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Working Paper

Optimal damages multipliers in oligopolistic markets

DICE Discussion Paper, No. 80

Provided in Cooperation with:

Düsseldorf Institute for Competition Economics (DICE), Heinrich Heine University Düsseldorf

Suggested Citation: Baumann, Florian; Friehe, Tim (2012) : Optimal damages multipliers in oligopolistic markets, DICE Discussion Paper, No. 80, ISBN 978-3-86304-079-6, Heinrich Heine University Düsseldorf, Düsseldorf Institute for Competition Economics (DICE), Düsseldorf

This Version is available at:

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IMPRINT

DICE DISCUSSION PAPER

Published by

Heinrich-Heine-Universität Düsseldorf, Department of Economics, Düsseldorf Institute for Competition Economics (DICE), Universitätsstraße 1, 40225 Düsseldorf, Germany

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DICE DISCUSSION PAPER

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ISSN 2190-9938 (online) – ISBN 978-3-86304-079-6

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Optimal Damages Multipliers in Oligopolistic Markets

Florian Baumann* Tim Friehe†

December 2012

Abstract

This paper establishes that tort damages multipliers higher than one can be an instrument to induce imperfectly competitive producers to invest in product safety at socially optimal levels. In their selection of product safety levels, producers seek to maximize profits, neglecting the fact that higher investment in product safety increases consumer welfare; the discrepancy between private and social safety incentives can be remedied by setting damages multipliers to values greater than one. We show that the optimal damages multiplier depends on the characteristics of competition, such as the number of firms, the degree of substitutability/complementarity when products are heterogeneous, firms' cost structures, and the mode of competition.

Keywords: product liability; product safety; market power; level of damages; punitive damages

JEL-Code: K13, H23

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1 Introduction

1.1 Motivation and main results

This paper studies the relationship between product liability law and product market competition. Product liability regulations are used in order to influence firms' decisions about safety investments that reduce the expected harm associated with potential product defects. The level of damages to be paid by firms in the event of product-related harm has substantial impact on the incentives created by legal liability. However, in markets with imperfect competition, firms' safety investments depend not only on incentives provided by the legal system but also on market-based incentives. The latter are shaped by characteristics of the firms involved, the number of firms, and how their strategic interaction unfolds. We contribute to the literature by describing the damages multiplier that induces first-best safety investment by oligopolistic firms. This multiplier necessarily takes into account the market-based incentives and, as a result, is dependent on characteristics of the firms and on characteristics of the competition between firms. In other words, we establish that the use of a relatively simple damages multiplier with a value greater than one can remedy distortions that would otherwise result in imperfectly competitive product markets.

Punitive damages may be interpreted as a real-life counterpart to the damages multiplier studied in the present paper in that the two instruments both feature compensation for damages exceeding the level of harm. In practice, the application of punitive damages generally requires the existence of intent or gross misconduct by the tortfeasor (see, e.g., Daughety and Reinganum 1997, Chu and Huang 2004), a precondition that is not addressed in our paper. Punitive damages are an important aspect of civil liability in the United States and are a constant source of controversy over their impact on social welfare and their optimal design (see, e.g., Calandrillo 2010, Luban 1998, Viscusi 1998). A frequently cited rationale for awarding punitive damages is the possibility that injurers could at times escape liability, in which case incentives for care would be suboptimal if damages were set equal to harm. An injurer might escape liability if a victim has difficulty proving causation or establishing that the harm was the result of the injurer's actions, or if expected litigation costs deter the victim

from suing (e.g., Polinsky and Shavell 1998). The view that punitive damages are reasonable from an economic standpoint if they offset the tortfeasor’s possibility of escaping liability has achieved near-universal acceptance among law and economics scholars (see, e.g., Calandrillo 2010, Miceli 2004, Visscher 2009).¹ Our analysis abstracts from the possibility of escaping liability, but nevertheless establishes a welfare-enhancing role for a damages multiplier in excess of one.

In order to set the stage for our analysis, we briefly refer to the case of the Ford Pinto.² At the design stage of the Pinto model, Ford decided to place the gasoline tank behind the rear axle, rendering the tank vulnerable in the event of a rear-end collision, despite the fact that the National Highway Transportation Safety Bureau was stressing the need for fuel-system integrity at the time. This decision proved fatal for some of Ford’s customers. The plaintiff in *Grimshaw v. Ford Motor Company* was awarded over \$2.5 million in compensatory and \$3.5 million in punitive damages. Another of the many possible examples is that of Wyeth Pharmaceuticals, which was ordered to pay punitive damages over its mishandling of hormone replacement drugs that were implicitly involved in causing cancer in three women. The company had allegedly ignored the drug’s health risks.³ Both Ford and Wyeth are firms with market power, as is true for the firms in our analysis.

To derive the optimal damages multiplier, we study a setup in which imperfectly competitive firms are subject to product liability and determine product safety before choosing either price or quantity. Consumers do not observe product safety before the purchase of the good, but form rational expectations about it. We thus consider the product to be an experience good (i.e., consumers become informed about the level of precaution after the purchase), which often holds true in reality (Polinsky and Shavell 2010).⁴ We establish that, with regard to product safety, it is optimal to use a damages multiplier greater than one in

¹However, it must be noted that this traditional rationale for punitive damages cannot explain all instances in which punitive damages have been awarded. For instance, in cases such as the oil spill along the Alaskan coastline caused by the Exxon Valdez in 1989, the likelihood of escaping litigation is practically non-existent: nonetheless, punitive damages were awarded in the Exxon Valdez case.

²See, e.g., Schwartz (1991) for a more detailed description.

³*Wyeth Must Pay \$134.1 Million in Menopause Drug Suit*, October 15, 2007 www.bloomberg.com.

⁴If, in contrast, consumers were able to perfectly observe firms’ safety decisions, the market equilibrium would be unaffected by the damages multiplier.

order to align the firms' interests with those of society. In our scenarios of imperfect competition, firms earn rents and select safety to maximize profits; the resulting output levels are too low from a welfare perspective. Higher safety levels increase fixed costs but entail lower marginal costs and higher equilibrium output levels. Firms only take this factor into account to the extent to which it increases profits, disregarding the fact that consumers also benefit from lower marginal costs and higher output. A damages multiplier greater than one incentivizes firms to increase their investment in safety, thereby *correcting* marginal costs downwards and equilibrium output upwards towards the socially desirable levels. The divergence between private and social incentives is similar to the case of R&D, in which investment in new methods of production leads to lower marginal production costs (see, e.g., Tirole 1988). Lower marginal production costs imply an increase in both consumer surplus and firm profits, although firms take only the latter into account. In contrast to these settings, however, in our framework, there is a remedy readily available to address the divergence in incentives - a remedy with a real-world analogue already in use (i.e., damages exceeding harm, such as punitive damages).

The optimal damages multiplier depends on the characteristics of the market. In particular, we show that it depends on the number of firms serving the market, the degree of substitutability/complementarity when products are heterogeneous, and firms' cost structures and corresponding market shares, as well as on the mode of competition (namely, competition either in prices or in quantity). Note that all of these characteristics are closely linked to the relationship between firm profits and social welfare. As a consequence, we find that the optimal level of damages is intrinsically connected to the profitability of the injurer's activity, a fact that has been empirically established to hold for punitive damages (Karpoff and Lott 1999). The damages multipliers we present are based on market information that is empirically available; this should enable their utilization in designing jury instructions, for example, given the fact that individuals often have difficulty assessing appropriate punitive damages (see, e.g., Sunstein et al. 1998, Viscusi 2001).

1.2 Relation to the literature

The present study achieves two objectives: First, it establishes the existence of a damages multiplier with a value greater than one that induces imperfectly competitive firms to choose first-best safety investment, and second, it describes how the multiplier is determined by market characteristics. Related studies in the literature include contributions that analyze punitive damages and those that consider both imperfect product competition and liability law.

