Tort Reform, Public Harm, and Welfare

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Abstract: A surprising array of US manufacturers enjoy broad immunity from tort liability for public harm. We examine the consequences of such immunity with a model of buyer and manufacturer care-taking in a market relationship that features incomplete liability assignment and a probability that the representative manufacturer could lose its immunity as the public grows frustrated with increasing public harm. We refer to this combination of features as 'contingent incomplete liability'. We find that reduced manufacturer liability can lead to less harmful products only under very restrictive conditions; and even when these are met, reduced manufacturer liability in competitive markets leads to lower expected social welfare. Under imperfect competition, expected social welfare may rise in limited circumstances. Regardless of market structure, tort reform favors market participants but only by pushing spillover costs to the public. This stark redistribution of welfare from public to private parties is undoubtedly at the heart of public objections to tort reform.

Key Words: Tort reform, liability, public harm, judgment-proof

JEL Codes: K13 (Tort law and product liability); D81 (Decision making under risk and/or uncertainty)

1 Introduction

A surprisingly diverse array of US producers enjoy broad immunity from tort liability for public harm vis-à-vis versions of tort reform. For instance, the federal Protection of Lawful Commerce in Arms Act (PLCAA) of 2005 grants the firearms industry immunity from liability for crimes committed with its products. Software manufacturers are generally insulated from products liability (for example, for data security breaches) but public harm accrues when corporate software failures enable data theft and the misuse of data such as social security numbers (see Barnes (2004), Hahn and Layne-Farrar (2006), and Beard et al. (2009) for discussion). Internet service and social media providers are immune from liability for the distribution of worms, viruses, other malicious code, and objectionable content, respectively, on their platforms via sections of the federal Communications Decency Act of 1996 and of the Digital Millennium Copyright Act of 1998. Public harm arises in this context from the spread of misinformation and general network instability (see, for example, Lichtman and Posner (2006) and Katzmann (2019)). And the fast food and sugar-sweetened beverage industries are immunized from liability for private and public health damages by state-level tort reforms known as commonsense consumption acts (CCAs) in 26 US states.[1,2]

Such immunity arose primarily on the perception that these manufacturers are not reasonably culpable for harm (and culpability is necessary though not sufficient for a finding of liability). Advocates for tort reform generally maintain that shifting culpability for harm from manufacturers to the buyers of their products, and relying on the fact that manufacturers and buyers are in a disciplining market relationship, can reduce risks and, by implication, raise social welfare.[3] We investigate these claims theoretically with a model of care-taking to reduce expected public harm by both buyers and producers in perfectly and imperfectly competitive market relationships.

The related theoretical literature includes Wittman (1981), Miceli et al. (2001), Hay and Spier (2005), Daughety and Reinganum (2006), and De Geest (2012). Hay and Spier (2005)—HS, henceforth—features several elements we believe we need in order to analyze relatively unexplored tensions in tort reform that run through the aforementioned industries: (1) bilateral care taken sequentially by a representative manufacturer and buyer in a market relationship; (2) public harm that is generated by the use of a product; and (3) a buyer that may be judgment-proof.[4] We

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[1]See Carpenter and Tello-Trillo (2015) and Pomeranz et al. (2019)) on CCAs, particularly with respect to fast food. See Allcott et al. (2019) on sugar-sweetened beverages. Note that public harm in these contexts comprises private health care costs that are passed on to public insurance funds.

[2]Most recently the U.S. Congress is considering bills that would grant firms broad immunity from Covid-19 related lawsuits by consumers and employees, and there is vigorous public debate–indeed, protests across the nation–regarding the qualified immunity from liability for public harm enjoyed by public employees such as police officers. Our work does not apply directly to these contexts but could with suitable modification.

[3]See Rubin and Shepherd (2007), Polinsky and Shavell (2009) and Hylton (2012) for comprehensive discussions of tort liability and tort reform as policy instruments.

[4]The next-best fit of modeling elements with the scope of our analysis is Daughety and Reinganum (2006); how-

extend the HS framework by incorporating the contribution in Daughety and Reinganum (2006) that public harm may be uncompensated for various reasons (in other words, that liability shares may not be completely assigned) and by adding two elements to this line of inquiry that appear to be overlooked: a manufacturer granted immunity from liability may nevertheless face a probability greater than zero that its immunity could be reversed, and this probability could be endogenous to the manufacturer's observable care. We refer to the combination of incomplete liability and a probability that all liability shifts to a manufacturer that may depend on its choice of care as 'contingent incomplete liability'.

