Product Liability versus Reputation

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Market reputation is often perceived as a cheaper alternative to product liability in the provision of safety incentives. We explore the interaction between legal and reputational sanctions using the idea that inducing safety through reputation requires implementing costly "market sanctioning" mechanisms. We show that law positively affects the functioning of market reputation by reducing its costs. We also show that reputation and product liability are not just substitutes but also complements. We analyze the effects of different legal policies, and namely that negligence reduces reputational costs more intensely than strict liability, and that court errors in determining liability interfere with reputational cost reduction through law. A more general result is that any variant of an ex post liability rule will improve the functioning of market reputation in isolation. We complicate the basic analysis with endogenous prices and observability by consumers of the outcome of court's decisions. (*JEL* K13, K23, L51, H24)

1. Introduction

This article analyzes the interaction between market reputation (a form of implicit relational contract between the manufacturer of a product and the consumer) and the law as tools to adequately address product hazards affecting consumers. The asymmetry of information between consumers and manufacturers with respect to the quality and safety of products generates incentive problems that may be solved or at least alleviated with

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either market reputation or the law. Thus, market reputation and the law for product hazards—product liability—would appear to be alternative instruments for improving safety and quality in markets.

Polinsky and Shavell (2010a) have invigorated an important debate over the convenience of rethinking product liability. Their claim that it is a costly instrument and that part, even a large part, of its benefits in terms of incentives for safety may be achieved in a more efficient way by reputational forces and by public regulation.[1] Klein and Leffler (1981) had already argued that the extralegal instrument of market reputation is a less costly alternative to formal incentive schemes to induce cooperation in asymmetric information settings. We present an argument that has—we believe—a broad scope of application, since reputation and law are tools to induce cooperation in a wide variety of settings. Our analysis emphasizes that market reputation may be costly in social terms, and that organized legal instruments (tort and contract law, or ex post regulation) may be socially valuable both to reduce the cost of relying on reputation as a tool to enhance desirable trade, and to make cooperation sustainable in settings in which reputation on its own could not induce it. Specially when the informational asymmetry is severe, the firm's surplus from future trade is not large, and the time horizon of many market participants is not long, the role of the legal system in encouraging trade becomes more relevant, perhaps essential.

Our argument goes along the following lines. First, market reputation is not costless; since cooperation between consumers and firms in asymmetric information environments requires to implement punishment mechanisms that are costly for both. Second, product liability reduces the "private" cost of market reputation. Technically, product liability allows the relaxation of the incentive compatibility constraint for the functioning of market reputation. Thus, we agree with Polinsky and Shavell (2010a) in their claim that the design of product liability should take into account the existence and effectiveness of private instruments such as market reputation. However, this article shows that such interaction does not necessarily imply that the level of legal liability should be reduced or eliminated when market reputation is available.

1. Polinsky and Shavell present in their original paper and in a reply to Goldberg and Zipursky (2010) (Polinsky and Shavell, 2010b) other arguments concerning the overall cost-benefit assessment of product liability, relating to the compensation benefits of product liability, the incentives for safety flowing from ex ante public regulation, and legal and other costs stemming from product liability. We do not deal with any of these factors here, and thus we do not cast a vote in the "uneasy case for product liability" debate. Specially, we do not deal with ex ante regulation, since it does not affect the interaction between legal liability and reputation. Moreover, ex ante regulation can be considered as providing the framework in which there is a relevant interplay between product liability and reputation, the tools that would deal with the incentive problems left yet unsolved by public ex ante regulation.

In this debate, others have responded to Polinsky and Shavell's claim on different grounds (Goldberg and Zipursky, 2010), and others have advanced different arguments against product liability (Priest, 2013; Rubin, 2011; Viscusi, 2013).

The core of the argument lies in the observation that consumer's knowledge[2] that a manufacturer may face potential legal liabilities[3] for misbehavior facilitates cooperation between firms and consumers, since it reduces the need to rely on private "punishments" by consumers to deter manufacturers from "cheating" in quality/safety. When legal rules that may impose adverse consequences on the firm are common knowledge, the optimal reputational punishment goes down, and in equilibrium there will be trade for a larger range of parameter values. Interestingly, we show this is true even for a very imperfect legal system. As long as expected liability for firms is not higher when they have undertaken appropriate behavior than when they have fallen short of it, the positive effects on market reputation hold.

This interaction between market reputation and legal rules, as far as we know, has not been fully recognized and analyzed before. There is a large body of literature on relational contracts and on the link between reputation and legal contract enforcement summarized in MacLeod (2007). However, most of this literature emphasizes substitution effects between both. Two papers show complementary effects different from the ones we identify: Sobel (2006) compares partnerships supported through relational contracting and partnerships supported through formal legal institutions, showing complementary effects in the form of opportunity costs of early cheating in relational contracts resulting from formal contract enforcement, thus increasing the number of such relationships. Greif (1994) provides historical evidence showing how Genoese traders used formal contract enforcement to encourage new relationships, instead of using information sharing on past behavior and ostracism to sanction opportunistic behavior. Dhillon and Rigolini (2011) also study the interactions between formal and informal institution. Their focus, however, is not legal policy nor minimizing the cost of reputational sanctions. They analyze, in a development context, an informal sanctioning mechanism which may be reinforced by consumers' investment in being connected to other consumers, interacting with a formal enforcement mechanism which, in turn, may be made less effective by firms through bribing activities. In their context, better informal enforcement reduces the incentives for bribing and, indirectly, improves legal enforcement. In a later paper, Baker and Choi (2013) also consider formal and informal incentives in a moral hazard setting similar to ours. Their model shows that legal sanctions—in the form of a liquidated damage contract payment from the manufacturer—following a costly litigation phase increases deterrence and may even displace reputational sanctions. Additionally, consumers may learn

2. This knowledge does not involve that of actual liabilities being imposed, simply the awareness of the existence and features of the legal regime from which liabilities may ensue. When legal outcomes can be observed by consumers the effect is strengthened.

3. In any form that actual or imaginable legal systems may provide for: liabilities based on product liability, on tort, on contract, on express or implied warranties, and so on.

upon the manufacturer's behavior through the outcomes of litigation, since these are always observed by consumers. Differently from their paper, we focus on alternative liability regimes (no liability, strict liability, negligence, punitive damages, etc.) and show their impact on reputational sanctions. In particular, we show that negligence is more effective for this purpose than strict liability. In our basic model our results about the interaction of legal and reputational incentives hold when consumers are unable to observe litigation outcomes and are only aware of the existence of an imperfect legal regime (i.e., with errors in deciding liability). In an extension we allow consumers to observe the outcome of the litigation process and we show that the reduction of the optimal reputational sanction is even larger.

The article is organized as follows. In Section 2 we present the basic model of reputation in our setting. We want to illustrate our idea in the simplest possible way. Thus, we have adapted as a model of market reputation a simplified version of the collusion model by Green and Porter (1984) as presented in Tirole (1988) and Cabral (2005).[4] In Section 3, we characterize the equilibrium of the model. In Section 4, we turn to the optimal equilibrium introducing product liability and establish the main results. In Section 5, we show that, to an important extent, reputation and product liability are not just substitutes but also complements. Section 6 presents an extension of the basic model to endogenous prices. Section 7 considers the interaction between market reputation and legal liability when consumers observe the outcome of the tort process at the time of determining the market sanction. Section 8 contains a brief discussion of the implications, and concludes. All the proofs are relegated to a technical appendix.

2. The Model

We use a standard unilateral accident model with imperfect information. A firm produces a good and chooses effort[5] in order to reduce the probability of accident when a consumer uses the product. In particular, we assume that the firm decides between two possible levels of effort, $e \in \{\underline{e}, \overline{e}\}$. The choice of the firm (effort) is private information, and thus not observable by the consumer. Effort is costly, $c_{\underline{e}} < c_{\overline{e}}$, and determines the probability of accident, $p_{\underline{e}} > p_{\overline{e}}$. For simplicity and without loss of generality, we take $c_{\underline{e}} = 0$, $c_{\overline{e}} = c$, $p_{\underline{e}} = 1$, and $p_{\overline{e}} = \pi$. In case of accident, consumer suffers a loss of D.

4. In particular, Cabral (2005) presents a model of product safety and cooperation between firms and consumers very similar to our baseline model. This article also points out that models based on repeated interaction should be denoted as trust models, while models based on Bayesian updating should be called reputation models. We do not take a stance in this debate, but have decided to keep the term "reputation" since it seems to be more widely used.

5. In the product safety context that we use, effort can be naturally be understood as "care", but in other settings different applications are also possible.

The firm may sell the product to a consumer with a willingness to pay for the good, V. In order to keep the model simple, we initially take as exogenous the price of the good, P. This is definitely a simplifying assumption, but it allows us to emphasize the basic link between market discipline and legal consequences. In Section 6 we endogenize P, and show that beside the fact that prices will be influenced by firm's market power, expectations about product failure, and by the legal regime, our main results hold.

Given this price, we assume that the consumer would buy the good if effort is high, but not otherwise:

$$V - P - \pi D > 0 > V - P - D \Rightarrow D > V - P > \pi D.$$

As supply has to be profitable for the firm, the price also satisfies, $P \geqslant c$.[6]

In a static framework, where first the firm decides the level of effort, and afterwards the consumer decides whether or not to buy the good without knowing the choice of effort, there would be no trade.