Punitive damages have received considerable attention in the law and economics literature. The primary efficiency argument for their use relies on redressing the possibility of escaping liability and is presented in detail in Polinsky and Shavell (1998).⁵ However, the multiplier principle has been criticized on various grounds (see, e.g., Craswell 1999). For example, it has been argued that the multiplier principle neglects litigation costs and injurer investment in avoidance (see Friehe 2010 and Hylton and Miceli 2005), and that punitive damages might induce distortions with respect to decisions on investments in capital equipment and thereby undermine deterrence (Boyd and Ingberman 1999). Rather than relying on arguments based on imperfect enforcement, Cooter (1983) asserts that punitive damages are required to offset illicit gains from noncompliance, while Hylton (1998) elaborates on the hypothesis that punitive damages should at times be used for complete deterrence instead of for purposes of internalization. In a recent contribution, Chu and Huang (2004) present a justification for punitive damages as they are frequently applied in practice, that is, limited to instances of outrageous misconduct and tied to the injurer's wealth. In contrast to all of the above contributions, this paper shows that damages in excess of the level of harm in product liability settings are efficiency-enhancing for reasons pertaining to the market structure. The study closest to our undertaking is Daughety and Reinganum (1997), which considers the possibility that firms want to signal their product safety in an asymmetric information setting and establishes that that there are minimum punitive damages required to arrive at a separating equilibrium. In addition, the scholars show that this minimum

⁵For an earlier discussion of the “rule of the reciprocal,” see Cooter (1989). The most recent survey on punitive damages is Polinsky and Shavell (2009).

punitive damages level decreases with the level of competition in the market. We similarly arrive at the conclusion that damages in excess of harm loses importance when competition in the market is fierce.

In our study, we address the performance of liability in a market with imperfectly competitive firms.⁶ In related research, Boyd (1994) studies a monopolist's safety and output choices, concluding that the optimal legal system is sensitive to the structure of the market; however, he does not investigate the optimal damages multiplier. Marette (2007) allows for an endogenous determination of the market structure, either monopoly or duopoly, depending on minimum safety standards and consumers' information level. We will assume that (i) firms first decide on product safety and then choose either price or output, (ii) safety investments are of a fixed nature and are thus not a function of output, and (iii) strict liability applies, although we provide a robustness check for the application of negligence in an extension. All of these assumptions are borrowed from Daughety and Reinganum (2006), who examine a differentiated goods oligopoly without incorporating a damages multiplier.⁷ In contrast to Daughety and Reinganum (2006), the safety investment selected in our model is private information. In addition, we do not consider the possibility that safety investments may be distorted for strategic purposes, ignoring the potential use of investments in safety as a means of business-stealing. In another line of inquiry, Daughety and Reinganum (1995) explore the signaling of a monopolist who first undertakes R&D and then sets the product's price, in order to analyze the impact of the sharing of losses between injurer and victim. Takaoka (2005) extends this work, analyzing three different informational scenarios. In our contribution, consumers cannot observe the product safety features but form rational expectations. This assumption has also been used by, among others, Baumann et al. (2011), who describe a setup in which liability less than harm may be optimal. In another study linking imperfect product-market competition and liability law, Bhole (2007) studies the optimal due-care standard in a monopoly setting with legal error; he establishes that when due care and a penalty multiplier are available as instruments, this may imply that the optimal level

⁶Geistfeld (2009) provides a survey on product liability.

⁷The importance of this type of setting, in which care is fixed and is not proportional to the activity level, has also been emphasized by Nussim and Tabbach (2009).

of due care will diverge from the level generally considered desirable. In our model, we allow for various market structures (including monopoly) and primarily focus on strict product liability.

Our analysis may be understood as investigating the link between product R&D and product liability. Viscusi and Moore (1993) provide an empirical analysis, arguing that product liability depresses R&D when liability costs are high, but stimulates it for low and intermediate levels of liability costs. Similarly, in our setup, increasing the damages multiplier to its optimal level helps to increase firms' investment in product safety before production.

The present study details optimal damages multipliers with values greater than one. In the literature on the economic analysis of tort law, damages that deviate from the level of harm have often been subject to scrutiny (Visscher 2009). In some cases, for example, it may be that injurers are incapable of compensating victims (i.e., that injurers are potentially *judgment-proof*). For cases in which the magnitude of harm is uncertain, it has been shown that, from a policy perspective, it may be optimal for care incentives to lower (increase) compensation below (above) the level of harm for some realizations of the random harm variable (Boyd and Ingberman 1994, Lewis and Sappington 1999). The fact that victims are often heterogeneous with respect to the level of harm suffered in the event of an accident brings the accuracy of damages into focus (Baumann and Friehe 2009, Kaplow and Shavell 1996). Furthermore, both litigation costs and risk aversion may have repercussions for the optimal level of damages (see, e.g., Polinsky and Rubinfeld 1988, Shavell 2007). In our analysis, we refrain from taking up such additional aspects; rather, we concentrate on the product safety incentives created by the combination of imperfectly competitive product markets and product liability.

The structure of the paper is as follows: Section 2 derives a function for consumer demand to be used subsequently throughout the paper. Section 3 analyzes the supply of a homogeneous good by an oligopolistic industry competing in quantities. Here, we will take up the issues of market entry, heterogeneous cost structures of firms, and negligence liability. Next, Section 4 contrasts duopolistic price and quantity competition in a setting

with heterogeneous goods. This enables us to highlight the importance of the mode of competition and of product differentiation for the optimal damages multiplier. Section 5 concludes the study.

2 Demand

We consider a continuum of identical consumers with the following utility function:⁸

$$V = U(y_1, \dots, y_n) + z, \quad (1)$$

where y_i is the quantity consumed of the product from firm i , $i = 1, \dots, n$, and z represents a composite good. Regarding U , it holds that there is diminishing marginal utility in every dimension (i.e., $U_{y_i} > 0 > U_{y_i y_i}$ for all $i = 1, \dots, n$) and that the marginal rate of substitution between any two goods is decreasing. Consumers seek to

$$\max_{z, \{y_i\}_{i=1}^n} V \text{ subject to } M - \sum_{i=1}^n q_i y_i - z \geq 0, \quad (2)$$

where M is exogenous income, the price of the composite good is normalized to one, and q_i is the effective consumer price of firm i 's product. This effective price of good i includes the market price and the consumer's share of expected harm, $q_i = p_i + (1 - \gamma)x(\bar{s}_i)h$.⁹ We assume that firms are strictly liable for harm suffered by consumers, meaning that firms cannot avoid liability by behaving in a particular way (a robustness check of our baseline analysis is presented in Section 3.3). The effective price q_i is determined by the allocation of expected harm between the firm and the consumer, where $\gamma \geq 0$ indicates the firm's share. Note that a level of γ less than one implies partial liability for firms, $\gamma = 1$ indicates full liability, and $\gamma > 1$ implies damages exceeding harm caused. We investigate a unilateral-care setup in which consumers can influence neither the probability nor the magnitude of harm.¹⁰ The probability x that the consumer will suffer harm h when consuming the

⁸The derivation of demand functions is similar to, e.g., Häckner (2000) and Daughety and Reinganum (2006).

⁹The concept that rational consumers will perceive the *full* price as consisting of the price actually charged plus expected uncovered accident losses is standard in the literature (see, e.g., Shavell 2004).

¹⁰Alternatively, our analysis may be interpreted as investigating a setting of strict liability with contributory negligence in which consumers' adherence to due care is assumed. Contributory negligence would be

good is dependent on the producer's actual product safety expenditures s_i invested before marketing the product to consumers, where $x' < 0 < x''$, $\lim_{s \rightarrow 0} x'(s) = -\infty$, and $x''' \geq 0$.¹¹ It is important to note that the consumption choice depends on the consumer's expectations of firm i 's safety effort, \bar{s}_i , rather than its actual level, s_i . This becomes relevant when we examine the firm's product safety decision, because the effective price q_i is not a function of actual safety efforts; rather, it depends on expectations of these efforts. However, because consumer expectations are rational, their beliefs about safety efforts expended by firms will coincide with the actual safety levels chosen by firms in equilibrium. Furthermore, we will assume that there are no adverse consequences from accidents due to consumption beyond the level of harm, which implies that we abstract from litigation costs, for example.