The rationales for investigating theoretically how these three factors interact to affect care-taking, public harm, and welfare are as follows. First, incomplete liability shares could result from shifting liability from manufacturers to buyers that are partially or completely judgment-proof, but liability share incompleteness could also result from other factors including legal errors, high litigation and settlement costs, 'scientific gerrymandering' as described by Edwards et al. (2021), and imperfect information amongst members of the harmed public as to their rights to bring suit against buyers. Second, a manufacturer could lose its immunity with positive probability as the public, through its legislatures/courts, grows frustrated with public harm. There is evidence that liability shares are indeed socially contingent and therefore subject to change—and sometimes abruptly. For example, Currie and MacLeod (2008, 801) describe how some state medical malpractice tort law reforms were repealed by legislatures or ruled unconstitutional by courts. Some legal commentators (for example, Siebel (2004) and Sonner (2013)), suggest that federal laws that currently shield the firearms industry from liability for crimes committed with their products are not iron-clad but rather socially contingent. Regarding software, Kim (2017), Chagal-Feferkorn (2019), and Choi (2019) suggest that manufacturers in information-rich industries such as autonomous vehicle production are increasingly aware that their culpability for private and public harm from software failures is vulnerable to legislative and/or judicial revision. Gaillard and Waibel (2018) describe how US credit rating agencies have lost their near-immunity from liability, beginning in the post-WWII era and accelerating following the Financial Crisis of 2008.

Third, in our model the probability that the manufacturer loses its immunity could be increasing in its observable care—if increasing care may be construed as an admission of culpability or a duty of care—or decreasing in its observable care, if society perceives that efforts to make products safer justify continued immunity. For instance, Wagner (1996) and Dana (2010) caution that a manufacturer's liability could increase if it undertakes product testing and discloses (that is, makes observable to potential plaintiffs and the courts) the care it has taken and the safety issues such

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ever, their model features unilateral care-taking by manufacturers only, whereas our focus is upon the phenomenon of granting conditional immunity to manufacturers when both manufacturers and buyers can take care within a market relationship and face incomplete shares of the liability for public harm.

testing revealed. Wagner (1996) writes at p. 775: "The failure of the common-law courts to provide manufacturers with reliable immunity after the manufacturer has conducted an exemplary safety testing program exacerbates the self-incriminatory effect of voluntary safety research." And Dana (2010) writes at p. 158: "The lower the perceived probability of detection without manufacturer research and the more the applicable liability standard veers toward requiring actual knowledge of risks on the part of the manufacturer, the more likely it is that the ex ante threat of liability will lead a manufacturer to choose not to conduct research into possible adverse effects, either before the product is marketed or once it is on the market." In a different context, the US Department of Interior is currently immune from liability for any public harm that arises from the reintroduction of large mammalian carnivores such as wolves to their native habitats under the Endangered Species Act. While locally affected parties such as ranchers are able to take some care to keep sheep and cattle away from wolves, Interior realizes that taking some care of its own is important for maintaining public support for the law. However, Doremus (1999, 57) cautions that Interior taking clearly observable care such as radio-collaring and fencing could provoke a court to find that in fact Interior is culpable for public harm and to revise if not fully reverse the initial granting of immunity. The model developed in the present study shows how this real-world possibility of immunity reversal suggested by Doremus and others affects bi-lateral care-taking in more general settings; we then examine the consequent levels of public harm and social welfare.

Our results have important implications concerning the market, distributional, and efficiency consequences of tort reform. First, we examine how contingent incomplete liability distorts private and social costs, output levels and expected welfare. We then examine how tort reforms that change the incomplete liability shares via a reduction in manufacturer liability affects product safety. As per a stated goal of tort reform, we find it is possible for product safety to improve as the manufacturer's share of liability for public harm falls; however, the conditions under which this obtains appear to be relatively strict. In particular, buyer and manufacturer care choices must be sufficiently strong strategic substitutes, there is some probability that all liability shifts to the manufacturer, and this probability must be strictly increasing in its care choice to a sufficient degree. If either of these conditions fail to hold, reducing manufacturer liability for public harm leads to less safe products. Regardless of whether reducing the manufacturer's liability share leads to more or less product safety, we demonstrate that even as market participants are better off with tort reform, expected harm borne by the public strictly increases. Moreover, expected social welfare strictly declines with reduced manufacturer liability for public harm in competitive product markets. This effect may not hold in imperfectly competitive markets; lower output from market power is to some degree offset by tort reform's propensity to raise output. In fact, we show that given contingent incomplete liability, expected social welfare under imperfect competition may be higher than under perfect competition. In addition, tort reform under imperfect competition and

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contingent incomplete liability can, under limited circumstances, increase expected social welfare. However, regardless of market structure, such reforms favor market participants by burdening the public with a greater amount of harm.