There are several ways to solve this market failure. We just concentrate on two. First, the legal system through ex post regulatory sanctions, tort liability, or by enforcing explicit contracts, such as warranty provisions,[7] may provide sufficient incentives for the firm to exert high effort, and trade will arise. Second, without any intervention from the legal system, market reputation may do the job.[8] We first focus on this reputational mechanism by placing the interaction between the firm and the representative consumer in a dynamic framework.

3. Market Reputation Without Legal Liability

We consider an infinite horizon framework with an infinitely lived firm and an infinitely lived consumer,[9] in which the basic game above is repeated over and over again. We start by assuming there is no legal liability, and contracts cannot be verified by a third party who could enforce, for

6. In other words, we assume that the price is such that the participation constraint of the firm is satisfied. Thus, in Section 4, in which we consider a liability regime, this assumption will imply that the price also covers the expected liability cost.

7. Warranties are enforceable ex post legal remedies that in our stylized setting of legal regimes in Section 4 can be analyzed in a similar way as strict liability. A warranty would determine the ex post restitution of price, or another stipulated sum, and strict liability would imply the ex post payment of damages, normally in an amount identical to the harm incurred by the consumer, although the amount of damages could be smaller or larger than harm.

8. Legal sanctions by themselves could wholly eliminate the manufactures's incentives problem. In reality, the presence of enforcement cost and loopholes, and judgment-proof problems, prevent the legal system to fully solve the market failure. In most real world markets, observation reveals that both legal liability and reputation are at work.

9. We could alternatively assume that there is an infinite sequence of one-period consumers who can observe the history of the game, under the additional assumption that consumers are able to coordinate in their punishment strategies.

instance, a warranty provision. Thus, only market reputation incentives are in place.

This repeated game has multiple equilibria, including the repetition of the no-trade (low effort) equilibrium in the static setting: the firm chooses low effort and consumer anticipates this and responds by not buying from the firm. We focus on the more interesting equilibria where there is co-operation between the firm and the consumer. In particular, we consider the following subgame-perfect equilibrium strategy inspired by Green and Porter (1984):

- Consumer begins trusting the firm in period 0, and buying the good at price P, starting the cooperation phase.
- Cooperation phase. Firm chooses high effort and consumer trusts the firm and buys the good at its price P. This high effort equilibrium lasts until consumer suffers an accident, starting the punishment phase.
- Punishment phase. When there is an accident, the no-trade equilibrium, in which the firm chooses low effort and consumer does not buy, takes place for T periods. After expiration of these T periods, the cooperation phase is reinstated.

We will denote the missing trade surplus in the punishment phase (T periods) as the “cost of reputation” (below we formally justify this label). Both agents would be better off if they did not stop trading during the punishment phase. However, both know that punishment is necessary to preserve incentives.

The cooperative equilibrium can be sustained with alternative relational contracts, for example, by making prices depend on the occurrence of accidents. Our mechanism (a refusal to buy from the firm for a given number of trade rounds) is simpler, and has the advantage of minimizing the informational and institutional conditions for a reputational sanction to work: there is no need to assume that firm and consumer observe the accident and its effects in the same way, or that there is some arrangement to ensure lower future prices.

We are in a setting of ex post imperfect information: the fact that an accident has occurred is an imperfect signal of the firm’s effort. If the signal were perfect, $\pi = 0$, then T could be infinite and the cost of reputation would be 0, since punishment would never be imposed in equilibrium. In our setting, the imperfect information leads agents to incur a cost of reputation. We concentrate on the pareto efficient relational contract between firm and consumer that we denote as the “optimal”, the one that maximizes the number of periods in which trade occurs, or, equivalently, minimizes the number of periods in which the market sanction is imposed. We believe that our optimal (or pareto efficient) contract is appealing, since alternative contracts can always be renegotiated. We are however agnostic about how parties may reach this optimal equilibrium.

We assume that both players face the same discount factor, $\delta \in (0, 1)$. When consumer and firm play the strategy described above, let V^+ and V^- be the continuation payoffs. V^+ the present value of the firm's profits in the cooperation phase, and V^- the present value of the firm's profits at the start of the punishment phase. We have:

$$V^+ = P - c + (1 - \pi)\delta V^+ + \pi\delta V^-,$$
$$V^- = \delta^T V^+.$$

Solving the equation system we obtain both present values in terms of the parameters of our model

$$V^+ = \frac{P - c}{1 - (1 - \pi)\delta - \pi\delta^{T+1}}, \tag{1}$$

$$V^- = \delta^T V^+ = \frac{\delta^T (P - c)}{1 - (1 - \pi)\delta - \pi\delta^{T+1}}. \tag{2}$$

Finally, for this equilibrium we must add an incentive compatibility constraint. The following inequality captures the lack of incentives of the firm to choose low effort:

$$V^+ \geqslant P + \delta V^-.$$

Using the definition of $V^+ = P - c + (1 - \pi)\delta V^+ + \pi\delta V^-$, the incentive compatibility constraint can also be written as:

$$(1 - \pi)\delta(V^+ - V^-) \geqslant c. \tag{3}$$

This expression reflects that cooperation is sustainable only when the gains from exerting effort (the difference in payoffs between the two phases, multiplied by the probability of keeping the cooperation phase and the discount rate) outweighs the cost savings from deviating (the cost of exerting effort).

We can rewrite the inequality above using the solution to the equation system V^+ and V^- (we plug equations (1) and (2) into equation (3)):

$$(1 - \pi)\delta \frac{(1 - \delta^T)(P - c)}{1 - (1 - \pi)\delta - \pi\delta^{T+1}} \geqslant c.$$

Let $\Phi(T)$ be the left side of the incentive compatibility constraint above. For our purposes, this function has a useful property:

Lemma 1. $\Phi(T)$ is strictly increasing in T.

Hence, to solve optimally the infinitely repeated game, we choose T in order to maximize V^+.

$$\max_T V^+ = \max_T \frac{P - c}{1 - (1 - \pi)\delta - \pi\delta^{T+1}}$$

subject to the following constraint:

$$\Phi(T) \geqslant c.$$

Given that our objective function satisfies $\frac{\partial V^+}{\partial T} < 0$,[10] the optimal T^* for our problem will be the minimum T that satisfies the identity $\Phi(T^*) = c$.[11] If $\Phi(\infty) > c$, by Lemma 1 this equation has a unique solution. In order to simplify the exposition, we treat T as a continuous variable. This is clearly just for expositional convenience, being T the number of no-trade periods, and thus really a discrete variable. More accurately, the optimal punishment T^* should be defined by the following conditions: $\Phi(T^* - 1) < c$ and $\Phi(T^*) \geqslant c$.

Next figure plots $\Phi(T)$ and c for the following parameter specifications: $\pi = 0.2$; $\delta = 0.8$; $P = 5.5$; and $c = 3.5$.

In our example, the optimal punishment T^* is 17 ($\Phi(16) < 3.5$ and $\Phi(17) > 3.5$).

T^* refers to the welfare cost of reputation under imperfect information. Let $W_P = \frac{V - c - \pi D}{1 - \delta}$ be welfare achieved under perfect information. Given T^*, the present discounted value of welfare under imperfect information will be given by the following expression:

$$W_I = V - c + (1 - \pi)\,\delta W_I + \pi(\delta^{T^*+1} W_I - D).$$

Then,

$$W_I = \frac{V - c - \pi D}{1 - (1 - \pi)\,\delta - \pi\delta^{T^*+1}}.$$

As the difference between welfare with perfect and with imperfect information, $W_P - W_I$, is increasing in the optimal punishment T^*, we denote T^* as the cost of reputation. Notice that this holds for a given $\pi < 1$. When π goes to 0, the imperfect information vanishes (accidents are perfect signals of low effort) and $W_P - W_I$ goes to 0.

T^* has been characterized for a given value of the discount factor δ, the probability of accident under high effort π, and the marginal profit $P - c$. Next lemma establishes how the optimal punishment T^* depends on this set of parameters.

Lemma 2. T^* is increasing in π and decreasing in $P - c$ and δ.

10. We have taken the profit function of the firm as the objective function for expositional reasons since the incentive compatibility constraint applies only to the firm. Consumer surplus and total surplus are also decreasing in T so using them as the objective function would have delivered the same result. In fact, we want to characterize the efficient solution that is also the optimal one for firm and consumer.

11. Naturally, any T larger than T^* satisfies the incentive compatibility constraint, and thus, provides incentives for the high effort equilibrium. However, only T^* maximizes firm's surplus, consumer surplus and, consequently, total surplus among the T satisfying the incentive compatibility constraint.

The intuition of Lemma 2 is as follows. The cost of reputation increases with π since it is a measure of the level of imperfect information, and decreases with $P - c$ and δ, since they increase the cost for the firm of missing trade due to relational sanctions.

4. Market Reputation with Legal Liability

Now we introduce legal liability in our dynamic framework. The approach taken from now on assumes the existence of the legal system,[12] where a court may, at least to some extent, verify, after an accident happens, whether the firm adopted one or another level of care and impose some degree of legal liability.[13] We consider a family of rules used by courts such that, in case of an accident, the firm should pay a monetary amount consisting of a certain fraction of the harm caused to the consumer. This fraction is not fixed but may depend on a legal finding conditional on the behavior of the firm. More specifically, the firm will be bound to pay:

- αD if there is an accident and firm exerted care, where $\alpha \in [0, 1]$.
- βD if there is an accident and firm did not exert care, where $\beta \geqslant \alpha$, and $\beta \in [0, 1]$.[14]

Notice that the only relevant condition on the “quality” of the legal system is that $\beta \geqslant \alpha$, that is, that the expected payment for the firm under a liability rule is never higher when the firm exerted effort than when it failed to do so.