For the following analyses, we specify

$$U(y_1, \dots, y_n) = \alpha \sum_{i=1}^n y_i - \left[\frac{\beta}{2} \sum_{i=1}^n y_i^2 + \frac{\delta}{2} \sum_{i=1}^n \sum_{j \neq i} y_i y_j \right], \quad (3)$$

where $\alpha, \beta > 0$ and the sign and level of δ will determine whether goods are substitutes ($\delta > 0$) or complements ($\delta < 0$) and homogeneous ($\delta = \beta$) or heterogeneous ($\delta \neq \beta$), respectively, where $\beta \geq |\delta|$. When we assume that income M and the preference parameter α are large enough so as not to restrict consumption choices for the goods, we can use $\partial U / \partial y_i - q_i = 0$ (which follows from (2) by noting that the Lagrange multiplier must be equal to one, given an interior solution) to state that

$$q_i = \alpha - \beta y_i - \delta \sum_{j \neq i} y_j \quad (4)$$

in the consumer's optimum for all i , $i = 1, \dots, n$. Equation (4) will be the foundation for all demand functions to be used in this paper.

Because V is linear in the composite good z , the description of the households' objective allows us to describe consumer welfare by

$$CW^* = \alpha \sum_{i=1}^n y_i^* - \left[\frac{\beta}{2} \sum_{i=1}^n y_i^{*2} + \frac{\delta}{2} \sum_{i=1}^n \sum_{j \neq i} y_i^* y_j^* \right] - \sum_{i=1}^n q_i^* y_i^*, \quad (5)$$

necessary when allowing for a consumer care choice, since otherwise there would be a moral hazard problem, especially when damages may exceed harm.

¹¹The last assumption is a weak sufficient condition for later results.

where we denote equilibrium values with an asterisk.

3 Optimal damages in the case of homogeneous good competition

Consider n firms producing a homogeneous good at a marginal cost c_i . We arrive at the corresponding inverted demand function by setting $\delta = \beta$ in (4), which leads to

$$q = \alpha - \beta Y, \quad (6)$$

where $Y = \sum_{i=1}^n y_i$. Note that in this section, from the consumers' point of view, goods produced by different firms are perfect substitutes. Accordingly, there is one level of the effective price q . As explained in Section 2, the level of q must at the same time be in accordance with

$$q = p_i + (1 - \gamma)x(\bar{s}_i)h. \quad (7)$$

Firms compete by setting quantities, i.e., we consider Cournot competition. We will examine price competition in the section analyzing the optimal damages multiplier in settings with heterogeneous goods.

The timing of the game is as follows: At Stage 1, firms select product safety, taking into account how they would optimally respond to anticipated competitor output levels. The product safety investment is observable neither by competitors nor by consumers (i.e., firm i 's determination of safety is private information).¹² At Stage 2, firms simultaneously select output for a given vector of competitor output levels. Formally, given that no information is exchanged between Stage 1 and Stage 2, the model could also be interpreted as one in which firms choose levels of both safety and output simultaneously.

In this section, we restrict the analysis to homogeneous goods and start with the assumption of symmetric firms. This allows us to straightforwardly derive the optimal damages multiplier and to suggest intuition for its level. Furthermore, the analysis of this baseline

¹²See Endres and Friehe (forthcoming) for an analysis of oligopolistic firms subject to liability in which first-stage investments can be observed by competitors and thus influence competition at the second stage, although without the consideration of damages multipliers.

model enables us to generalize to circumstances with free entry, heterogeneous firms, and settings governed by negligence liability instead of strict liability.

3.1 Symmetric firms

The assumption of symmetric firms allows us to set $c_i = c$ for all i . Firm i 's profits are then given by

$$\begin{aligned}\pi_i &= [p_i - c - \gamma x(s_i)h]y_i - s_i \\ &= [\alpha - \beta Y - EMC(\bar{s}_i, s_i, \gamma)]y_i - s_i,\end{aligned}\tag{8}$$

where $EMC(\bar{s}_i, s_i, \gamma) = c + (1 - \gamma)x(\bar{s}_i)h + \gamma x(s_i)h$ is the precursor of total social marginal costs per output unit, at this stage influenced by expectations of safety, the actual level of safety, and the level of γ (should the expected and actual level of safety diverge).

At Stage 2, firms simultaneously determine output. Profit maximization results in the first-order condition

$$\frac{\partial \pi_i}{\partial y_i} = \alpha - 2\beta y_i - \beta Y_{-i} - EMC(\bar{s}_i, s_i, \gamma) = 0,\tag{9}$$

where $Y_{-i} = \sum_{j=1, j \neq i}^n y_j$. Accordingly, the output level that maximizes firm i 's profits given the output of the other firms follows from

$$y_i = \frac{\alpha - \beta Y_{-i} - EMC(\bar{s}_i, s_i, \gamma)}{2\beta}.\tag{10}$$

In other words, equation (10) gives the best response of firm i for a given Y_{-i} . Using this information in equation (8), we arrive at

$$\pi_i = \frac{(\alpha - \beta Y_{-i} - EMC(\bar{s}_i, s_i, \gamma))^2}{4\beta} - s_i.\tag{11}$$

At Stage 1, firms determine their investments in product safety. In view of (11), the first-order condition is

$$\frac{\partial \pi_i}{\partial s_i} = \frac{\alpha - \beta Y_{-i} - EMC(\bar{s}_i, s_i, \gamma)}{2\beta}(-\gamma x'(s_i)h) - 1 = 0.\tag{12}$$

This condition clearly illustrates that consumers' willingness to pay does not react to changes in s_i , because firm i 's actual safety investment at Stage 1 is private information. As a result, an increase in the level of safety only implies a decrease in the marginal liability costs γxh .

We are now in a position to evaluate the symmetric equilibrium in which actual safety levels correspond to expected levels and are the same for all firms, $\bar{s}_i = s_i = s$. Regarding overall output, we obtain $Y = ny^*$. To be precise, the equilibrium outcome is

$$y^* = \frac{\alpha - MC}{\beta(n+1)} \quad (13)$$

$$q^* = \frac{\alpha + nMC}{n+1} \quad (14)$$

$$\pi^* = \frac{(\alpha - MC)^2}{\beta(n+1)^2} - s = \beta y^{*2} - s, \quad (15)$$

where $MC = c + x(s)h$ represents the total social marginal costs per unit of output.

Before we turn to the social planner's choice of γ , for ease of comparison we restate the firm's condition for privately optimal safety expenditures (12) using the equilibrium levels:

$$\frac{\partial \pi_i}{\partial s_i} = \frac{\alpha - MC}{\beta(n+1)}(-\gamma x'(s)h) - 1 = y^*(-\gamma x'(s)h) - 1 = 0. \quad (16)$$

We assume that the social planner seeks to maximize the sum of producer surplus and consumer welfare. Similar to Daughety and Reinganum (2006), we consider a constrained social planner. The only instrument at the planner's discretion is γ , the damages multiplier. Specifically, the social planner must accept the firms' decentralized decision-making, but can attempt to achieve a favorable outcome by the selection of γ . Referring to equation (5), we can state consumer welfare, CW , for the present case:

$$\begin{aligned} CW^* &= [\alpha - q^* - \beta y^*(1/2 + (n-1)/2)] ny^* \\ &= \frac{n^2}{2} \frac{(\alpha - MC)^2}{\beta(n+1)^2} = \frac{n^2}{2} \beta y^{*2}. \end{aligned} \quad (17)$$