2   Model fundamentals

As in HS (2005), we consider a representative manufacturer, m, and a representative buyer, b, in a market for a good with consumption that can cause public harm for which the manufacturer or buyer or some combination of them could be found culpable and liable.[5] Both parties are risk-neutral. The marginal cost of producing and selling q units to the buyer is normalized to zero. The buyer has a quasi-linear utility function

$$U(q,z) = \int_0^q P(z)dz + y, \tag{1}$$

where $P(q)$ is the buyer's strictly declining marginal benefit for units of the good and y is a numeraire commodity with price equal to one. Both the manufacturer and the buyer take observable care, x^m and x^b, respectively, per unit of q to reduce expected harm, $H(x^m, x^b)$, per unit. The expected harm function is strictly convex. The sign of $\partial^2 H/\partial x^m \partial x^b$ depends upon whether manufacturer care and buyer care are substitutes or complements. In particular, $\partial^2 H/\partial x^m \partial x^b$ is positive (negative) when care types are substitutes (complements), as the marginal harm avoided decreases (increases) as the other care type increases (see, for example, Bartsch (1997)).[6] The marginal cost of care taken by either party is one.

Under these conditions the social welfare function is

$$SW(q, x^m, x^b) = \int_0^q [P(z) - H(x^m, x^b) - x^m - x^b]dz. \tag{2}$$

The first-best levels of quantity, q^*, and care, x^{m*} and x^{b*}, maximize (2). The assumptions that $P(q)$ is strictly decreasing and $H(x^m, x^b)$ is strictly convex guarantee that these levels are unique. In addition, we assume strictly positive amounts of the choice variables throughout our work. Under our assumptions, the first-best care levels minimize the expected per-unit social costs of the product and the level of output equates the consumer's marginal benefit of consuming the good to minimum expected per-unit social costs. Note that as Daughety and Reinganum (2006) describe, when expected harm is proportional to the consumer's use of the product as modeled here, per-unit

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[5]We (and HS) abstract from the possibility that consumption also causes private harm; we assume that the consumer's marginal benefit is net of expected private harm.

[6]Our assumption that $H(x^m, x^b)$ is strictly convex precludes functions of the form $H(x^m + x^b)$ for which x^m and x^b are perfect substitutes in reducing expected harm.

care choices are independent of the level of output.

We characterize the equilibrium levels of manufacturer care, buyer care and output under strict liability rules that assign liability for public harm to the buyer up to the level of their financial assets, with some residual liability assigned to the manufacturer. Thus, assume a strict liability rule for which the buyer is liable for and has assets to pay a percentage $\delta^b \in [0,1]$ of harm and the manufacturer is liable for and has assets to pay the percentage of harm $\delta^m \in [0,1]$. We add to the HS framework three real-world possibilities, and refer to their combination as contingent incomplete liability. First, as Daughety and Reinganum (2006) argue, liability may not be completely assigned; so we allow $\delta^m + \delta^b \leq 1$. Second, we consider the possibility that society may for various reasons grant partial or complete immunity from liability to manufacturers vis-à-vis tort reform but may also reconsider a manufacturer's initial immunity to civil liability lawsuits. Hence, suppose that there is some probability that liability shifts entirely to the manufacturer (effectively, $\delta^b = 0$ and $\delta^m = 1$). Third, this probability may depend on the manufacturer's choice of care. In our analysis this probability is weakly positive but it is strictly less than one. Let $\rho(x^m) \in [0,1)$ denote the probability that all liability shifts to the manufacturer.[7]

The timing in the model is as follows. The manufacturer moves first with its care choice. Then, the buyer observes the manufacturer's care choice and simultaneously chooses the number of units of the good to purchase and their own choice of care. Liability is assigned in the final stage; either $\delta^m \geq 0, \delta^b > 0, \delta^m + \delta^b \leq 1$ with probability $1 - \rho(x^m)$, or $\delta^m = 1, \delta^b = 0$ with probability $\rho(x^m)$.

Under the conditions of our model the representative buyer's budget constraint is

$$w = \left[H(x^m, x^b)\delta^b(1 - \rho(x^m)) + x^b + p \right] q + y, \tag{3}$$

where w is the consumer's wealth and p is the endogenous equilibrium price of q. Moreover, the manufacturer's expected profit is

$$B(q, x^m) = \left[p - H(x^m, x^b)(\delta^m + (1 - \delta^m)\rho(x^m)) - x^m \right] q. \tag{4}$$

Most of our analysis assumes that the representative manufacturer is perfectly competitive, although we examine the implications of imperfect product market competition later. In our first proposition we characterize the competitive equilibrium levels of care and output. Since the proposition is straightforward and only slightly modified from HS, we have placed its proof in the appendix.

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[7]We can envision $\rho(x^m)$ as the product of (1) the probability that a manufacturer's care will be so great as to trigger a finding of culpability or a duty of care and (2), conditional on (1), the probability that a manufacturer's care will be judged robust enough to warrant keeping its immunity from liability intact. Hence, $p'(x^m)$ can be positive if is not clear that the manufacturer has a duty of care and negative when the manufacturer knows it has a duty of care, and therefore taking more care can reduce $\rho(x^m)$.