Thus, every liability rule is a specification (α, β). Notice that this parameterization allows us to consider as particular cases the most relevant rules used in the law and considered by the Law and Economics literature:

(i) Strict Liability: Firm must pay the entire amount of harm, no matter if it exerted high care or not, that is, $\beta = \alpha = 1$.
(ii) Negligence rule: Firm is liable for the entire harm if and only if it exerted low care, that is, $\beta = 1$ and $\alpha = 0$.
(iii) Negligence rule with errors in determining liability: This liability rule includes the realistic complication that a jury or a court could incur two possible errors when determining liability based on the true level of effort exerted by the firm. Type I error implies convicting an “innocent” firm (firm who exerted high effort), that is

12. For simplicity, we will use the illustration of product liability, but our framework would cover also contract warranties and liabilities, and with straightforward changes, other ex post legal sanctions.

13. This implies that however imperfectly, the evidence presented before the court allows the production of a signal on which to condition the payment by the firm. As will be clear in the text, this is consistent with a highly imperfect legal system, and high levels of court error in imposing liability, since our family of liability rules only excludes those that make the expected liability of the firm lower with low effort than with high effort.

14. α and β could also be interpreted as probabilities of a finding of liability against the firm given high effort and low effort, respectively.

$\alpha > 0$. Type II error takes place when a "guilty" (exerting low effort) firm is not found liable, that is, $\beta < 1$.

(iv) No liability: $\beta = \alpha = 0$.

Initially, we do not consider the possibility of damages multipliers, but after our first round of results we will consider the effects of the legal system using damages multipliers (or punitive damages), that is, $\alpha\lambda D$ and $\beta\lambda D$ with $\lambda \geqslant 1$.[15]

To solve the new infinite horizon game, we follow a similar procedure to the one in the previous section. Let V_R^+ and V_R^- be the Present Discounted Value of the firms' profits in the cooperation and the punishment phase, respectively, including now the expected monetary sanction imposed by product liability. By definition, we have:

$$\begin{aligned} V_R^+ &= P - c + (1-\pi)\,\delta V_R^+ + \pi\,\delta\,[V_R^- - \alpha D], \\ V_R^- &= \delta^T V_R^+. \end{aligned} \tag{4}$$

Notice that we are assuming that the liability payment takes place in the next period. We find this assumption consistent with the observation that legal liability comes with a delay, often a significant one, since it is typically necessary to wait for the court decision. We must note that this assumption, due to discounting, entails a degree of undercompensation through legal liability. We think that this is probably the case in most situations, and that the award of pre-judgment interest by courts, although it is an important corrective, would not achieve perfect compensation in reality. Without this, or some other form of imperfection or cost in legal liability, the incentive compatibility constraint trivially holds, and liability rules allow trade in the static game.

Liability rules also affect the incentive compatibility constraint, so in order to express that the firm would have no incentive to exert low effort, now we have:

$$V_R^+ \geqslant P + \delta[V_R^- - \beta D].$$

We use the definition of V_R^+ to rewrite the incentive compatibility constraint as:

$$\delta(1-\pi)[V_R^+ - V_R^-] + \delta[\beta - \pi\alpha]D \geqslant c. \tag{5}$$

Following similar computations as in the previous section, we obtain the incentive compatibility constraint legal liability as the inequality given by:

$$\Psi(T, \alpha, \beta) \geqslant c,$$

15. Legal systems set upper bounds on λ. For instance, in the United States, BMW of North America, Inc. v. Gore, 517 U.S. 559 (1996) sets criteria to determine an upper bound on punitive damages. For instance, private antitrust suits in United States allow for treble damages: $\lambda = 3$. In Civil Law jurisdictions the generally applicable constraint is $\lambda = 1$.

where this new function is:

$$\Psi(T,\alpha,\beta)=(1-\pi)\delta\frac{(1-\delta^{T})(P-c-\delta\pi\alpha D)}{1-(1-\pi)\delta-\pi\delta^{T+1}}+\delta D(\beta-\pi\alpha). \tag{6}$$

Notice that, by construction, $\Phi(T)=\Psi(T,0,0)$. In words, that the incentive compatibility constraint under a perfect no liability rule, that is, when α and β are equal to zero, is the same as the one when only reputation is at work as in Section 3.

We are interested in comparing both incentive compatibility constraints, the one achieved through reputation alone versus the one including the effect of legal liability. More specifically, we focus on the optimal number of periods during which consumers stop buying the product when $(\alpha,\beta)=(0,0)$ (reputational sanctions alone as no liability) versus other values of the parameters α, β (various forms of positive legal liability).

We start by analyzing how the incentive compatibility constraint (the function $\Psi(T,\alpha,\beta)$) depends on the reputational punishment, and on the specification of the liability rule (α,β).

Lemma 3. $\Psi(T,\alpha,\beta)$ is increasing in T, increasing in β, and decreasing in α.

The intuition of Lemma 3 is related to the incentive compatibility constraint as follows: The larger the reputational punishment is, the easier it is that the incentive compatibility constraint is satisfied. This is because exerting effort reduces the probability of punishment, $\alpha\leqslant\beta$. In the same line, increasing β (decreasing α) makes exerting effort more attractive, and this makes more likely that the incentive compatibility constraint is satisfied.

We define $T_R^*(\alpha,\beta)$ as the optimal number of periods in which there is no trade under the liability rule (α,β). $T_R^*(\alpha,\beta)$ is the solution to the following problem:

$$\max_T\ V_R^+=\frac{P-c-\pi\delta\alpha D}{1-(1-\pi)\delta-\pi\delta^{T+1}}$$

subject to the incentive compatibility constraint:

$$\Psi(T,\alpha,\beta)\geqslant c.$$

As in the previous case, given that $\frac{\partial V_R^+}{\partial T}<0$, and $\Psi(T,\alpha,\beta)$ is increasing in T, $T_R^*(\alpha,\beta)$ is the unique solution to the equation $\Psi(T_R^*,\alpha,\beta)=c$. The next proposition uses the implicit characterization of $\Psi(T_R^*,\alpha,\beta)=c$ and Lemma 3 to analyze how the optimal punishment under legal liability depends on the liability parameters (α,β).

Proposition 1. The optimal reputational punishment under liability, $T_R^*(\alpha,\beta)$, is decreasing in β and increasing in α.

Proposition 1 is illustrated by Figure 2 that plots $\Psi(T, \alpha, \beta)$ and c with the same parameters as in Figure 1, $\pi = 0.2$; $\delta = 0.8$; $P = 5.5$; $c = 3.5$; with $D = 4.5$ and several values for α and β.

The solid line plots $\Psi(T^*_R, \alpha, \beta)$ for $\alpha = 0.2$ and $\beta = 0.6$, and the optimal punishment in such case is $T^*_R(0.2, 0.6) = 2$. The dashed line considers the case $\alpha = .4$ and $\beta = 0.6$, for which the optimal punishment is $T^*_R(0.4, 0.6) = 3$. Then, as Proposition 1 states, these two cases show that $T^*_R(\alpha, \beta)$ is increasing in α. Similarly, the dotted line considers $\alpha = 0.2$ and $\beta = 0.8$, for which the optimal punishment is $T^*_R(0.2, 0.8) = 1$. Notice that comparing $T^*_R(0.2, 0.6) = 2$ with $T^*_R(0.2, 0.8) = 1$ also shows, as stated in Proposition 1, that $T^*_R(\alpha, \beta)$, is decreasing in β.

The next corollary of Proposition 1 ranks the two major liability rules in terms of their effect on reputational costs.

Corollary 1. The optimal reputational punishment is higher under strict liability than under negligence, that is, $T^*_R(1, 1) > T^*_R(0, 1)$.

Moreover, the negligence rule is the best policy from the welfare point of view among all possible legal rules (α, β), since $T^*_R(0, 1)$ is the minimum among all possible $T^*_R(\alpha, \beta)$.

Also, the previous results have implications for the effect of judicial errors (under negligence) on reputational costs.

Corollary 2. The optimal reputational punishment under liability, $T^*_R(\alpha, \beta)$, is increasing in the probability of judicial errors, α and $1 - \beta$.

Another direct application of Proposition 1 is that negligence is superior to the benchmark case (without legal liability), $T^*_R(0, 0) > T^*_R(0, 1)$. However, if we want to compare strict liability with the benchmark case, we cannot invoke Proposition 1, since the effect of both parameters α and β on the optimal length of the market punishment is ambiguous. The next result provides a general comparison between liability rules and the benchmark case.

Proposition 2. The optimal reputational punishment under any liability rule (α, β) is lower than without legal liability, that is, $T^*_R(0, 0) > T^*_R(\alpha, \beta)$.

The examples plotted in Figures 1 and 2 also illustrate Proposition 2 since $T^*_R(0.2, 0.8) = 1 < T^*_R(0.2, 0.6) = 2 < T^*_R(0.4, 0.6) = 3 < T^*_R(0, 0) = 17$. Proposition 2 implies that any variant of an ex post liability rule combined with reputational sanctions will outperform, in terms of minimizing reputational costs, the pure market reputation alternative. Even extremely noisy or mechanistic rules (as pure strict liability, which pays no attention to the evidence of the firm's choice of care) will improve the functioning of market reputation in isolation. Evidently, we cannot (and do not) make claims as to the overall social desirability of any liability system over no liability at all, as we do not consider the cost of implementing a court and liability system, and solely consider minimizing missing efficient trade.

