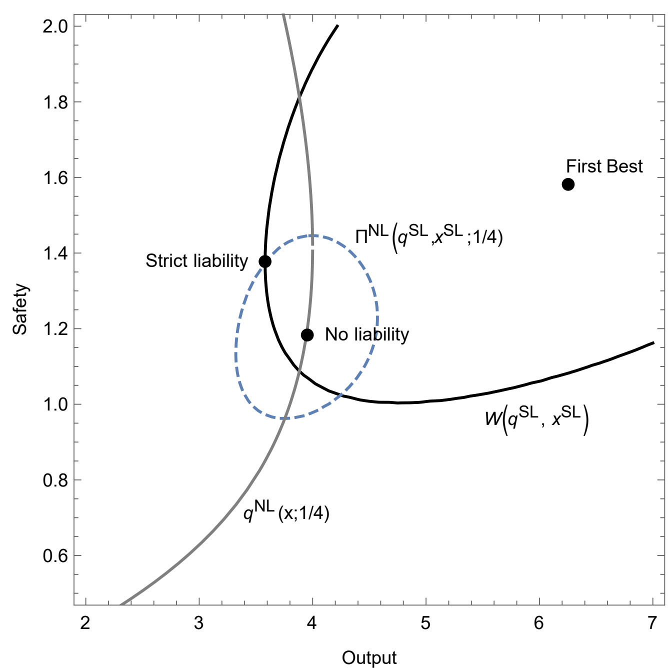

Figure 2: Welfare isoquant for outcome under strict liability ($W(q^{SL}, x^{SL})$), output under no liability as a function of safety ($q^{NL}(x; 1/4)$), isoprofit-curve in no liability regime for outcome under strict liability ($\Pi^{NL}(q^{SL}, x^{SL})$); $\alpha = 1/4$, $\beta = 3/4$.

Under no liability, the firm will provide higher output than under strict liability if the product safety standard is set at $\hat{x}^{SL}$. This increase in output is principally socially desired because the output obtained under strict liability is too low from a social perspective. More generally, the firm will comply with a due level of product safety $\bar{x}$ in the negligence regime if

$$\Pi(q^{NL}(\bar{x}), \bar{x}) \geq \Pi(q^{SL}, x^{SL}). \tag{19}$$

3.4.1 Product Safety Standard Independent of Output

We denote Condition (19) as the compliance constraint. Facing the due level of product safety $\bar{x}$, the firm optimally chooses output $q^{NL}(\bar{x}) = \arg\max\ \Pi(q, \bar{x}(q))$. As long as the quantity stays below the (conditional) social optimum, both moves (the increase in safety and the increase in quality) are welfare-improving. When imposing a fixed standard, the social planner can choose the product safety to maximize welfare subject to the compliance constraint and anticipate the monopolist's optimal quantity choice given the safety standard (depicted as $q^{NL}(x; 1/4)$ in Figure 2). As Figure 2 illustrates, due levels of product safety $\bar{x}$ exist (e.g., $\bar{x} = x^{SL}$ for this parameter constellation) such that a negligence regime using this due product safety level as the standard yields higher welfare than the regimes with either no or strict liability.

According to Proposition 1(iii), if $\beta > \hat{\beta}(\alpha)$, no liability can induce higher welfare than strict liability. While the firm's product safety under no liability is clearly socially suboptimal given the quantity produced, the actual quantity in the no liability regime can be too high or too low. It is too low if the quantity distortion due to the extraction of consumer surplus is a larger problem than that due to the uncompensated harm, that is, if b is sufficiently high (the exact threshold follows from comparing the first-order conditions (5) and (2)).[8] In this case, a marginal increase in the level of product safety – induced by an appropriately chosen standard – and the firm's associated response with higher output, is unambiguously welfare-enhancing. Thus:

[8] For a fixed standard of care $\bar{x}$, the first-order conditions demand $q^{NL}(\bar{x})(2b+\alpha\theta^2 h(\bar{x})q^{NL}(\bar{x})^{\theta-2}) = q^W(\bar{x})(b+(\alpha+\beta)\theta h(\bar{x})q^W(\bar{x})^{\theta-2})$. Suppose $q^{NL}(\bar{x}) > q^W(\bar{x})$. Then, the second factor on the left-hand side must be smaller than its counterpart on the RHS in order to satisfy the equation, which requires $b < \theta h(x)((\alpha+\beta)q^W(\bar{x})^{\theta-2} - \alpha\theta q^{NL}(\bar{x}^{\theta-2})$. The inequality cannot be met if b is too high. For β close enough to $\hat{\beta}$, it would even require a negative b. In contrast, if b is sufficiently high, the second factor on the LHS is larger than its counterpart on the RHS, so that $q^{NL}(\bar{x}) < q^W(\bar{x})$ is necessary to satisfy the equation. For $\theta = 2$, the (necessary and) sufficient condition for $q^{NL}(\bar{x}) < q^W(\bar{x})$ simplifies to $b > 2(\beta - \alpha)h(\bar{x})$.