Proposition 1: Let the competitive equilibrium levels of care and output be $(\widehat{x}^m, \widehat{x}^b, \widehat{q})$. These values are characterized by the following equations:

$$\widehat{x}^b = argmin_{x^b} H(x^m, x^b) \delta^b (1 - \rho(x^m)) + x^b; \tag{5}$$

$$\widehat{x}^m = argmin_{x^m} H(x^m, \widehat{x}^b) \left(\delta^m + \delta^b + (1 - \delta^m - \delta^b)\rho(x^m) \right) + x^m + \widehat{x}^b; \tag{6}$$

$$P(\widehat{q}) = H(\widehat{x}^m, \widehat{x}^b) \left(\delta^m + \delta^b + (1 - \delta^m - \delta^b)\rho(\widehat{x}^m) \right) + \widehat{x}^m + \widehat{x}^b. \tag{7}$$

We assume throughout that the equilibrium choices of care and output, $(\widehat{x}^m, \widehat{x}^b, \widehat{q})$, are unique. In (5), $H(x^m, x^b)\delta^b(1 - \rho(x^m))$ is the buyer's expected liability for harm per unit of consumption. With probability $\rho(x^m)$ the buyer's expected liability for harm is zero. Thus, the buyer's equilibrium care choice, $\widehat{x}^b$, minimizes their expected liability and cost of care per-unit of consumption, given the manufacturer's care choice. The manufacturer's expected per-unit liability for public harm is $\rho(x^m)H(x^m, x^b) + (1 - \rho(x^m))H(x^m, x^b)\delta^m$. Adding this to the buyer's expected per-unit liability gives us

$$H(x^m, \widehat{x}^b) \left(\delta^m + \delta^b + (1 - \delta^m - \delta^b)\rho(x^m) \right),$$

which is the combined per-unit liability of the manufacturer and the buyer. Thus, Eq. (6) states that the manufacturer's choice of care minimizes the expected per-unit combined costs of production and use of the product. We will refer to this latter term as the *expected per-unit market cost* of the good and later compare it to the expected per-unit social cost of the good. Eq. (7) states that the quantity traded of the good equates the buyer's marginal benefit for the good to the sum of the manufacturer's and buyer's expected per-unit costs of selling and using the product. That is, the equilibrium quantity traded equates the buyer's marginal benefit to the expected per-unit market cost of producing and using the product.

Our next proposition sets forth the conditions under which the competitive market equilibrium coincides with the first-best outcome. The results are almost the same as in HS Proposition 1 except for the consideration of $\rho(x^m)$, so we have relegated the proof to the appendix.

Proposition 2: Assume that the manufacturer is a competitive firm. Then the market achieves first-best levels of care and output if and only if the consumer bears all liability for public harm, the manufacturer is completely immune, and there is no chance that the manufacturer will lose its immunity. That is, $(\widehat{x}^m, \widehat{x}^b, \widehat{q}) = (x^{m*}, x^{b*}, q^*)$ if and only if $\delta^b = 1$, $\delta^m = 0$ and $\rho(x^m) = 0$.

As HS and others describe, the manufacturer in this competitive, bi-lateral care context chooses

to embed socially optimal care in its product even when there is zero chance that it could face liability for public harm. The reason is that the buyer values and pays for the manufacturer's care-taking as an instrument for optimally managing the buyer's liability for public harm.[8] Of course, it is well known in the literature that assigning all the liability to the buyer is first-best only if they are not judgment-proof. If the buyer is partially or completely judgment-proof, then Proposition 2 in HS (2005) states that the second-best optimal strict liability rule pushes the residual liability to the manufacturer, who is assumed not to be judgment-proof, thus maintaining $\delta^m + \delta^b = 1$ (in other words, liability is completely assigned to the manufacturer and the buyer pair so that expected public harm is covered). (We will confirm that this second-best result also holds in our framework at a later point in our analysis.) In contrast, in our work that follows: (1) liability is ultimately incompletely assigned so that $\delta^m + \delta^b < 1$; (2) there may be some probability that all the liability will shift to the manufacturer so that $\rho(x^m) > 0$; and (3) the manufacturer's choice of care can change this probability. In the next section, we examine the qualitative market, distributional, and efficiency effects of these three factors.

3 Market and welfare effects of contingent incomplete liability and tort reform under perfect competition

In this section we present the main results of our analysis. We begin by establishing some baseline results concerning the effects of incomplete liability assignment and the chance that all liability shifts to the manufacturer in a competitive market; that is, contingent incomplete liability. We then consider the effects of a common type of tort reform that reduces manufacturer liability while holding the buyer's liability fixed. We first determine the conditions under which this kind of tort reform can lead to a safer product, and then determine the market and social welfare effects of this kind of reform.