The social planner's objective may thus be stated as maximizing social welfare, SW ,

$$\begin{aligned} SW^* &= n\pi^* + CW^* \\ &= n \left[\frac{(\alpha - MC)^2}{\beta(n+1)^2} \left(1 + \frac{n}{2}\right) - s \right] = n \left[\beta y^{*2} \left(1 + \frac{n}{2}\right) - s \right] \end{aligned} \quad (18)$$

by choosing the policy variable γ , which is equivalent to determining s in our setup. The corresponding first-order condition is given by

$$\frac{\partial SW^*}{\partial s} = n \left[\frac{\alpha - MC}{\beta(n+1)^2} (2+n)(-x'(s)h) - 1 \right] = 0, \quad (19)$$

from which we obtain

$$y^* \left(-\frac{2+n}{1+n} x'(s)h \right) - 1 = 0. \quad (20)$$

This allows us to state the following proposition:

Proposition 1 *Assume Cournot competition between symmetric firms in a homogeneous product market. Then: (i) there is a damages multiplier γ^B that induces firms to select socially optimal safety investments, and (ii) the multiplier is given by $\gamma^B = 1 + 1/(1+n)$, is equal to 3/2 in the monopoly case, and decreases with the number of firms, reaching one as $n \rightarrow \infty$.*

Proof. The level of γ follows from comparing (20) and (16). The statement regarding the change in the multiplier when the number of firms changes follows from the derivative of γ^B with respect to n . ■

The rationale for the optimal damages multiplier can be explained as follows: An increase in the level of safety investment increases a firm's profits obtained in the market in proportion to its output and the damages multiplier γ . The firm compares this marginal benefit to the additional outlays for investing in safety, see equation (16). At $\gamma = 1$, the profit-maximizing safety investment with asymmetric information on safety is the same as the profit-maximizing investment with symmetric information. This is a well-established result. However, with imperfect competition, the socially optimal damages multiplier is greater than one, because an increase in safety investment has a positive effect on consumer surplus in addition to the effect on firm profits. This is evident from the fact that a higher level of safety implies both a lower equilibrium price and a higher output level. For example, in the case of a monopoly, consumer welfare amounts to half of the producer surplus. Accordingly, the optimal damages multiplier is equal to 3/2, as this leads to the internalization of the positive externality of safety investments on consumer welfare by the monopolist. With an increase in the number

of firms, each firm's market share and output declines. The influence of safety investments by any single firm on consumer welfare decreases as well, which implies that the socially optimal damages multiplier declines with the number of firms serving the market.

3.2 Endogenous market entry of symmetric firms

The above derivation of the optimal damages multiplier has taken the number of firms as a given. In the following section, we would like to establish that the optimality of using a damages multiplier greater than one is robust to an extension of the framework, in order to allow for an endogenous number of firms. To accomplish this, we expand the setting of the baseline model with an initial stage at which firms sequentially decide on entry, finding entry profitable as long as expected profits are greater than or equal to fixed entry costs K . This argument introduces the condition $\pi^* = K$, where π^* is defined as in equation (15). In addition, the firm's first-order condition with respect to safety efforts, equation (16), must hold in equilibrium. Both equations include the endogenous variables of safety investments s and the number of firms n , as well as the policy parameter γ . Rearranging equation (16) and applying it in $\pi^* = K$, we obtain

$$\frac{\beta}{(\gamma x'(s)h)^2} - s = K. \quad (21)$$

This equation is independent of the number of firms and allows us to establish the relationship between the damages multiplier γ and investment in safety s .¹³ Consequently, we can focus on the market entry condition $\pi^* = K$ to establish the link between safety investments and the number of firms, which indirectly gives us the link between the policy parameter γ and the number of firms.

Total differentiation of $\pi^* = K$ yields

$$\left(2 \frac{\alpha - MC}{\beta(n+1)^2} (-x'(s)h) - 1 \right) ds - 2 \frac{(\alpha - MC)^2}{\beta(n+1)^3} dn = 0. \quad (22)$$

Modifying both terms using the firms' first-order condition with respect to safety investments

¹³This relationship is positive, with a higher damages multiplier resulting in increased safety investments.

(16), we arrive at

$$\frac{dn}{ds} = \frac{\frac{2}{\gamma(n+1)} - 1}{\frac{2\beta}{(n+1)\gamma^2 x'(s)^2 h^2}} = \frac{\gamma x'(s)^2 h^2}{\beta} \frac{2 - \gamma(n+1)}{2}. \quad (23)$$

For $\gamma \geq 1$, the relationship between the level of safety investment and the number of firms is negative. Higher investment expenditures increase firms' fixed costs and thus reduce the number of firms in equilibrium.¹⁴

We now return to the social planner's optimization problem. With market entry costs, social welfare reduces to consumer welfare because equilibrium profits are equal to market entry costs. The first-order condition for a maximum of social welfare is thus given by

$$\frac{dSW}{ds} = \frac{n^2(\alpha - MC)}{\beta(n+1)^2}(-x'(s)h) + \frac{n(\alpha - MC)^2}{\beta(n+1)^3} \frac{dn}{ds} = 0, \quad (24)$$

where the second term denotes the effect on consumer welfare due to the accompanying change in the number of firms serving the market. Again making use of the first-order condition for firms' investments in safety, equation (16), the above expression can be simplified to

$$\frac{dSW}{ds} = \frac{(2 - \gamma)n}{2\gamma} = 0. \quad (25)$$

This leads to the following result:

Proposition 2 *Assume Cournot competition between an endogenous number of firms in a homogeneous product market. Then, we find that the second-best damages multiplier that maximizes social welfare is given by $\gamma^E = 2$.*

Proof. This claim follows from (25), which holds only for the level of γ^E specified. ■

We find that the optimal damages multiplier in a setup with endogenous firm entry is equal to two and, accordingly, falls outside of the range for optimal damages multipliers described in Proposition 1. In other words, in this setting, optimal damages are even higher than for an exogenous number of firms and are independent of the eventual number of firms active in the market. This can be explained as follows: Note that in this extension of the

¹⁴For lower levels of the damages multiplier, firms might profit from an increase in the multiplier due to the possibility of circumventing the problem of asymmetric information.

baseline model, the policy maker addresses two objectives with the policy lever in question, γ . As previously held true, the policy maker seeks to induce appropriate product safety investment by firms serving the market. In addition, however, the level of the damages multiplier gives the social planner some control over the number of firms, because $dn/d\gamma < 0$ for $\gamma > 1$. When firms individually decide on market entry in our baseline model without policy interventions, the number of firms is excessive due to a business-stealing effect, as firms do not internalize the repercussions of their entry on the market shares of competing firms (see Mankiw and Whinston 1986); therefore, the planner finds it optimal to set damages in excess of the level for the monopoly case in our baseline model in order to address excessive entry. The damages multiplier is only a second-best instrument in this endogenous entry setup, as safety investment is distorted upwards. In contrast, if we were to allow for a second instrument in addition to γ (such as a tax on market entry), the planner would choose to retain the previously established optimal damages multiplier, γ^B , and would combat excessive market entry by means of the alternative instrument.

The finding of socially excessive firm entry does not generalize to all settings of imperfect competition. It may be interesting to observe how the damages multiplier functions in a setup that allows for insufficient entry; such a situation could arise in a setting with differentiated goods, since each new entrant creates intrinsic value for consumers by offering a new variety of product (see Mankiw and Whinston 1986). To address this issue, in the appendix we present findings from a model of monopolistic competition with market entry similar to that developed by Dixit and Stiglitz (1977). For this scenario, we establish that the damages multiplier will be strictly greater than one when the number of firms is fixed, whereas it will be equal to one when the number of firms is endogenously determined (for the specific utility function applied). This highlights the fact that, as intuition suggests, the optimal damages multiplier will be lower when it must also address the problem of insufficient firm entry. Given that it is costly in terms of welfare to address both the safety level and the number of firms via the damages multiplier (as compared to a scenario with two instruments) and because there are other instruments (such as start-up subsidies) that are particularly well-suited to regulating entry, in this paper we primarily focus on the case in which the damages

multiplier is used only to promote optimal safety investment while other policy instruments guide aspects of market entry.