Proposition 2 *If $\beta > \hat{\beta}(\alpha)$ and b is sufficiently high, there exist due levels of product safety $\bar{x}$ such that a negligence regime with a due level $\bar{x}$ yields higher welfare than no liability and strict liability.*

Note that the condition $\beta > \hat{\beta}(\alpha)$ is a necessary condition for a negligence regime to be welfare superior to the alternative regimes of no or strict liability, while the condition on b formulated in Proposition 2 is sufficient, but not necessary.

3.4.2 Product Safety Standard as a Function of Output

If we allow the standard of care to be a function of output, the social planner's problem is relaxed, as she is no longer limited to the set of points on the firm's best-response function $q^{NL}(\bar{x})$. Instead, she can deter a range of output choices by, for example, associating excessive product safety standards with them. Therewith, she can induce her favorite (q^*, x^*) out of those that satisfy the compliance constraint (19). Specifically , she can choose any point in Figure 2 in the area surrounded by the dashed graph representing the firm's isoprofit-curve, illustrating profits obtained under strict liability.

As can be seen in the figure, in order to effectively guide the firm's choice towards the desired outcome, the due level of product safety may be non-monotonic in the quantity. It is apparent that with full flexibility to choose such a function, the social planner can always improve welfare with an appropriately designed negligence regime if $\beta > \hat{\beta}(\alpha)$.

3.4.3 Product Approval by a Regulator

In order to complement our analysis, we point out the impact of a regulatory standard of product safety in the context of our model framework for the case $\beta > \hat{\beta}(\alpha)$.

If the firm's product is subject to approval by a regulator who is free to choose a minimum product safety standard $\underline{x}$, such a regulator can potentially achieve an even better outcome than a negligence regime with an appropriately chosen due level of product safety. This is obtained because such a regulator's optimization problem is less constrained than that of a social planner using negligence. While the compliance constraint deters the firm from opting into strict liability (and earning optimized monopoly profits in this regime) by not adhering to the due level of product safety, the regulator must only respect a constraint that gives rise to non-negative profits. Thus, the reachable outcomes under the compliance constraint in a negligence regime with an output-independent due level of safety $\bar{x}$ are a subset of those that are reachable by imposing a minimum product safety standard $\underline{x}$ and no liability. In this setting, if $\underline{x}$ is chosen optimally, there is no room for a welfare-improvement by imposing a negligence regime with a fixed due care level $\bar{x}$.

If the due level of safety can be imposed as a function of the quantity (but the regulatory standard cannot), holding the firm liable in a negligence regime may still increase welfare, as it allows points in the set described by the compliance constraint that are not on the firm's response function q^{NL}.

4 Conclusion

Firm activity often creates expected harm for both consumers and third parties or the environment. Nevertheless, this fact has been neglected in the literature about firm liability. This paper shows that the results can drastically change when third parties/the environment incurs expected harm simultaneously to consumers. In contrast to the findings by Daughety and Reinganum (2014) about the consumer-only scenario, we establish circumstances in which no liability and negligence can outperform strict liability. This possibility emerges only when third-party harm is sufficiently important as a harm category relative to consumer harm.

Our analysis is kept very simple. For example, we assume linear demand, a convex power function where consumer harm and third-party harm have the same functional form and simply add up, and a monopolistic firm. Nevertheless, the basic insight that third-party harm is an important factor for decisions over liability rules in a context with cumulative harm is more reflective of reality and relevant in more complex settings.

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A Welfare Maximization

We specify welfare as

$$W = \left(a - \frac{b}{2}q - c(x)\right) q - \gamma h(x) q^{\theta} \tag{20}$$

and obtain the first-order conditions

$$W_q(q, x) = a - bq - c(x) - \gamma\theta h(x) q^{\theta-1} = 0 \tag{21}$$

$$W_x(q, x) = -c'(x)q - \gamma h'(x) q^{\theta} = 0. \tag{22}$$

From these conditions, we obtain

$$W_{qq}(q, x) = -b - \gamma(\theta^2 - \theta)h(x)q^{\theta-2} < 0 \tag{23}$$

$$W_{qx}(q, x) = -c'(x) - \gamma\theta h'(x) q^{\theta-1} \tag{24}$$

$$W_{xx}(q, x) = -c''(x)q - \gamma h''(x) q^{\theta} < 0. \tag{25}$$

At the welfare-maximizing combination of safety and output, the social planner fulfills condition (22). Using a reformulation of this expression to restate the cross-partial derivative as

$$W_{qx}(q, x) = -\gamma(\theta - 1)h'(x)q^{\theta-1} > 0, \tag{26}$$

we find that

$$D = W_{qq}W_{xx} - (W_{qq})^2 > 0 \tag{27}$$

because

$$\gamma^2 q^{2(\theta-1)}[(\theta^2 - \theta)hh'' - (\theta - 1)^2(h')^2]$$

by $\theta > 1$ and the assumption that h is strictly convex.