3.1 Contingent incomplete liability

Contingent incomplete liability distorts care choices and output from first-best. In particular, there is a wedge between expected per-unit social and market costs, expected per-unit social cost is

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[8]The "only if" part of Proposition 2 does not hold if x^m and x^b are perfect substitutes in reducing per-unit expected harm. In this case, it is straightforward to show that first-best levels of care and output are achieved even though $\delta^b < 0$ and $\rho(x^m) \geq 0$ as long as all residual liability is assigned to the manufacturer. Given that x^m and x^b are not perfect substitutes, the probability that all liability shifts to the manufacturer by itself also prevents achievement of first-best. It is possible to show that assigning all liability to the buyer but maintaining the possibility that all liability will shift to the manufacturer will reduce the buyer's care choice from first-best. In turn, this will also distort the manufacturer's care choice and the equilibrium level of output.

higher, output is either higher or lower than first-best depending on the relationship between equilibrium and first-best expected per-unit market costs, and social welfare is lower. To demonstrate these effects we first define *MC* and *SC* as the per-unit expected market costs and per-unit expected social costs, respectively. That is,

$$MC = H(x^m, x^b) \left(\delta^m + \delta^b + (1 - \delta^m - \delta^b)\rho(x^m) \right) + x^m + x^b, \tag{8}$$

and

$$SC = H(x^m, x^b) + x^m + x^b. \tag{9}$$

By adding and subtracting $H(x^m, x^b)$ on the right side of (8) we can write

$$MC = SC - H(x^m, x^b) \left[1 - \left(\delta^m + \delta^b + (1 - \delta^m - \delta^b)\rho(x^m) \right) \right]. \tag{10}$$

Let $\widehat{MC}$ and $\widehat{SC}$ be the equilibrium expected per-unit market and social costs, respectively, under contingent incomplete liability, that is, $\delta^m + \delta^b < 1$ and $\rho(x^m) \in [0,1)$. Under these conditions, $\widehat{MC} < \widehat{SC}$ because $1 - \left(\delta^m + \delta^b + (1 - \delta^m - \delta^b)\rho(x^m) \right)$ in (10) is strictly greater than zero. Note that the incomplete assignment of liability is necessary and sufficient to produce the wedge between expected per-unit market and social costs. Of course, this implies that a positive probability that all liability shifts to the manufacturer is not necessary to produce that wedge. In fact, note that $\rho(x^m) > 0$ decreases the difference between expected per-unit market and social costs under incomplete liability.

Let the first-best (that is, under $\delta^b = 1$ and $\rho(x^m) = 0$) expected per-unit market and social costs be MC^* and SC^*, respectively. Expected market and social costs coincide under the complete assignment of liability so $MC^* = SC^*$. Note that since the first-best care choices uniquely minimize expected per-unit social costs, SC^* is the unique minimum of (9). Therefore, since care choices are distorted from first-best under contingent incomplete liability, $SC^* < \widehat{SC}$; that is, contingent incomplete liability strictly increases expected per-unit social costs.

The output distortion under contingent incomplete liability depends on how $\widehat{MC}$ differs from MC^*. In particular, (7) implies that $P(q) = MC$. Since $P(q)$ is downward sloping, q^* is greater than (less than) $\widehat{q}$ if MC^* is less than (greater than) $\widehat{MC}$. Of course, there is a very special case in which $q^* = \widehat{q}$ because $MC^* = \widehat{MC}$, but we think it is safe to ignore this unlikely outcome.

To see how expected per-unit market costs are distorted from first-best, note first that $\widehat{MC}$ is the unique minimum of (8) and (10), given the buyer's care response to the manufacturer's care choice (5). Therefore, we can use the envelope theorem to calculate $\partial \widehat{MC}/\partial \delta^b = \partial \widehat{MC}/\partial \delta^m = H(\widehat{x}^m, \widehat{x}^b)(1 - \rho(\widehat{x}^m)) > 0$, which indicates that expected per-unit market cost strictly increases with both the manufacturer's and the buyer's share of liability. Therefore, relative to the first-best

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assignment of liability, $\delta^b = 1$ and $\delta^m = 0$, incomplete liability assignment increases expected per-unit market cost as the buyer's liability is reduced, but can increase expected per-unit market cost if the manufacturer's liability is increased from zero. In turn, then, the incomplete assignment of liability can result in higher or lower output relative to first-best output.