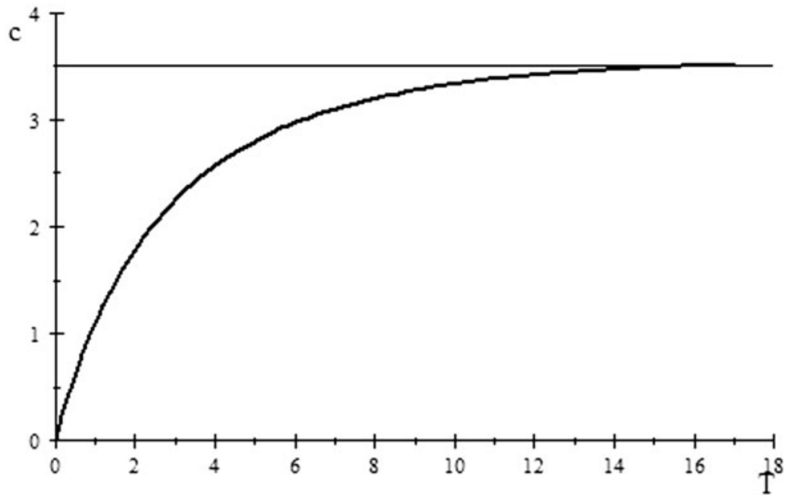

Figure 1. Incentive Compatibility Constraint without Legal Liability.

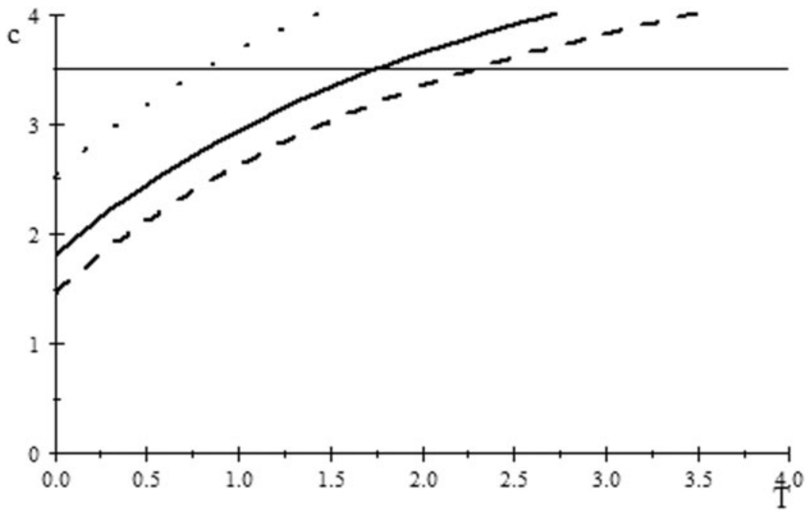

Figure 2. Incentive Compatibility Constraint with Legal Liability.

Thus, there is no direct transplant of our conclusions at the policy level. But we believe that the result that any liability rule actually improves the functioning of market reputation by reducing its costs deserves proper weight in the policy debate over the interaction between the legal system and market reputation.

Finally, we turn to the issue of damages multipliers, $\alpha\lambda D$ and $\beta\lambda D$ with $\lambda \geqslant 1$. It is immediate to rewrite the expressions above in terms of the damages multiplier, by replacing D with λD. Similarly than above, the optimal reputational punishment is characterized by $\Psi(T_R^*, \alpha, \beta, \lambda) = c$.

Proposition 3. The optimal reputational punishment under liability, $T_R^*(\alpha, \beta, \lambda)$, is decreasing in the damage multiplier λ.

This result is less direct than one may think at first blush. Increasing the legal penalty in case of an accident through a damages multiplier has a clear positive effect on the incentives for effort, since exerting effort reduces the probability to pay the enhanced damages (recall that $\alpha \leqslant \beta$). However, since there is imperfect information, and legal penalties may be imposed even on the cooperative path, larger penalties reduce the overall value of the long-term relationship, and thus, the incentive to cooperate. The proof in Appendix A shows, nevertheless, that the first effect dominates the second, and thus that damages multipliers reduce the optimal reputational sanction.

It is interesting to consider the special case in which $\lambda = \frac{1}{\delta}$, a damage multiplier that would undo the undercompensation caused by the time gap in imposing legal liability that we discussed above. With this multiplier and perfect strict liability or perfect negligence, liability alone would provide the right incentives for effort (as the standard Law and Economics theory of liability shows), and the optimal reputational sanction would be zero: $T_R^*\left(1, 1, \frac{1}{\delta}\right) = T_R^*\left(0, 1, \frac{1}{\delta}\right) = 0$.[16]

5. Product Liability and Reputation: Complements or Substitutes?

As product liability and reputation may achieve in isolation the same outcomes in terms of incentives, it is clear, and in fact it seems to be a widely shared idea, that they are substitutes as instruments to induce adequate behavior. Along this line, in the previous section we have showed that the availability of legal sanctions reduces the optimal reputational sanctions. This result emphasizes the substitution effects between both instruments, since this implies that legal liability may replace reputational sanctions preserving the level of incentives of the firm. In this section, we want to show the complementarity effects between legal liability and reputation. In certain scenarios, reputation alone would not be able to sustain trade, but introducing legal liability on top of the market sanctions makes trade feasible. Let's consider the range of parameters for which trade between the firm and the consumer can be sustained. Product liability makes it possible that market reputation allows cooperation to happen for a larger set of parameter values than market reputation alone would be able to induce in equilibrium. In other words, legal liability makes

16. Following Proposition 3, this is also true for $\lambda > \frac{1}{\delta}$.

reputation more successful in ensuring trade in markets, thus illustrating a complementarity effect of legal liability with respect to market reputation.

Proposition 4. (i) In the absence of legal liability, the trade equilibrium may arise only if $\delta \geqslant \delta^*_{min} = \frac{c}{P(1-\pi)}$. (ii) In presence of legal liability, the trade equilibrium may arise for a larger set of discount rates.

In the first part of Proposition 4, we characterize the minimum discount rate δ^*_{min} by assuming the maximum penalty $T^* = \infty$, and the fact that the incentive compatibility constraint should be binding, $\Psi(\infty, 0, 0) = c$. Concerning the second part of Proposition 4, it follows from the fact that in the presence of the legal liability the incentive compatibility constraint is no longer binding for δ^*_{min} and $T^* = \infty$.

6. Endogenous Prices

A natural extension to our basic analysis would endogenize product prices. We may allow for this complication in our framework by assuming that the firm enjoys full market power, as other related papers in the literature do, such as Baker and Choi (2013). More specifically, if we would give all bargaining power to the firm, it would set the price at the level in which the consumer is indifferent between participating in the market or not, that is, $P = V - \pi(1-\alpha)D$. Then, by simply replacing this price into the expressions in previous sections all our results holds.[17]

It seems interesting to consider the case in which limits to the market power of the monopolist (e.g., due to a potential entrant) exist. We can model this by assuming that the firm's profits are bounded. In particular, we assume that $V^+_R = k$, for all values of (α, β) including (0, 0) (no legal liability), where k is a measure of the market power of the firm, which may be related to the entry cost to the market or the competitive pressures on the firm.

Given the previous analysis and this bounded profit condition, the equilibrium price P^*_E and the optimal punishment T^*_E are going to be the solution to the following system of equations.

$$\begin{aligned} V^+_R(P, T, \alpha) &= k, \\ \Psi(P, T, \alpha, \beta) &= c. \end{aligned} \tag{7}$$

Notice that although we have introduced the dependence on (P, T), functions V^+_R and Ψ are the ones characterized in the previous section by equations (4) and (6).

17. This is immediate for all our results but for Lemma 2 in which the incentive compatibility constraint changes the way in which incentives depend on π, since P depends now also on π. In particular, in the proof of Lemma 2 we state the direct effect of π over incentives, $\frac{\partial\Phi(T^*,\pi)}{\partial\pi} < 0$, and we have to add $\frac{\partial\Phi(T^*,P-c)}{\partial P-c}\frac{\partial P-c}{\partial\pi}$. As $\frac{\partial\Phi(T^*,P-c)}{\partial P-c} > 0$ and $\frac{\partial P-c}{\partial\pi} < 0$. This new effect does not change the result.

In the following, we assume that the system above has a unique solution. This assumption is not innocuous. It is clear, for example, that if k is close to 0 (the firm does not have market power at all), we have the well-known non-equilibrium existence result of implicit contracts, since some rents are necessary for satisfying the incentive compatibility constraint. But for large enough k, the system of equations should have a unique solution. $V_R^+(P; T)$ is increasing in P and decreasing in T, implying that for every k, there is an increasing function $T_k(P)$ such that $V_R^+(P, T_k(P), \alpha) = k$ for all P. Similarly, $\Psi(P, T, \alpha, \beta) = c$ is increasing in both P and T, which implies that for every c, there is a decreasing function $T_c(P)$ such that $\Psi(P, T_c(P), \alpha, \beta) = c$ for all P. Then, for a pair (k, c) we may obtain an equilibrium price and an optimal punishment (P_E^*, T_E^*) such that $T_E^* = T_k(P_E^*) = T_c(P_E^*)$. This "supply" and "demand" equilibrium is illustrated in Figure 3.