B Comparative-Statics Results for Firm and Proof of Lemma 1

Starting from the profit equation specified in equation (10) in the main document,

$$\Pi(q, x) = (a - bq - c(x))q - \alpha\kappa h(x)q^{\theta},$$

we obtain the first-order conditions in (11) and (12),

$$\Pi_q(q,x) = a - 2bq - c(x) - \alpha\kappa\theta h(x)q^{\theta-1} = 0$$
$$\Pi_x(q,x) = -c'(x)q - \alpha\kappa h'(x)q^{\theta} = 0.$$

From these conditions, we obtain

$$\Pi_{qq}(q,x) = -2b - \alpha\kappa(\theta^2-\theta)h(x)q^{\theta-2} < 0 \tag{28}$$
$$\Pi_{qx}(q,x) = -c'(x) - \alpha\kappa\theta h'(x)q^{\theta-1} \tag{29}$$
$$\Pi_{xx}(q,x) = -c''(x)q - \alpha\kappa h''(x)q^{\theta} < 0. \tag{30}$$

At the profit-maximizing combination of safety and output, the firm fulfills condition (12). Using a reformulation of this expression to restate the cross-partial derivative as

$$\Pi_{qx}(q,x) = -\alpha\kappa(\theta-1)h'(x)q^{\theta-1} > 0, \tag{31}$$

we find that

$$H = \Pi_{qq}\Pi_{xx} - (\Pi_{qq})^2 > 0 \tag{32}$$

because

$$\alpha^2\kappa^2q^{2(\theta-1)}[(\theta^2-\theta)hh'' - (\theta-1)^2(h')^2]$$

by $\theta > 1$ and the assumption that h is strictly convex.

The comparative-static properties of the firm's problem follow from

$$\begin{pmatrix} \Pi_{qq} & \Pi_{qx} \\ \Pi_{xq} & \Pi_{xx} \end{pmatrix} \begin{pmatrix} dq \\ dx \end{pmatrix} = \begin{pmatrix} -\Pi_{q\kappa} \\ -\Pi_{x\kappa} \end{pmatrix} d\kappa \tag{33}$$

where

$$\Pi_{q\kappa} = -\alpha\theta h(x)q^{\theta-1} < 0 \tag{34}$$
$$\Pi_{x\kappa} = -\alpha h'(x)q^{\theta} > 0. \tag{35}$$

This implies that the output and safety levels change as follows with a change in κ:

$$\frac{dq}{d\kappa} = \frac{\Pi_{qx}\Pi_{x\kappa} - \Pi_{q\kappa}\Pi_{xx}}{H} = \frac{\alpha^2(h')^2q^{2\theta-1}\kappa(\theta-1) - \alpha\theta hq^{\theta-1}(c''q + \alpha\kappa h''q^{\theta})}{H} < 0 \tag{36}$$
$$\frac{dx}{d\kappa} = \frac{\Pi_{qx}\Pi_{q\kappa} - \Pi_{x\kappa}\Pi_{qq}}{H} = -\frac{\alpha h'q^{\theta}2b}{H} > 0 \tag{37}$$

where the sign in (36) stems from

$$\alpha^2 q^{2\theta-1}\kappa\theta[(h')^2 - hh''] < 0$$

as a result of the convexity of h.

The fact that the firm subjected to strict liability internalizes all social marginal effects when it comes to product safety means that $x^{SL} = x^W$ for all β. Considering output, the firm under strict liability internalizes the adequate marginal costs but inadequate marginal benefits, such that $q^{SL} < q^W$ for all β. At $\beta = \hat{\beta}$, product safety and output levels are independent of whether strict liability or no liability is used. As a result, the profit-maximizing conditional product safety under no liability is short (in excess) of the socially optimal level when $\beta > \ (<) \, \hat{\beta}$. The consideration of a higher (lower) β means (via a higher (lower) κ^{SL}) that output under strict liability decreases (increases) relative to the level obtained when $\beta = \hat{\beta}$, whereas the conditional output under no liability is not affected (as κ^{NL} is not varied) by the respective variation in β.