While the effects of incomplete liability on expected per-unit market cost and output are ambiguous, the possibility all liability shifts to the manufacturer unambiguously increases expected per-unit market cost and reduces output. To demonstrate these effects, assume for this exercise that the probability all liability shifts to the manufacturer is $\rho(x^m, \theta) > 0$, where θ is an exogenous parameter such that $\partial \rho(x^m, \theta)/\partial \theta > 0$. From (5) the first-order condition for $\widehat{x}^b$ is

$$\frac{\partial H(x^m, x^b)}{\partial x^b} \delta^b (1 - \rho(x^m, \theta)) + 1 = 0, \tag{11}$$

from which we have $\widehat{x}^b = \widehat{x}^b(x^m, \delta^b, \theta)$ and we can easily derive $\partial \widehat{x}^b(x^m, \delta^b, \theta)/\partial \theta < 0$. Thus, an exogenous increase in the probability all liability shifts to the manufacturer leads the buyer to reduce their choice of care. Now, consider the expected per-unit market cost function including the effects of θ;

$$\widehat{MC} = H(\widehat{x}^m, \widehat{x}^b(x^m, \delta^b, \theta)) \left(\delta^m + \delta^b + (1 - \delta^m - \delta^b)\rho(\widehat{x}^m, \theta) \right) + \widehat{x}^m + \widehat{x}^b(x^m, \delta^b, \theta).$$

Application of the envelope theorem (and dropping the function arguments) yields

$$\frac{\partial \widehat{MC}}{\partial \theta} = \frac{\partial \widehat{x}^b}{\partial \theta} \left[\frac{\partial H}{\partial x^b} \left(\delta^m + \delta^b + (1 - \delta^m - \delta^b)\rho \right) + 1 \right] + H(1 - \delta^m - \delta^b)\frac{\partial \rho}{\partial \theta}.$$

Using (11),

$$\frac{\partial \widehat{MC}}{\partial \theta} = \frac{\partial \widehat{x}^b}{\partial \theta} \frac{\partial H}{\partial x^b} (\rho + (1 - \rho)\delta^m) + H(1 - \delta^m - \delta^b)\frac{\partial \rho}{\partial \theta} > 0. \tag{12}$$

The sign follows because $\partial \widehat{x}^b/\partial \theta < 0$, $\partial H/\partial x^b < 0$ and $\partial \rho/\partial \theta > 0$. The result is that expected per-unit market costs strictly increase with a parametric increase in the probability all liability shifts to the manufacturer. In turn, this implies that equilibrium output strictly declines with a parametric increase in this probability. Note from (12) that these effects occur even if liability is completely assigned.

We illustrate the welfare effects of the distortions caused by contingent incomplete liability in Figures 1a and 1b. Observe in both figures that the expected per-unit market and social costs are the same under the first-best assignment of liability and $\rho(x^m) = 0$. The intersection of $MC^* = SC^*$ and the consumer's marginal benefit of consumption $P(q)$ identifies the first-best level of output q^*. Under contingent incomplete liability, expected per-unit social cost is strictly higher

so that $\widehat{SC} > SC^*$. Figures 1a and 1b differ because in Figure 1a, $\widehat{MC} < MC^*$ and equilibrium output $\widehat{q}$ is strictly higher than first-best output, while $\widehat{MC} > MC^*$ in Figure 1b so that equilibrium output $\widehat{q}$ is less than first-best output. In both figures, the lined area is the change in expected market surplus—where expected market surplus is equal to expected buyer surplus because the manufacturer continues to earn zero expected profit—while the shaded area is uncompensated expected public harm, $\left(\widehat{SC} - \widehat{MC}\right)\widehat{q}$.
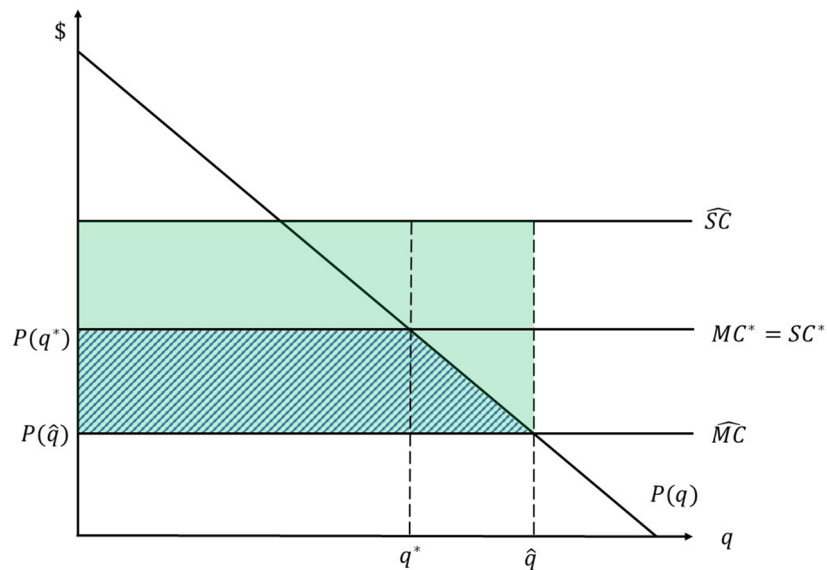
(a) Output is higher than first-best.
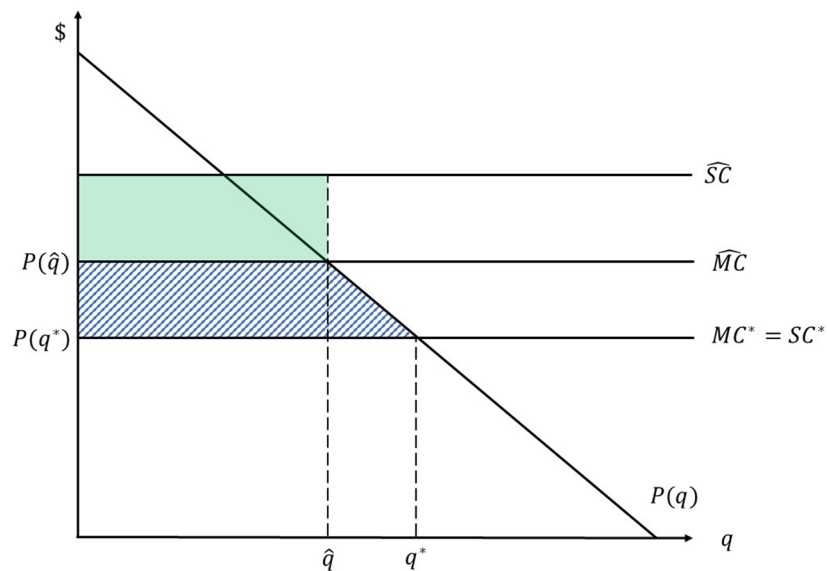
(b) Output is lower than first-best.