3.3 Firms subject to negligence

In this section, we assume that firms are subject to negligence rather than strict liability. This is meant as a robustness check for our baseline analysis and is warranted because despite the widespread reliance on strict product liability, an aspect of negligence determines the actual definition of a product defect (see, e.g., Shavell 2004: 222). In implementing negligence, we will assume that there is uncertainty over the behavioral standard that firms should uphold in order to be free from liability, in the spirit of Craswell and Calfee (1986). As perceived by the firm, due product safety investment s_s is a random variable with support $[\underline{s}, \hat{s}]$ and a cumulative distribution function $F(s)$. We assume that the support is so broad that taking care \hat{s} is dominated by some lower safety level, i.e., uncertainty keeps its bite. Firms will be judged negligent if the product safety investment falls short of the realized behavioral standard. Consequently, the probability of being judged negligent is equal to $(1 - F(s_i))$ for firm i . In contrast, the actual standard will be smaller than firm i 's safety investment with probability $F(s_i)$, in which case the consumer bears all losses. This fact changes the effective consumer price to

$$q = p_i + (1 - \gamma)h(1 - F(\bar{s}_i))x(\bar{s}_i) + hF(\bar{s}_i)x(\bar{s}_i) \quad (26)$$

and firm i 's profits to

$$\pi_i = [\alpha - \beta Y - (1 - \gamma)h(1 - F(\bar{s}_i))x(\bar{s}_i) - hF(\bar{s}_i)x(\bar{s}_i) - c - \gamma h(1 - F(s_i))x(s_i)]y_i - s_i. \quad (27)$$

The analysis of the second stage at which firms simultaneously determine output is similar to that described for the baseline model; here, we use

$$EMC_N(\bar{s}_i, s_i, \gamma) = c + \gamma h(1 - F(s_i))x(s_i) + (1 - \gamma)h(1 - F(\bar{s}_i))x(\bar{s}_i) + hF(\bar{s}_i)x(\bar{s}_i)$$

instead of $EMC(\bar{s}_i, s_i, \gamma)$. At Stage 1, we obtain the first-order condition for safety invest-

ments:

$$\frac{\partial \pi_i}{\partial s_i} = \frac{\alpha - \beta Y_{-i} - EMC_N(\bar{s}_i, s_i, \gamma)}{2\beta} (-\gamma x'(s_i)h) [(1 - F(s_i)) - F'(s_i)x(s_i)/x'(s_i)] - 1 = 0. \quad (28)$$

Equation (28) can be restated using the equilibrium levels (still given by (13)-(15)) as

$$\frac{\partial \pi_i}{\partial s_i} = \frac{\alpha - MC}{\beta(n+1)} (-\gamma x'(s_i)h) [(1 - F(s_i)) - F'(s_i)x(s_i)/x'(s_i)] - 1 = 0. \quad (29)$$

The social planner's maximization of the sum of profits and consumer welfare is not affected by the change in the applied liability rule, which is why the first-order condition (restated here for convenience) is still given by

$$\frac{\alpha - MC}{\beta(n+1)} \left(-\frac{2+n}{1+n} x'(s)h \right) - 1 = 0.$$

This allows us to reach the following conclusion:

Proposition 3 *Assume Cournot competition between symmetric firms subject to negligence liability in a homogeneous product market. Then, there is a damages multiplier γ^N that induces firms to select socially optimal safety investments, given by*

$$\gamma^N = \frac{(2+n)}{(1+n)} \frac{1}{(1 - F(s_i)) - F'(s_i)x(s_i)/x'(s_i)}. \quad (30)$$

Proof. The required level of γ follows from comparison of (20) and (29). ■

Intuitively, the optimal damages multiplier for firms subject to negligence with an uncertain due care standard must address both the distortions in firms' incentives resulting from uncertainty as well as the discrepancy between privately and socially optimal safety investments. Note that as long as the second term in (30) is greater than or equal to one, the multiplier under negligence will be at least as great as that under strict product liability. This condition regarding the second term lends itself to a straightforward interpretation. Specifically, the second term will be greater than or equal to one if

$$\frac{F'}{F} \leq -\frac{x'}{x}, \quad (31)$$

which will always hold if the accident probability reacts more strongly to changes in s than the distribution function F does. This is quite intuitive, given that there are two consequences

of uncertain due care (see, e.g., Bartsch 1997): (i) the damage discount originating from $(1 - F(s_i))h < h$, and (ii) the liability effect stemming from private incentives to avoid expected liability payments by increasing the level of safety investment, as represented by $-F'h$. The condition (31) may be interpreted as a requirement that the damage discount effect trump the liability effect with regard to incentives for safety investment.¹⁵

3.4 Heterogeneous firms

Our baseline model examines symmetric firms. In this section, we explore whether the damages multiplier might vary when firms differ in their cost structures. In order to keep the analysis simple, we restrict it to the case of two firms with firm-specific constant unit costs c_i , where $c_i \neq c_j$. This leads to

$$\begin{aligned}\pi_i &= [p_i - c_i - \gamma x(s_i)h]y_i - s_i \\ &= [\alpha - \beta Y - EMC_i(\bar{s}_i, s_i, \gamma)]y_i - s_i,\end{aligned}\tag{32}$$

where $EMC_i(\bar{s}_i, s_i, \gamma) = c_i + (1 - \gamma)x(\bar{s}_i)h + \gamma x(s_i)h$.

At Stage 2, the profit-maximizing response of firm i to given output by firm j is represented by

$$y_i = \frac{\alpha - \beta y_j - EMC_i(\bar{s}_i, s_i, \gamma)}{2\beta}\tag{33}$$

and leads to

$$\pi_i = \frac{(\alpha - \beta y_j - EMC_i(\bar{s}_i, s_i, \gamma))^2}{4\beta} - s_i.\tag{34}$$

At Stage 1, a firm's privately optimal investment in product safety is determined by

$$\frac{\partial \pi_i}{\partial s_i} = \frac{\alpha - \beta y_j - EMC_i(\bar{s}_i, s_i, \gamma)}{2\beta}(-\gamma x'(s_i)h) - 1 = y_i(-\gamma x'(s_i)h) - 1 = 0.\tag{35}$$

Next, we evaluate the equilibrium in which the actual safety levels are equivalent to the

¹⁵If firms bear liability only for the harm actually caused by their negligence (as formulated by Grady (1983) and Kahan (1989), for example), uncertainty over the safety standard is more likely to result in lower levels of safety investment, *ceteris paribus*, suggesting even greater need for punitive damages.

expected safety effort, $\bar{s}_i = s_i$. Specifically, the equilibrium outcome is

$$y_i^{**} = \frac{\alpha + MC_j - 2MC_i}{3\beta} \quad (36)$$

$$q^{**} = \frac{\alpha + MC_i + MC_j}{3} \quad (37)$$

$$\pi_i^{**} = \frac{(\alpha + MC_j - 2MC_i)^2}{9\beta} - s_i = \beta y_i^{**2} - s_i, \quad (38)$$

where $MC_i = c_i + x(s_i)h$ reflects the total social marginal costs per unit of output from firm i .