Intuitive comparative statics can be derived using these $T_k(P)$ and $T_c(P)$ inverse functions. Consider that the market power of the firm increases to $k' > k$. This shifts upwards the profit inverse function, $T_{k'}(P) < T_k(P)$. If we keep the price fixed, higher profits involve lower punishment, and $T_c(P)$ does not change. Figure 4 shows that the new equilibrium is characterized by higher prices and lower reputational punishment. Intuitively, firms' rents and the cost of reputational punishment (the opportunity cost of no trade) increases, which in turn leads to lower reputational punishment in equilibrium.

In the same line, consider now that the cost of effort increases to $c' > c$. This moves upwards the incentive inverse function, $T_{c'}(P) > T_c(P)$. If we keep the price fixed, higher costs of effort involve higher reputational punishment, and $T_k(P)$ does not change. Figure 4 shows that the new equilibrium is characterized by higher prices and higher reputational punishment. Intuitively, higher costs make more difficult to satisfy the incentive compatibility constraint, than higher punishment is required. Finally, higher punishment must be compensated with higher equilibrium price for keeping constant the equilibrium price. Figure 5 illustrates these comparative statics exercises.

The formal characterization of the equilibrium can be obtained with the following procedure. We plug the expression of Ψ characterized by equation (6) into the incentives equation (7). Then we identify $V_R^+(P; T)$ and replacing it by k.

$$\Psi(P, T, \alpha, \beta) = c$$

$$(1-\pi)\delta\frac{(1-\delta^T)(P-c-\delta\pi\alpha D)}{1-(1-\pi)\delta-\pi\delta^{T+1}}+\delta D(\beta-\pi\alpha) = c$$

$$(1-\pi)\delta(1-\delta^T)V_R^+(P; T)+\delta D(\beta-\pi\alpha) = c$$

$$(1-\pi)\delta(1-\delta^T)k = c-\delta D(\beta-\pi\alpha).$$

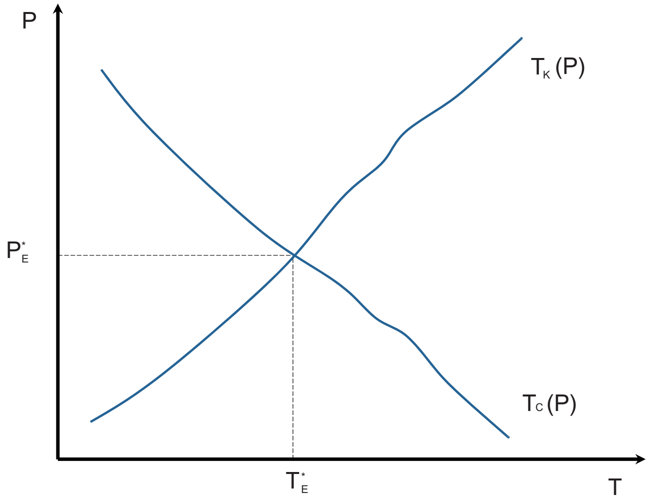

Figure 3. Equilibrium Price and Optimal Punishment.

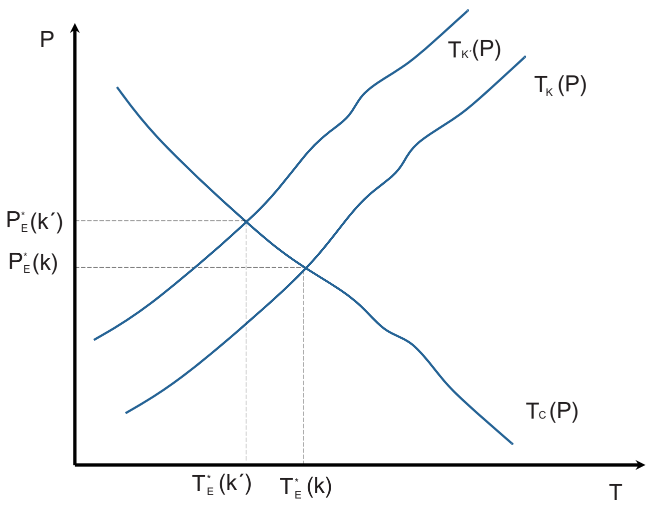

Figure 4. Equilibrium Price and Optimal Punishment with Increased Marked Power.

Thus, the optimal reputational punishment $T_E^*(\alpha, \beta)$ is defined by the equality

$$\delta^{T_E^*(\alpha,\beta)} = \delta - \frac{c - \delta D(\beta - \pi\alpha)}{k(1-\pi)}.$$

Using that the left side of the equality is decreasing in T_E^* and the right side is increasing in β and decreasing in α, we can characterize how the optimal punishment depends on β and α.

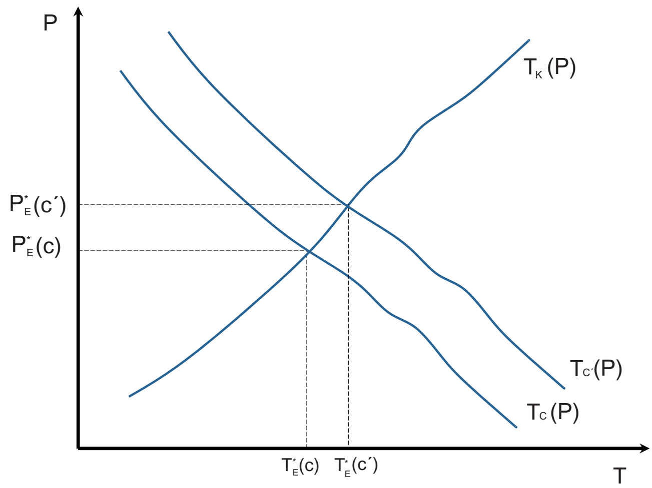

Figure 5. Equilibrium Price and Optimal Punishment with Increased Cost of Effort.

Proposition 5. (i) The optimal reputational punishment with endogenous prices, $T_E^*(\alpha, \beta)$, is decreasing in β and increasing in α. (ii) The optimal reputational punishment under any liability rule (α, β) is lower than without product liability law, that is, $T_E^*(\alpha, \beta) < T_E^*(0, 0)$.

Therefore, Proposition 5 shows that our main results are robust to the introduction of endogenous prices. In particular, it states that (i) the cost of reputation is decreasing in the probability of judicial errors, and (ii) the cost of reputation is lower when a tort system exists. We can also formalize the qualitative analysis undertaken above. T_E^* is increasing in π and c, and decreasing in D and k.

The next step is to characterize the equilibrium price by plugging the equilibrium punishment, T_E^*, into the profits constraint equation.

$$V_R^+(P^*;\, T_E^*(\alpha, \beta), \alpha) = k.$$

Proposition 6. (i)The equilibrium prices are increasing in α and decreasing in β, in other words, equilibrium prices are increasing in judicial errors. (ii) For every constellation of parameters, there is a cut-off $0 < \alpha^* \leqslant 1$, such that if $\alpha < \alpha^*$ the equilibrium price is lower with legal liability than without it.

Part (i) of Proposition 6 follows from the profit function V_R^+ decreasing in α and $T_E^*(\alpha, \beta)$, and the optimal reputational punishment $T_E^*(\alpha, \beta)$ increasing in α and decreasing in β. As profits remain constant, if the profit function increases (decreases), equilibrium price should decrease (increase). Part (ii) follows from the fact that the equilibrium price with $\alpha = 0$ is lower than the equilibrium price in the benchmark case without legal liability. This is because the firm does not incur any liability costs (in case of high effort) and $T_E^*(0,\beta) < T_E^*(0,0)$, which increases the profit function and leads to a lower equilibrium price. Finally, the equilibrium price increases in α and may or not be higher than the equilibrium price without liability depending on the level of harm, D.

7. The Legal System Provides Information to the Market

In previous sections we have not considered the possibility that consumers may observe the outcome of the tort process following an accident. If this were the case, the reputational sanction—the number of periods in which trade with the firm is discontinued—can be contingent, upon the liability findings of courts. In this section we introduce such a feedback from the legal system to the market.

There are various factors that may affect the plausibility of assuming the existence of a signal to the market stemming from the specific court outcomes of the cases involving the products of a given firm. The immediacy of lawsuits in the aftermath of a product-related accident, the length of legal proceedings, the availability of settlement between the firm and the plaintiffs in the suit and the confidentiality of the terms of settlement, the clarity of court's decisions concerning the allocation of liability, and the level of consumers' knowledge over the final decisions in the cases, and their content, all seem to influence the way in which a signal based on the outcome of particular court cases can influence the number of rounds of interrupted trade.