Figure 1: The welfare effects of contingent incomplete liability in a competitive market.

Since output is higher than first-best in Figure 1a, market surplus increases by the lined area in the graph. However, uncompensated expected public harm increases from zero to $\left(\widehat{SC} - \widehat{MC}\right)\widehat{q}$. Consequently, the shaded, unlined area in the graph is the reduction in expected social welfare from contingent incomplete liability. In this case the incomplete assignment of liability benefits market participants by burdening the public with additional harm and this additional public harm outweighs the increase in the welfare of market participants. In Figure 1b the lined area is a reduction in expected market surplus that is due to lower output. In this case, the reduction in social welfare is the combination of the reduction in expected market surplus and the increase in uncompensated expected public harm. Note that the welfare loss from contingent incomplete liability is lower (higher) when output is lower (higher) than first-best.

3.2 Tort reform

We now investigate the market and welfare effects of *reducing* manufacturer liability, given contingent incomplete liability. We first consider whether this set of circumstances leads to a more or less harmful product. We then consider the market and welfare effects of reducing manufacturer liability.

To determine whether tort reform results in a more or less harmful product we need to sign

$$\frac{\partial \widehat{H}}{\partial \delta^m} = \left(\frac{\partial H}{\partial x^m} + \frac{\partial H}{\partial x^b} \frac{\partial \widehat{x}^b}{\partial x^m} \right) \frac{\partial \widehat{x}^m}{\partial \delta^m}, \tag{13}$$

where, to conserve notation we define $\widehat{H} = H(\widehat{x}^m, \widehat{x}^b)$. Below we will define $\widehat{\rho} = \rho(\widehat{x}^m)$. (Note that we have dropped all the function arguments in (13), and will do so from now on except when it is useful to show these arguments.) The last term on the right side of (13) is the marginal effect of the manufacturer's liability share on its choice of care. The term in parentheses contains the direct effect of the manufacturer's choice of care on per-unit expected harm and the indirect effect of this choice on expected harm that works through the buyer's reaction to the manufacturer's choice of care. A reduction in the manufacturer's share of liability results in a more harmful product if (13) is strictly negative; the product is safer if (13) is positive. The following proposition reveals necessary and sufficient conditions under which a reduction in the manufacturer's liability share leads to a more harmful product.

Proposition 3: A reduction in the manufacturer's share of liability results in strictly greater expected public harm per unit of output if and only if one of the following conditions holds:

$$\frac{\partial \widehat{x}^b}{\partial x^m} > -\left(1 + \widehat{H}(1 - \delta^m - \delta^b)\widehat{\rho}'\right);$$ (14)

$$\widehat{\rho}' < \frac{(1 - \widehat{\rho})}{\widehat{H}}\left(\frac{\partial H}{\partial x^m} + \frac{\partial H}{\partial x^b}\frac{\partial \widehat{x}^b}{\partial x^m}\right).$$ (15)

Proof of Proposition 3: We begin by showing how the elements of (14) and (15) determine the signs of the components of (13). In particular, we establish the following:

$$sgn\left(\frac{\partial H}{\partial x^m} + \frac{\partial H}{\partial x^b}\frac{\partial \widehat{x}^b}{\partial x^m}\right) = -sgn\left(\frac{\partial \widehat{x}^b}{\partial x^m} + 1 + \widehat{H}(1 - \delta^m - \delta^b)\widehat{\rho}'\right);$$ (16)

$$sgn\left(\frac{\partial \widehat{x}^m}{\partial \delta^m}\right) = sgn\left(\widehat{\rho}' - \frac{(1 - \widehat{\rho})}{\widehat{H}}\left(\frac{\partial H}{\partial x^m} + \frac{\partial H}{\partial x^b}\frac{\partial \widehat{x}^b}{\partial x^m}\right)\right).$$ (17)