Before we turn to the social planner's choice of γ , for ease of comparison we restate firm i 's condition for privately optimal safety expenditures (35) using the equilibrium levels:

$$\begin{aligned} \frac{\partial \pi_i}{\partial s_i} &= \frac{\alpha - \beta(\alpha + MC_i - 2MC_j)/(3\beta) - MC_i}{2\beta} (-\gamma x'(s)h) - 1 \\ &= \frac{\alpha + MC_j - 2MC_i}{3\beta} (-\gamma x'(s)h) - 1 = y^{**}(-\gamma x'(s)h) - 1 = 0. \end{aligned} \quad (39)$$

The social planner takes into account the benefits both to firms and to consumer welfare, which can be stated as

$$\begin{aligned} CW^{**} &= \alpha(y_1^{**} + y_2^{**}) - (\beta/2(y_1^{**2} + y_2^{**2}) + \beta y_1^{**} y_2^{**}) - q^{**}(y_1^{**} + y_2^{**}) \\ &= \frac{(2\alpha - MC_1 - MC_2)^2}{18\beta} = \frac{\beta}{2}(y_1^{**} + y_2^{**})^2. \end{aligned} \quad (40)$$

The social planner maximizes social welfare:

$$\begin{aligned} SW^{**} &= \pi_1^{**} + \pi_2^{**} + CW^{**} \\ &= \beta y_1^{**2} - s_1 + \beta y_2^{**2} - s_2 + \frac{\beta}{2}(y_1^{**} + y_2^{**})^2. \end{aligned} \quad (41)$$

Now, we consider the idea that the damages multiplier can be made contingent on firm characteristics; this seems both plausible and realistic with respect to punitive damages awards, for example, since a firm's market share is readily observable. In this case, we can examine the derivatives with respect to s_i :

$$\begin{aligned} \frac{\partial SW^{**}}{\partial s_i} &= \beta [3y_i^{**} + y_j] \frac{\partial y_i^{**}}{\partial s_i} + \beta [2y_j^{**} + y_i^{**}] \frac{\partial y_j^{**}}{\partial s_i} - 1 \\ &= -x'(s)h \left[\frac{5}{3}y_i^{**} - \frac{1}{3}y_j^{**} \right] - 1 = 0. \end{aligned} \quad (42)$$

Comparison of equations (39) and (42) reveals that there is one type-specific multiplier that aligns the firms' interests with that of the policy maker, given by

$$\gamma_i^A = \frac{4}{3} + \frac{MC_j - MC_i}{\alpha + MC_j - 2MC_i}, \quad (43)$$

where

$$\frac{MC_j - MC_i}{\alpha + MC_j - 2MC_i} = \frac{y_i^{**} - y_j^{**}}{y_i^{**}}. \quad (44)$$

Proposition 4 *Assume Cournot competition between asymmetric firms in a homogeneous goods market. Then, there is a damages multiplier γ_i^A that induces firm i to select the socially optimal safety investment level.*

Proof. The required level of γ follows from equation (43). ■

The insight we gain from this variation of the model can be summarized as follows: The optimal damages multiplier depends on variations in market shares among firms resulting from differences in marginal costs. An optimal damages multiplier of $4/3$ would result for a duopoly in which firms were symmetric (see Proposition 1). However, as the firm with the lower marginal costs serves a larger share of the market, its influence on consumer welfare is more pronounced. This should be reflected in a higher damages factor for this firm, and *vice versa* for the less efficient firm. Since marginal costs of production are inversely related to a firm's profit level, the result can also be interpreted as finding that a higher damages multiplier should be applied to firms with a higher profit level.

4 Optimal damages in the case of heterogeneous good competition

In this section, we consider competition between firms producing goods that are heterogeneous, and we allow for competition in price and in quantity. The case of differentiated goods is the more realistic setting, such that the additional insights will have practical relevance. For the sake of simplicity, we will focus on circumstances in which two firms are active in the market.

The basic timing from Section 3 will be maintained such that firms choose safety s_i at the first stage before choosing either the privately optimal price or output level at Stage 2. We start with the examination of Bertrand competition.

4.1 Competition in price (Bertrand)

The demand function stemming from inverting (4) in the case of two firms and heterogeneous goods (i.e., $\beta \neq \delta$) results in

$$y_i = \frac{1}{\beta^2 - \delta^2} [\alpha(\beta - \delta) - \beta q_i + \delta q_j] \quad (45)$$

for $i, j = 1, 2, i \neq j$. To simplify the notation, we will use $Z = \frac{1}{\beta^2 - \delta^2}$ and $A = \alpha(\beta - \delta)$ in the following analysis. Accordingly, firm i 's profits are given by

$$\pi_i = (p_i - c - \gamma x(s_i)h)Z(A - \beta p_i - \beta(1 - \gamma)x(\bar{s}_i)h + \delta q_j) - s_i. \quad (46)$$

Firms simultaneously choose profit-maximizing prices at Stage 2. These are determined by the first-order condition

$$\frac{\partial \pi_i}{\partial p_i} = Z(A - 2\beta p_i + \beta c + \beta \gamma x(s_i)h - \beta(1 - \gamma)x(\bar{s}_i)h + \delta q_j) = 0, \quad (47)$$

which results in a price equal to

$$p_i = \frac{A + \beta c + \beta \gamma x(s_i)h - \beta(1 - \gamma)x(\bar{s}_i)h + \delta q_j}{2\beta}. \quad (48)$$

Equation (48) may again be interpreted as firm i 's best response to a given effective price of firm j . Using this price level allows us to restate firm i 's profits as a function that no longer depends on p_i :

$$\pi_i = Z \frac{(A - \beta EMC(\bar{s}_i, s_i, \gamma) + \delta q_j)^2}{4\beta} - s_i \quad (49)$$

At the first stage, firms seek to maximize profits by selecting the appropriate safety investment s_i , arriving at the first-order condition

$$\frac{\partial \pi_i}{\partial s_i} = Z \frac{A - \beta EMC(\bar{s}_i, s_i, \gamma) + \delta q_j}{2} (-\gamma x'(s_i)h) - 1 = 0. \quad (50)$$

After having characterized private decision-making, we are now in a position to describe the symmetric equilibrium in which $s_i = s$ and $p_i = p$ hold. The equilibrium levels can be stated precisely as

$$p^+ = \frac{A + \beta c - \beta(1 - 2\gamma)x(s)h + \delta(1 - \gamma)x(s)h}{2\beta - \delta} \quad (51)$$

$$q^+ = \frac{A + \beta MC}{2\beta - \delta} \quad (52)$$

$$y^+ = \frac{\beta}{\beta + \delta} \frac{\alpha - MC}{2\beta - \delta} \quad (53)$$

$$\pi^+ = \frac{\beta(\beta - \delta)}{\beta + \delta} \frac{(\alpha - MC)^2}{(2\beta - \delta)^2} - s = \frac{\beta^2 - \delta^2}{\beta} y^+ 2 - s, \quad (54)$$

where we use $A = \alpha(\beta - \delta)$ and $Z = 1/(\beta^2 - \delta^2)$ in y^+ and π^+ .

Before examining the social planner's choice of the damages multiplier in the case of Bertrand competition between two firms producing differentiated goods, we restate firm i 's first-order condition for optimal safety expenditures using the equilibrium value of the effective price:

$$\frac{\beta}{\beta + \delta} \frac{\alpha - MC}{2\beta - \delta} (-\gamma x'(s)h) - 1 = y^+ (-\gamma x'(s)h) - 1 = 0. \quad (55)$$

Finally, we turn to the planner's optimization. Consumer welfare is critical for the social planner's maximization of social welfare; this is given by

$$CW^+ = \alpha 2y^+ - \beta y^{+2} - \delta y^{+2} - 2q^+ y^+ = \frac{\beta^2}{\beta + \delta} \frac{(\alpha - MC)^2}{(2\beta - \delta)^2} = (\beta + \delta) y^{+2}. \quad (56)$$

With this in mind, we arrive at the following expression for social welfare:

$$SW^+ = 2\pi^+ + CW^+ = \frac{(\beta + \delta)(3\beta - \delta)}{\beta} y^{+2} - 2s = \frac{\beta}{\beta + \delta} (3\beta - 2\delta) \frac{(\alpha - MC)^2}{(2\beta - \delta)^2} - 2s, \quad (57)$$

which implies that we may state the first-order condition for socially optimal safety expenditures as

$$\begin{aligned} & \frac{\beta}{\beta + \delta} \frac{3\beta - 2\delta}{2\beta - \delta} \frac{\alpha - MC}{2\beta - \delta} (-x'(s)h) - 1 \\ &= \left(1 + \frac{\beta - \delta}{2\beta - \delta}\right) y^+ (-x'(s)h) - 1 = 0. \end{aligned} \quad (58)$$

This allows us to submit the following result:

Proposition 5 *Assume Bertrand competition between two symmetric firms producing differentiated goods. Then: (i) there is a damages multiplier γ^P that induces firms to select the socially optimal safety investment level, and (ii) the multiplier is given by $\gamma^P = 1 + (\beta - \delta)/(2\beta - \delta)$, and decreases with δ .*

Proof. The required level of γ follows from comparison of (58) and (55). The statement regarding the change in the multiplier when δ changes follows from the derivative of γ^P with respect to δ . ■

The social planner chooses a damages multiplier that is greater than one, since $\beta > |\delta|$. The intuition for this optimal level of the damages multiplier is again closely linked to competition in the market. The two goods are substitutes when $\delta > 0$; thus, the closer δ is to β , the fiercer the price competition between the two firms will be. The prescription for the optimal damages multiplier states that the more distinct the products in the market are from the consumers' perspective, the more important damages exceeding harm become. Since firm profits increase with the degree of product differentiation, we again obtain a close link between a firm's profit level and the optimal design of the damages multiplier.