Formally, we define a new infinite horizon game in which the market sanctions may depend on court outcomes. Thus, in case of an accident, a punishment phase starts but the length of this punishment depends on the observed court's decision. Notice that punishing the firm in case of accident even if the firm is found not liable may be optimal, since courts can make both Type I and Type II errors. In particular, we have:

$$V_F^+ = P - c + (1-\pi)\delta V_F^+ + \pi\delta\alpha[V_{FL}^- - D] + \pi\delta(1-\alpha)V_{FNL}^-,$$

$$V_{FL}^- = \delta^{T_L} V_F^+,$$

$$V_{FNL}^- = \delta^{T_{NL}} V_F^+.$$

Solving the equation system, we obtain:

$$V_F^+ = \frac{P - c - \pi\delta\alpha D}{1-(1-\pi)\delta - \pi(\alpha\,\delta^{T_L+1} + (1-\alpha)\,\delta^{T_{NL}+1})},$$

Liability rules also affect the incentive compatibility constraint, so in order to express that the firm has no incentive to exert low effort, now we have:

$$V^+ \geqslant P + \delta[\beta[V_{FL}^- - D] + (1-\beta)V_{FNL}^-].$$

Following similar computations than in the previous sections, we obtain the incentive compatibility constraint under product liability as the inequality given by:

$$\Psi_F(T_L, T_{NL}, \alpha, \beta) \geqslant c,$$

where this new function is:

$$\Psi_F(T_L, T_{NL}, \alpha, \beta) = \frac{\left\{ \begin{array}{l} \delta[(1-\pi)+\pi(\alpha\delta^{T_L}+(1-\alpha)\delta^{T_{NL}}) \\ -(\beta\delta^{T_L}+(1-\beta)\delta^{T_{NL}})](P-c-\pi\delta\alpha D) \end{array} \right\}}{1-(1-\pi)\delta-\pi\delta(\alpha\delta^{T_L}+(1-\alpha)\delta^{T_{NL}})} + \delta D(\beta - \pi\alpha).$$

Notice that if $T_L = T_{NL} = T$ by construction, $\Psi_F(T, T, \alpha, \beta) = \Psi(T, \alpha, \beta)$ and $\Psi_F(T, 0, 1, 1) = \Psi(T, 1, 1)$.

We are interested in characterizing the optimal punishment with feedback from the tort process, which will be the solution to the following problem:

$$\max_{T_L, T_{NL}} V_F^+ = \frac{P-c-\pi\delta\alpha D}{1-(1-\pi)\delta-\pi\delta(\alpha\delta^{T_L}+(1-\alpha)\delta^{T_{NL}})}$$

subject to the incentive constraint:

$$\Psi_F(T_L, T_{NL}, \alpha, \beta) \geqslant c.$$

Then, we need to determine the optimal reputational punishment when the firm is liable, T_L, and when it is not, T_{NL}. In order to compare the solution to this problem (with two reputational punishment variables (T_L, T_{NL})) with the optimal reputational punishment in the previous framework with only one instrument T_R, we focus on the impact of the reputational punishment on the objective function. We say that (T_L, T_{NL}) generates lower expected punishment costs than T_R if $\alpha\delta^{T_L}+(1-\alpha)\delta^{T_{NL}} > \delta^{T_R}$. In fact, the solution to the problem is the pair (T_L^*, T_{NL}^*) that satisfies the incentive compatibility constraint and maximizes $\alpha\delta^{T_L^*}+(1-\alpha)\delta^{T_{NL}^*}$ (minimizes the expected punishment costs).

Proposition 7. (i) The optimal reputational punishment with feedback, (T_L^*, T_{NL}^*), targets the liable firm, minimizing the punishment when the firm is not liable. This implies that the optimal relational contract (T_L^*, T_{NL}^*) may have two formats: $(T_P^* = T, T_{NP}^* = \infty)$ or $(T_P^* = 0, T_{NP}^* = T)$. (ii) The optimal reputational punishment with feedback, (T_L^*, T_{NL}^*), generates lower expected punishment costs than without it, T_R^*, that is, $\alpha\delta^{T_L^*}+(1-\alpha)\delta^{T_{NL}^*} > \delta^{T_R^*}$.

Figure 6 illustrates the intuition of part (i) of Proposition 7.

The optimal reputational punishment (T_L^*, T_{NL}^*) is either $(T_P^*=T, T_{NP}^*=\infty)$ or $(T_P^* = 0, T_{NP}^* = T)$ since among all the points in the iso-curve $\alpha\delta^{T_L^*}+(1-\alpha)\delta^{T_{NL}^*} = U^*$, minimizing the reputational punishment when the firm is not liable, maximizes the expected punishment of the firm that does not exert effort, and this relaxes the incentive compatibility

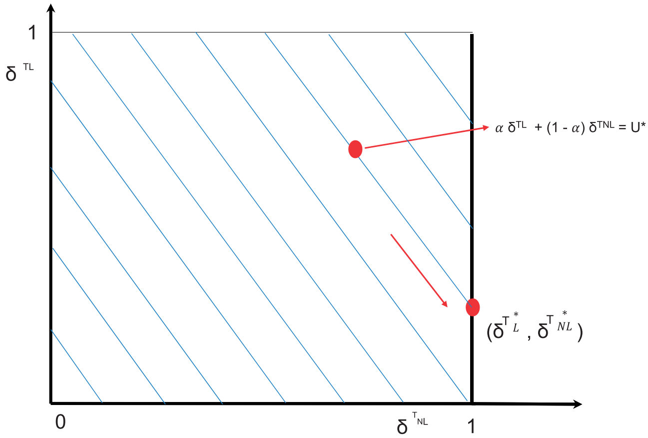

Figure 6. Optimal Reputational Punishment with Feedback from the Legal System.

constraint and maximizes $\alpha\delta^{T_L}+(1-\alpha)\delta^{T_{NL}}$. Part (ii) of Proposition 7 directly follows from the idea that the non-feedback equilibrium $T_L = T_{NL} = T_R^*$ is feasible but it is not the optimal solution.

Finally, the negative relationship between the performance of the liability system and judicial errors also holds when the market receives information from the tort process.

Proposition 8. The optimal reputational punishment with feedback, (T_L^*, T_{NL}^*) is increasing ($\alpha\delta^{T_L^*}+(1-\alpha)\delta^{T_{NL}^*}$ is decreasing) in judicial errors, decreasing in β, and increasing in α.

8. Conclusions

The law interferes in several ways with consumer markets, and in manufacturers/consumers interactions. One of the most important channels for this is the use of ex post legal sanctions. These sanctions are not cheap to design and to implement. Especially, product liability has received severe criticism for its high costs, among other failures (Polinsky and Shavell, 2010a; Viscusi, 2013). It is thus tempting to rely solely on market solutions, specially, on market reputation: consumers will take care of punishing the manufacturer by ceasing to buy its products for some time. Under this threat, manufacturers will be subject to the right incentives.

However, when there is imperfect information, that is, accidents and defects appear even if manufacturers have optimally invested in safety and quality, the provision of incentives implies in equilibrium the need to incur positive reputational costs. These costs constitute a social welfare loss incurred for the entire period in which consumers “punish” the manufacturer. This is a necessary cost of market reputation under imperfect information.

We have shown that the Law may improve matters by reducing reputational costs. If consumers know that market forces are not alone in providing incentives for manufacturers, the size and duration of the “market sanction” decreases. The law makes market forces cheaper to operate. Of course, some level of perception by consumers of the existence of legal mechanisms ex post “sanctioning” in case of accidents is necessary.

We have also shown that the features of the legal regime in place matters for the effect of legal sanctions on market sanctions. Errors—both Type I and Type II—by courts when imposing liability to manufacturers diminish the positive effect of legal sanctions on market sanctions. The same happens with more indiscriminate or less tailored liability regimes, such as strict liability.[18] Negligence, at least if the standards are properly determined, and the level of error in its functioning is limited, is a superior regime. The question of observability of this distinctive feature of negligence by consumers, who are the ones taking the decisions to impose market sanctions, is an important assumption, although public knowledge may probably be accurate enough to distinguish between strict liability and negligence-based liability.

We have tried the simplest setting that we were able to devise. Many complications are possible and would indeed be relevant for the effect of legal rules on consumer markets. We will just mention two of them. The market structure may have an impact on the effects of legal remedies, as it has been shown in the context of some legal remedies—rescission or termination of the contract if there is a defect.[19] Collective action problems among consumers and issues of litigation (from class actions to litigation fees and selection and compensation structures for lawyers[20]) have also been entirely set aside in our analysis, despite their undeniable importance. Still, we believe that the effects we have identified in this article may have a bearing upon policy debates concerning the desirability of legal liability and its design, taking into account the market forces that operate in consumer markets.

18. We consider only the incentive dimension of liability regimes, and not other possible and important properties, such as compensation. It is obvious that strict liability entails higher levels of expected compensation for the victims of product accidents or product defects, and thus consumers would react differently to strict liability and to negligence considering this dimension. Given that our interest lies only in the provision of incentives for manufacturers, we disregard this effect. It is as if we conceived strict liability decoupled into a rule for incentives to the potential injurer (here the manufacturer) and an insurance policy covering the victim’s harm. Our analysis refers only to the former.

19. Stremitzer (2012).

20. See Spier (2007).

Recently, a wave of Law and Economics papers has revisited the interaction of relational contracting with formal and binding contracts: Gilson, Sabel, and Scott (2009, 2010, 2013), Bozovic and Hadfield (2013), Baker and Choi (2014), and Gil and Zanarone (2014). They all informally illustrate the advantages that under certain scenarios firms may obtain when complementing their relational contracts with formal legal agreements. Our results may have implications for this interaction, since they suggest that formal contracts may add to the relational contracts by reducing the cost of implementing relational sanctions, and by sustaining advantageous interactions that reputation alone could not make to work. As in our setting, the importance of these effects would vary with the informational asymmetries, the stakes of the productive interaction, and the time horizon of the agents.

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Appendix A

Proof of Lemma 1. Let $\varphi(x) = \frac{1-x}{1-(1-\pi)\delta-\pi x\delta}$. Now, we have $\Phi(T) = (1-\pi)\delta\varphi(x(T))$, with $x(T) = \delta^T$. Applying the change rule, $\Phi(T)' = (1-\pi)\delta\varphi'(x(T))x'(T)$. As $x(T)$ is decreasing ($x'(T) = \delta^T ln\delta < 0$), in order to show that Φ is increasing in T, we have to show that $\varphi(x)$ is decreasing in x, $\varphi(x)' = \frac{-(1-\delta)}{(1-(1-\pi)\delta-\pi x\delta)^2} < 0$. This concludes the proof.

Proof of Lemma 2. We write the binding incentive compatibility condition that characterizes the optimal punishments as follows, $\Phi(T^*(a), a) - c = 0$, where $a \in \{\pi, \delta, P-C\}$. By the implicit function theorem we obtain $T^{*\prime}(a) = -\frac{\frac{\partial\Phi(T^*,a)}{\partial a}}{\frac{\partial\Phi(T^*,a)}{\partial T^*}}$. Given that for Lemma 1 $\frac{\partial\Phi(T^*,a)}{\partial T^*} > 0$, the sign$\{T^{*\prime}(a)\} = -$sign$\{a\}$. Given that, (i) $\frac{\partial\Phi(T^*,P-c)}{\partial P-c} = (1-\pi)\delta\frac{(1-\delta^T)}{1-(1-\pi)\delta-\pi\delta^{T+1}} > 0$ and $\frac{\partial T^*}{\partial P-c} < 0$. (ii) $\frac{\partial\Phi(T^*,\pi)}{\partial\pi} = (P-c)(1-\delta^T)\delta[\frac{-(1-(1-\pi)\delta-\pi\delta^{T+1})-(1-\pi)(\delta-\delta^{T+1})}{(1-(1-\pi)\delta-\pi\delta^{T+1})^2}] < 0$ and $\frac{\partial T^*}{\partial\pi} > 0$.

Finally,

$$\frac{\partial\Phi(T^*,\delta)}{\partial\delta} = (P-c)(1-\pi)$$

$$\left[\frac{(1-(T+1)\delta^T)\left(1-(1-\pi)\delta-\pi\delta^{T+1}\right)+(\delta-\delta^{T+1})((1-\pi)+\pi(T+1)\delta^T)}{\left(1-(1-\pi)\delta-\pi\delta^{T+1}\right)^2}\right]$$

$$= (P-c)(1-\pi)\left[\frac{(1-\delta^{T+1}-(T+1)\delta^T+(T+1)\delta^{T+1})}{\left(1-(1-\pi)\delta-\pi\delta^{T+1}\right)^2}\right]$$

$$= (P-c)(1-\pi)\left[\frac{(1-(T+1)\delta^T+T\delta^{T+1})}{\left(1-(1-\pi)\delta-\pi\delta^{T+1}\right)^2}\right] > 0,$$

where the sign positive comes from the fact that $1-(T+1)\delta^T+T\delta^{T+1}$ is strictly decreasing and 0, when $\delta=1$, therefore for all $\delta<1$, the expression is positive. Then, $\frac{\partial\Phi(T^*,\delta)}{\partial\delta}>0$ and $\frac{\partial T^*}{\partial\delta}<0$.

Proof of Lemma 3. Calculating the partial derivatives of the function Ψ we obtain:

$$\frac{\partial\Psi}{\partial\beta} = \delta D > 0,$$

$$\frac{\partial\Psi}{\partial\alpha} = \frac{(1-\pi)\delta(1-\delta^T)(-\delta\pi D)}{1-(1-\pi)\delta-\pi\delta^{T+1}} - \delta D\pi < 0,$$

where the last inequality is due to the negative numerator and positive denominator of the first term. Finally, to show Ψ is increasing in T, it suffices to remind the fact that $\Phi(T)$ is increasing in T and both functions depend on T in the same way. ■

Proof of Proposition 1. By the implicit function theorem and the definition of T_R^*, $\Psi(T_R^*,\alpha,\beta)=c$, we obtain $\frac{\partial T_R^*}{\partial\alpha} = -\frac{\frac{\partial\Psi}{\partial\alpha}}{\frac{\partial\Psi}{\partial T_R^*}} = -\frac{\le 0}{>0} > 0$. Similarly, $\frac{\partial T_R^*}{\partial\beta} = -\frac{\frac{\partial\Psi}{\partial\beta}}{\frac{\partial\Psi}{\partial T_R^*}} = -\frac{\ge 0}{>0} < 0$. ■

Proof of Corollary 1. The result follows directly from part (i) of Proposition 1, since $\frac{\partial T_R^*}{\partial\alpha}>0$. ■

Proof of Corollary 2. The result follows directly from Proposition 1. ■

Proof of Proposition 2. It suffices to compute Ψ for a particular pair of liability parameters $(\alpha,\beta)\neq(0,0)$ and no liability, and given the restrictions on the parameters of the model, it can be shown that:

$$\Psi(T,\alpha,\beta) > \Psi(T,0,0).$$

This inequality follows from substituting the particular cases considered. First, incentive compatibility constraint under (α,β) takes the form:

$$(1-\pi)\delta\frac{(1-\delta^T)(P-c-\delta\pi\alpha D)}{1-(1-\pi)\delta-\pi\delta^{T+1}}+\delta D(\beta-\pi\alpha)\geqslant c.$$

On the other hand, incentive compatibility constraint according to the case of no liability takes the form:

$$\delta(1-\pi)\frac{(P-c)(1-\delta^T)}{1-(1-\pi)\delta-\pi\delta^{T+1}}\geqslant c.$$

Thus, we need to know which of both left sides of the inequalities above is greater. Comparing both expressions we find:

$$\Psi(T,\alpha,\beta)=\Psi(T,0,0)-\frac{\delta(1-\pi)\delta\pi\alpha D(1-\delta^T)}{1-\delta(1-\pi)-\pi\delta^{T+1}}+\delta D(\beta-\pi\alpha).$$

Then our objective is equivalent to show

$$(1-\pi)\delta\frac{(1-\delta^T)\delta\pi\alpha D}{1-(1-\pi)\delta-\pi\delta^{T+1}} < \delta D(\beta-\pi\alpha)$$

$$(1-\pi)\delta(1-\delta^T)\,\delta\pi\alpha D < \delta D(\beta-\pi\alpha)(1-(1-\pi)\delta-\pi\delta^{T+1})$$

$$(\delta-\pi\delta-\delta^{T+1}+\pi\delta^{T+1}+1-(1-\pi)\delta-\pi\delta^{T+1})\,\pi\alpha < \beta(1-(1-\pi)\delta-\pi\delta^{T+1})$$

$$(1-\delta^{T+1})\pi\alpha < \beta(1-(1-\pi)\delta-\pi\delta^{T+1})$$

$$-\pi\delta^{T+1}+\pi < 1-\delta+\pi\delta-\pi\delta^{T+1}$$

$$(1-\pi)\delta < 1-\pi.$$

Finally, from this result we conclude that:

$$T_R^*(\alpha,\beta) < T_R^*(0,0).$$ ■

Proof of Proposition 3. Let $\Psi_M(T_R^*,\alpha,\beta,\lambda)=c$ be the new incentive compatibility with damages multipliers, where

$$\Psi_{DM}(T_R^*,\alpha,\beta,\lambda)=(1-\pi)\delta\frac{(1-\delta^T)(P-c-\delta\pi\alpha\lambda D)}{1-(1-\pi)\delta-\pi\delta^{T+1}}+\delta\lambda D(\beta-\pi\alpha).$$

We compute the partial derivative with respect to the damages multiplier λ.

$$\begin{aligned}\frac{\partial \Psi_{DM}}{\partial \lambda} &= -\frac{(1-\pi)\delta(1-\delta^{T})\delta\pi\alpha D}{1-(1-\pi)\delta-\pi\delta^{T+1}}+\delta D(\beta-\pi\alpha) \\ &= \frac{-(1-\pi)\delta(1-\delta^{T})\delta\pi\alpha D+\delta D(\beta-\pi\alpha)(1-(1-\pi)\delta-\pi\delta^{T+1})}{1-(1-\pi)\delta-\pi\delta^{T+1}} \\ &= \frac{\delta\beta D(1-(1-\pi)\delta-\pi\delta^{T+1})-\delta\alpha D\pi(1-\delta^{T+1})}{1-(1-\pi)\delta-\pi\delta^{T+1}} \\ &= \frac{\delta\beta D(1-\pi)(1-\delta)+\delta D(\beta-\alpha)\pi(1-\delta^{T+1})}{1-(1-\pi)\delta-\pi\delta^{T+1}} > 0.\end{aligned}$$

Finally, by the implicit function theorem and the definition of T_R^*, $\Psi_{DM}(T_R^*, \alpha, \beta, \lambda) = c$, we obtain $\frac{\partial T_R^*}{\partial \lambda} = -\frac{\frac{\partial \Psi_{DM}}{\partial \lambda}}{\frac{\partial \Psi_{DM}}{\partial T_R^*}} = -\frac{\geq 0}{>0} < 0.$ ■