4.2 Competition in quantity (Cournot)

In this section, we return to quantity competition to consider the effects of differentiated goods on the damages multiplier. Given that the analysis itself is similar to the case of Bertrand competition, our exposition will be brief.

Using the inverted demand functions described in equation (4), we find the profit-maximizing output at Stage 2 to equal

$$y_i = \frac{\alpha - \delta y_j - (1 - \gamma)x(\bar{s}_i)h - \gamma x(s_i)h - c}{2\beta}, \quad (59)$$

implying second-stage profits of

$$\pi_i = \frac{(\alpha - \delta y_j - (1 - \gamma)x(\bar{s}_i)h - \gamma x(s_i)h - c)^2}{4\beta} - s_i. \quad (60)$$

Firm i chooses safety expenditures at the first stage at the same time as firm j , seeking to

fulfill

$$\frac{\partial \pi_i}{\partial s_i} = \frac{\alpha - \delta y_j - (1 - \gamma)x(\bar{s}_i)h - \gamma x(s_i)h - c}{2\beta}(-\gamma x'(s_i)h) - 1 = 0. \quad (61)$$

In equilibrium, we obtain

$$y^{++} = \frac{\alpha - MC}{2\beta + \delta} \quad (62)$$

$$\pi^{++} = \beta \frac{(\alpha - MC)^2}{(2\beta + \delta)^2} - s = \beta y^{++2} - s. \quad (63)$$

It is important to note at this point that the denominator of y^{++} is different from that obtained for the equilibrium price under Bertrand competition. This can be related back to the fact that decision variables are strategic complements in classical Bertrand competition and strategic substitutes in classical Cournot competition.

Finally, in equilibrium, the firm's first-order condition for product safety expenditures can be expressed as

$$\frac{\alpha - MC}{2\beta + \delta}(-\gamma x'(s)h) - 1 = y^{++}(-\gamma x'(s)h) - 1 = 0. \quad (64)$$

Next, we examine consumer welfare in more detail in order to have both determinants of social welfare ready to establish the socially optimal damages multiplier. For the effective price in equilibrium, we use

$$q^{++} = \frac{\alpha\beta + (\beta + \delta)MC}{2\beta + \delta}, \quad (65)$$

leading to

$$\begin{aligned} CW^{++} &= 2\alpha y^{++} - \beta y^{++2} - \delta y^{++2} - 2q^{++}y^{++} \\ &= (\beta + \delta) \frac{(\alpha - MC)^2}{(2\beta + \delta)^2} = (\beta + \delta)y^{++2}. \end{aligned} \quad (66)$$

This result enables us to maximize social welfare

$$SW^{++} = 2\pi^{++} + CW^{++} = (3\beta + \delta) \frac{(\alpha - MC)^2}{(2\beta + \delta)^2} - 2s = (3\beta + \delta)y^{++2} - 2s \quad (67)$$

with respect to the level of the multiplier, which in our case is equivalent to determining the optimal safety expenditure. Simplifying the first-order condition for ease of comparison, we establish that

$$\frac{3\beta + \delta}{2\beta + \delta} \frac{\alpha - MC}{2\beta + \delta}(-x'(s)h) - 1 = \left(1 + \frac{\beta}{2\beta + \delta}\right) y^{++}(-x'(s)h) - 1 = 0. \quad (68)$$

This completes the analysis. To summarize:

Proposition 6 *Assume Cournot competition between two symmetric firms producing differentiated goods. Then: (i) there is a damages multiplier γ^Q that induces firms to select socially optimal safety investments, and (ii) the multiplier is given by $\gamma^Q = 1 + \beta/(2\beta + \delta)$, and decreases with δ .*

Proof. The required level of γ follows from comparison of (68) and (64). The statement regarding the change in the multiplier when δ changes follows from the derivative of γ^Q with respect to δ . ■

Intuition as to the level and the adaptation of the damages multiplier in response to a change in δ follows the analysis presented for Bertrand competition. At this point, we are in the position to also compare the optimal damages multipliers in different modes of competition.

Proposition 7 *The optimal damages multiplier applicable to duopolistic firms that offer differentiated products and compete in quantities surpasses the multiplier for price-setting firms if $\delta \neq 0$.*

Proof. To support this proposition, we compare the levels of the optimal damages multipliers in the two settings; this results in:

$$\begin{aligned}
1 + \frac{\beta}{2\beta + \delta} = \gamma^Q &> \gamma^P = 1 + \frac{\beta - \delta}{2\beta - \delta} \\
\beta(2\beta - \delta) &> (\beta - \delta)(2\beta + \delta) \\
2\beta^2 - \beta\delta &> 2\beta^2 + \beta\delta - 2\beta\delta - \delta^2 \\
\delta^2 &> 0.
\end{aligned} \tag{69}$$

■

The result we obtain with respect to the dependence of the level of optimal damages on the mode of competition can once again be traced back to the divergence of private and social interests. Comparison of the optimal damages multipliers allows additional insights. As

the calculations above show, we can establish that the difference between social benefits and benefits perceived by firms resulting from higher levels of investment in safety is proportional to output, but also hinges on the mode of competition. Indeed, for given marginal costs, firms under quantity competition choose lower output levels than firms under price competition. The social planner takes into account that by increasing the damages multiplier, he or she can actually reduce the marginal costs that result in equilibrium, and therefore can also contribute to an increase in the amount of product traded in the market. The benefits of doing so are higher in the event of quantity competition, which explains the higher optimal damages multiplier in this setting as compared to price competition. This is also illustrated by the fact that as $\delta \rightarrow \beta$, the optimal damages multiplier is reduced to one in the scenario of price competition, since firms in this case have already set prices in accordance with marginal costs; in contrast, in quantity competition, the optimal damages factor approaches $4/3$ as $\delta \rightarrow \beta$.

5 Conclusion

In the literature, the use of a damages multiplier greater than one (which may be likened to punitive damages) has been justified as offsetting advantages gained by tortfeasors who escape liability. In practice, punitive damages are often imposed even in classes of accidents with practically no possibility of escaping liability. According to the standard rationale, a damages multiplier would be unwarranted in these instances. This paper establishes that a damages factor exceeding one is well-suited to address another fundamental reason underlying private decision-makers' selection of socially inadequate safety investments. Imperfectly competitive firms select behavior to maximize profits, disregarding repercussions for consumer welfare. We show that imposing damages greater than harm is an instrument to remedy this discrepancy between producers' objectives and society's interests in the case of product safety investment.

We find that the optimal damages multiplier is closely tied to the characteristics of competition in the market. This is due to the fact that the divergence between firms'

interests and those of society will similarly depend on the characteristics of competition. In particular, we show that the optimal damages multiplier depends on the number of firms, the degree of substitutability/complementarity when products are heterogeneous, and firms' cost structures, as well as on the mode of competition - namely, competition either in price or in quantity.

As a concluding note, we would like to point out that the optimality of damages exceeding compensatory damages has proven to be robust in several variations of our baseline model. We conjecture that our primary findings would also generalize to settings with more basic demand and production functions, although the optimal damages level will often not be reducible to a simple number.