Proof of Proposition 4. (i) Given Lemma 2, the minimum discount rate $\delta^*_{\min}$ is associated to the maximum penalty $T^* = \infty$. Then, the incentive compatibility constraint, $\Phi(T) = c$ (which should be binding for δ^*_{min}) simplifies to

$$(1-\pi)\delta^*_{\min}\frac{(P-c)}{1-(1-\pi)\delta^*_{\min}} = c$$

$$\delta^*_{\min} = \frac{c}{P(1-\pi)}.$$

For lower discount rates of $\delta^*_{\min}$ the incentive compatibility constraint cannot be satisfied. (ii) The proof of Proposition 2 shows that for any pair of liability parameters $(\alpha, \beta) \neq (0, 0)$, $\Psi(T, \alpha, \beta) > \Psi(T, 0, 0)$. Then for all $\delta \geqslant \delta^*_{\min}$, the incentive compatibility constraint is satisfied for the maximum punishment and it is not binding, $\Psi(\infty, \alpha, \beta) > c$. Therefore, trade may arise in equilibrium if $\delta \geqslant \delta^*_{\min}$ and for continuity of $\Psi(\infty, \alpha, \beta)$ in δ, the incentive compatibility should be satisfied for values of δ strictly lower than $\delta^*_{\min}$. ■

Proof of Proposition 5. The optimal reputational punishment with endogenous prices $T_E^*(\alpha, \beta)$ is defined by the equality

$$\delta^{T_E^*(\alpha,\beta)} = \delta - \frac{c-\delta D(\beta-\pi\alpha)}{k(1-\pi)}.$$

As the left side of the equality is decreasing on T_E^* and the right side is increasing on β and decreasing on α, then $T_E^*(\alpha, \beta)$, is decreasing in β and increasing in α. Finally, as $\delta D(\beta - \pi\alpha) \geqslant 0$, for the same argument, $T_E^*(\alpha, \beta) < T_E^*(0, 0)$, since

$$\delta - \frac{c}{k(1-\pi)} < \delta - \frac{c - \delta D(\beta - \pi\alpha)}{k(1-\pi)}. \qquad \blacksquare$$

Proof of Proposition 6. (i) We plug the optimal reputational punishment $T_E^*(\alpha, \beta)$ into the profits equation.

$$V_R^+(P^*; T_E^*(\alpha, \beta), \alpha) = k.$$

Then, increasing α increases the price, $\frac{\partial P_E^*}{\partial \alpha} = -\frac{\frac{\partial V_R^+}{\partial \alpha}}{\frac{\partial V_R^+}{\partial P_E^*}} = -\frac{\leq 0}{>0} > 0,$

because the profit function V_R^+ is decreasing in α

$$\frac{\mathrm{d}V_R^+}{\mathrm{d}\alpha} = \frac{\partial V_R^+}{\partial \alpha} + \frac{\partial V_R^+}{\partial T_E^*}\frac{\partial T_E^*}{\partial \alpha} < 0$$

since $\frac{\partial V_R^+}{\partial \alpha} < 0$, $\frac{\partial V_R^+}{\partial T_E^*} < 0$, and $\frac{\partial T_E^*}{\partial \alpha} > 0$.

For the same taken, we can show that increasing β decreases the price, $\frac{\partial P_E^*}{\partial \beta} = -\frac{\frac{\partial V_R^+}{\partial \beta}}{\frac{\partial V_R^+}{\partial P_E^*}} = -\frac{\geq 0}{>0} < 0$, because the profit function V_R^+ is increasing in β, $\frac{\partial V_R^+}{\partial \beta} = \frac{\partial V_R^+}{\partial T_E^*}\frac{\partial T_E^*}{\partial \beta} > 0$. (ii) See the arguments provided in the main text. ■

Proof of Proposition 7. (i) We rewrite the incentive compatibility constraint.

$$\frac{\begin{array}{c}\left[\delta[(1-\pi)(1-(\alpha\delta^{T_L}+(1-\alpha)\delta^{T_{NL}}))\right.\\ \left.+(\beta-\alpha)(\delta^{T_{NL}}-\delta^{T_L})](P-c-\pi\delta\alpha D)\right]\end{array}}{1-(1-\pi)\delta-\pi\delta(\alpha\delta^{T_L}+(1-\alpha)\delta^{T_{NL}})} + \delta D(\beta-\pi\alpha) \geqslant c.$$

Consider the following change of variable $U = \alpha\delta^{T_L} + (1-\alpha)\delta^{T_{NL}}$, which implies $\delta^{T_L} = \frac{U}{\alpha} - \frac{(1-\alpha)}{\alpha}\delta^{T_{NL}}$, and then $\delta^{T_{NL}} - \delta^{T_L} = \frac{\delta^{T_{NL}}}{\alpha} - \frac{U}{\alpha}$.

$$\frac{\delta\left[(1-\pi)(1-U)+(\beta-\alpha)\left(\frac{\delta^{T_{NL}}}{\alpha}-\frac{U}{\alpha}\right)\right](P-c-\pi\delta\alpha D)}{1-(1-\pi)\delta-\pi\delta U} + \delta D(\beta-\pi\alpha) \geqslant c$$

$$\frac{\left[(1-\pi)(1-U)+(\beta-\alpha)\left(\frac{\delta^{T_{NL}}}{\alpha}-\frac{U}{\alpha}\right)\right]}{1-(1-\pi)\delta-\pi\delta U} \geqslant \frac{c-\delta D(\beta-\pi\alpha)}{\delta(P-c-\pi\delta\alpha D)}.$$

Let $\chi(x) = \frac{\left[(1-\pi)(1-x)+(\beta-\alpha)\left(\frac{\delta^{T_{NL}}}{\alpha}-\frac{x}{\alpha}\right)\right]}{1-(1-\pi)\delta-\pi\delta x}$. Now, we want to show that $\chi(x)$ is decreasing in x.

$$\chi'(x) = \frac{-((1-\pi)+\frac{(\beta-\alpha)}{\alpha})(1-(1-\pi)\delta-\pi x\delta) - \left[(1-\pi)(1-x)+(\beta-\alpha)(\frac{\delta^{T_{NL}}}{\alpha}-\frac{x}{\alpha})\right](-\pi\delta)}{(1-(1-\pi)\delta-\pi x\delta)^2}$$

$$\chi'(x) = \frac{-(1-\pi)[(1-(1-\pi)\delta-\pi x\delta-(1-x)\pi\delta] - \frac{(\beta-\alpha)}{\alpha}[(1-(1-\pi)\delta-\pi x\delta-\pi\delta^{T_{NL}+1}+\pi\delta x)]}{(1-(1-\pi)\delta-\pi x\delta)^2}$$

$$\chi'(x) = \frac{-(1-\pi)(1-\delta) - \frac{(\beta-\alpha)}{\alpha}[1-(1-\pi)\delta-\pi\delta^{T_{NL}+1}]}{(1-(1-\pi)\delta-\pi x\delta)^2} \leqslant 0.$$

As the optimal reputational punishment policy is characterized by the maximum $U = \alpha\delta^{T_L}+(1-\alpha)\delta^{T_{NL}}$ that satisfied the incentive compatibility constraint, and $\chi(x)$ is decreasing, this implies that incentive compatibility constraint must be binding.

Then

$$\frac{\left[(1-\pi)(1-U^*)+(\beta-\alpha)(\frac{\delta^{T_{NL}}}{\alpha}-\frac{U^*}{\alpha})\right]}{1-(1-\pi)\delta-\pi\delta U^*} = \frac{c-\delta D(\beta-\pi\alpha)}{\delta(P-c-\pi\delta\alpha D)}.$$

As the left-hand side of the equality is decreasing in U^*, and increasing in $\delta^{T_{NL}}$, this implies that $\frac{\partial U^*}{\partial\delta^{T_{NL}}} > 0$. Then, the optimal policy requires to maximize $\delta^{T_{NL}}$ (minimize T_{NL}). This implies that in the optimal solution, $T_L^* \neq \infty \rightarrow T_{NL}^* = 0$, or alternatively $T_{NL}^* \neq 0 \rightarrow T_L^* = \infty$. Hence, $(T_{NL}^*, T_L^*) \in \{0, T) \cup \{T, \infty)\}$.

(ii) The proof that the optimal punishment with feedback, (T_L^*, T_{NL}^*), generates lower expected punishment cost than without it, T_R^*, that is, $U^* = \alpha\delta^{T_L^*}+(1-\alpha)\delta^{T_{NL}^*} > \delta^{T_R^*}$, it is just to notice that $T_L = T_{NL} = T_R^*$ was feasible and it is not optimal. This is on the other hand easy to verify by comparing the two binding incentive compatibility constraints.

$$\frac{(1-\pi)(1-U^*)}{1-(1-\pi)\delta-\pi\delta U^*} = \frac{c-\delta D(\beta-\pi\alpha)}{\delta(P-c-\pi\delta\alpha D)} - \frac{(\beta-\alpha)(\frac{\delta^{T_{NL}}}{\alpha}-\frac{U^*}{\alpha})}{1-(1-\pi)\delta-\pi\delta U^*}. \quad (A1)$$

$$\frac{(1-\pi)(1-\delta^{T_R^*})}{1-(1-\pi)\delta-\pi\delta^{T_R^*}} = \frac{c-\delta D(\beta-\pi\alpha)}{\delta(P-c-\pi\delta\alpha D)}. \quad (A2)$$

Notice that the left side of both equalities is the same and it is a decreasing function of $U^*$and $\delta^{T_R^*}$. The right-hand side of the first equality (A1) is lower (the second term is negative) than the right side of equation (A2) and this implies that $U^* = \alpha\delta^{T_L^*}+(1-\alpha)\delta^{T_{NL}^*} > \delta^{T_R^*}$. ■

Proof of Proposition 8. Following the same arguments than in (ii) in Proposition 1, the proof follows from the fact that the right-hand side of the equality (A1) above is decreasing in β and increasing in α. ■

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