Appendix: Product differentiation, market entry, and the optimal damages factor

For the homogenous Cournot model presented in the main text, it is well-established that excessive entry will occur. This leads to the conclusion that the optimal damages factor will be even higher in the free-entry variation of the model than when the number of firms is considered exogenous. However, when products are differentiated, firms' incentives to enter a market might actually be lower than those considered by a social planner, resulting in insufficient market entry (see, Mankiw and Whinston 1986, Tirole 1988). In order to address the potential consequences of this scenario for the optimal damages multiplier, we use a standard approach to investigate market entry and product diversification, analyzing a model of monopolistic competition similar to that developed by Dixit and Stiglitz (1977).

Specifically, we use the representative consumer's utility function

$$U = \left(\int_0^n y_j^\rho \right)^{1/\rho} z, \quad (70)$$

where the notation follows that used in the main text and $1/(1 - \rho)$ represents the elasticity of substitution between the different varieties j of the product y , $0 < \rho < 1$. Each firm in the market produces one variety of the product. With the price of the numeraire good z

normalized to one, the consumer's budget constraint can be represented by

$$M = z + \int_0^n q_j y_j dj. \quad (71)$$

Solving the consumer's optimization problem, we obtain

$$z = \frac{M}{2} \quad (72)$$

for the numeraire good and

$$y_i = \left(\frac{A}{q_i} \right)^{\frac{1}{1-\rho}} = \left(\frac{A}{p_i + (1-\gamma)x(\bar{s}_i)h} \right)^{\frac{1}{1-\rho}} \quad (73)$$

as the demand function for each variety i , $i = 1, \dots, n$, of the differentiated product, where

$$A = \frac{M}{2 \int_0^n y_j^\rho}. \quad (74)$$

Consequently, firm i 's profit equation can be stated as

$$\pi_i = [p_i - EMC(\bar{s}_i, s_i, \gamma)] y_i(p_i) - s_i \quad (75)$$

where $EMC(\bar{s}_i, s_i, \gamma) = c + (1-\gamma)x(\bar{s}_i)h + \gamma x(s_i)h$. From this, the optimal price

$$p_i = q_i - (1-\gamma)x(\bar{s}_i)h = \frac{EMC(\bar{s}_i, s_i, \gamma)}{\rho} - (1-\gamma)x(\bar{s}_i)h \quad (76)$$

can be derived. The corresponding output level is equal to

$$y = \left(\frac{A\rho}{EMC_i} \right)^{1/(1-\rho)}. \quad (77)$$

Given these results, firm i 's profit function amounts to

$$\pi_i = (1-\rho)\rho^{\rho/(1-\rho)} A^{1/(1-\rho)} EMC(\bar{s}_i, s_i, \gamma)^{-\rho/(1-\rho)} - s_i, \quad (78)$$

which gives rise to the firm's first-order condition with respect to safety investments:

$$\frac{\partial \pi_i}{\partial s_i} = -y_i \gamma x'(s_i)h - 1 = -\rho^{1/(1-\rho)} A^{1/(1-\rho)} EMC(\bar{s}_i, s_i, \gamma)^{-1/(1-\rho)} \gamma x'(s_i)h - 1 = 0. \quad (79)$$

To establish the market equilibrium, we recognize that each firm chooses the same output level in equilibrium. This implies that

$$A = \frac{M}{2ny^\rho}, \quad (80)$$

resulting in

$$A^{1/(1-\rho)} = \frac{M}{2n} \left(\frac{c + x(s)h}{\rho} \right)^{\rho/(1-\rho)}. \quad (81)$$

The corresponding equilibrium solutions for output, profit, and optimal safety investment are

$$y = \frac{M}{2n} \frac{\rho}{c + x(s)h} \quad (82)$$

$$\pi = (1 - \rho) \frac{M}{2n} - s \quad (83)$$

$$1 = -\frac{M\rho}{2n(c + x(s)h)} \gamma x'(s)h. \quad (84)$$

The consumers' utility in equilibrium can thus be expressed by

$$U^* = n^{1-\rho} \rho \frac{M^2}{4(c + x(s)h)} = n^{1/\rho} y \frac{M}{2}. \quad (85)$$

Exogenous number of market participants

Since the utility function is no longer quasi-linear in nature, the sum of consumer surplus and firms' expected profits does not represent a suitable candidate for measuring social welfare. Therefore, we follow the standard approach and assume that the policy maker maximizes the representative consumer's utility, recognizing that firms' profits add to the consumer's income. Consequently, the following analysis focuses on the consumer's utility, assuming that the total income M consists of some base income m and profits earned by firms:

$$M = m + n\pi = m + (1 - \rho) \frac{M}{2} - ns = 2 \frac{m - ns}{1 + \rho}. \quad (86)$$

Accordingly, the social planner seeks to maximize

$$U^* = n^{(1-\rho)/\rho} \frac{\rho}{(1 + \rho)^2} (m - ns)^2 \frac{1}{c + x(s)h}. \quad (87)$$

After taking the derivative with respect to s and employing the first-order condition for a firm's safety investment, equation (84), we find the optimal damages multiplier to be equal to

$$\gamma^* = \frac{1 + \rho}{2\rho}. \quad (88)$$

The optimal damages multiplier depends on the fierceness of competition between firms in the differentiated good sector, which is measured by the degree of substitutability between products. When $\rho \rightarrow 1$, products are perfect substitutes and the damages multiplier converges to one, while the derivative of the optimal damages multiplier with respect to ρ is negative. Overall, the lower the degree of substitutability between products (i.e., the lower the level of ρ), the higher the optimal damages multiplier; this multiplier exceeds one for $\rho < 1$.

The optimal damages multiplier with firm entry

In a scenario with free entry, the income level M reduces to m , since expected profits are just equal to entry costs K . Furthermore, from the entry condition

$$\pi = (1 - \rho) \frac{m}{2n} - s = K, \quad (89)$$

we find that higher safety investments reduce the number of firms in the market, since

$$\frac{dn}{ds} = -\frac{2n^2}{m(1 - \rho)}. \quad (90)$$

Maximizing the consumer's utility in equilibrium, we obtain the first-order condition

$$\begin{aligned} \frac{dU^*}{ds} &= (1 - \rho) \frac{M^2}{4} \frac{1}{c + x(s)h} n^{(1-2\rho)/\rho} \frac{dn}{ds} \\ &\quad - n^{(1-\rho)/\rho} \frac{M^2 \rho}{4} \frac{1}{(c + x(s)h)^2} x'(s)h = 0. \end{aligned} \quad (91)$$

We employ the firm's first-order condition with respect to safety investments, equation (84), and dn/ds from equation (90) to determine that the optimal damages multiplier is equal to $\gamma^{**} = 1$.

With free entry, the optimal damages multiplier is equal to one for all ρ , and is thus necessarily lower than the optimal damages multiplier when the number of firms is exogenous.

This can easily be explained by the fact that there is insufficient market entry by firms in the present set-up as compared to a first-best solution. Consequently, the social planner will reduce the damages multiplier in order to increase the number of firms, because a lower multiplier entails lower safety investments by firms (i.e., lower fixed costs of production for firms). The solution is of a second-best nature, as the social planner is balancing the imperfections of insufficient safety investments with a shortage of market participants. For the Cobb-Douglas utility function considered here, the social planner's incentives to offer more than full compensation in order to correct insufficient safety investments just cancels out the incentives to implement a lower damages multiplier in order to stimulate market entry. More generally, the deviation of the optimal damages multiplier from the multiplier that results for a given number of firms depends on whether private incentives for market entry are too high or low from a social welfare perspective, and on how severe this discrepancy is. However, as argued earlier, it is not desirable to utilize the damages multiplier to manage both of these issues when other instruments are also available. Market entry decisions may be guided by subsidies or the imposition of additional entry costs. In such a scenario, according to the findings detailed in this paper, the damages multiplier could then be used to promote optimal safety investments that would hold for a given number of firms in the market.

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Universitätsstraße 1 _ 40225 Düsseldorf
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ISSN 2190-9938 (online)
ISBN 978-3-86304-079-6