Start by writing the first-order condition for the manufacturer's care choice from (6) as

$$\left(\delta^m + \delta^b + (1 - \delta^m - \delta^b)\widehat{\rho}\right)\left(\frac{\partial H}{\partial x^m} + \frac{\partial H}{\partial x^b}\frac{\partial \widehat{x}^b}{\partial x^m}\right) + \frac{\partial \widehat{x}^b}{\partial x^m} + 1 + \widehat{H}(1 - \delta^m - \delta^b)\widehat{\rho}' = 0.$$ (18)

Eq. (16) follows directly from (18) because $\delta^m + \delta^b + (1 - \delta^m - \delta^b)\widehat{\rho} > 0$. To establish (17), let $F(\widehat{x}^m, \delta^m)$ denote the left side of (18). Then,

$$\frac{\partial \widehat{x}^m}{\partial \delta^m} = -\frac{\partial F/\partial \delta^m}{\partial F/\partial x^m}.$$

Since $\partial F/\partial x^m > 0$ to satisfy the second-order condition for the choice of x^m, $sgn\left(\partial \widehat{x}^m/\partial \delta^m\right) = sgn\left(-\partial F/\partial \delta^m\right)$. From (18) calculate

$$-\frac{\partial F}{\partial \delta^m} = -(1 - \widehat{\rho})\left(\frac{\partial H}{\partial x^m} + \frac{\partial H}{\partial x^b}\frac{\partial \widehat{x}^b}{\partial x^m}\right) + \widehat{H}\widehat{\rho}'.$$ (19)

Eq. (17) follows from $sgn\left(\partial \widehat{x}^m/\partial \delta^m\right) = sgn\left(-\partial F/\partial \delta^m\right)$, $\widehat{H} > 0$ and (19).

From here on let

$$\frac{\partial \widetilde{H}}{\partial x^m} = \frac{\partial H}{\partial x^m} + \frac{\partial H}{\partial x^b}\frac{\partial \widehat{x}^b}{\partial x^m}$$ (20)

denote the total effect of the manufacturer's care on per-unit expected harm from the product.

Likewise, (13) can be written as

$$\frac{\partial \widehat{H}}{\partial \delta^m} = \frac{\partial \widetilde{H}}{\partial x^m} \frac{\partial \widehat{x}^m}{\partial \delta^m}. \tag{21}$$

To establish the 'if' part of the proposition, first note that (14) and (16) imply $\partial \widetilde{H}/\partial x^m < 0$, which from (17) implies $\partial \widehat{x}^m / \partial \delta^m > 0$. Therefore, $\partial \widehat{H}/\partial \delta^m < 0$ if (14) holds. Moreover, (15) and (17) imply $\partial \widehat{x}^m / \partial \delta^m < 0$, which, according to (17), requires $\partial \widetilde{H}/\partial x^m > 0$. Therefore, $\partial \widehat{H}/\partial \delta^m < 0$ if (15) holds.

To establish the 'only if' part of the proposition we demonstrate that $\partial \widehat{H}/\partial \delta^m < 0$ cannot be true if

$$\frac{\partial \widehat{x}^b}{\partial x^m} \leq - \left(1 + \widehat{H}(1 - \delta^m - \delta^b)\widehat{\rho}' \right) \tag{22}$$

and

$$\widehat{\rho}' \geq \frac{(1 - \widehat{\rho})}{\widehat{H}} \frac{\partial \widetilde{H}}{\partial x^m}. \tag{23}$$

First note from (16) and (17) that if either (22) or (23) hold with equality, then $\partial \widehat{H}/\partial \delta^m = 0$. If (22) holds with the strict inequality, then $\partial \widetilde{H}/\partial x^m > 0$ from (16). If (23) holds with strict inequality, then $\partial \widehat{x}^m / \partial \delta^m > 0$ from (17). Together, if both (22) and (23) hold with strict inequality, then $\partial \widehat{H}/\partial \delta^m > 0$. Thus, $\partial \widehat{H}/\partial \delta^m < 0$ cannot hold if both (22) and (23) hold. This completes the proof of the proposition. $\square$

Proposition 3 provides necessary and sufficient conditions for a reduction in manufacturer liability to lead to a more harmful product, focusing on the relative values of the buyer's strategic response to the manufacturer's care choice and the effect of the manufacturer's care choice on the probability that it may have to bear all the liability. The proposition suggests that reducing manufacturer liability can increase, decrease or leave unchanged per-unit expected public harm from the use of the product, so resolving this issue is an empirical matter to be determined on a case-by-case basis. However, the conditions under which reduced manufacturer liability leads to a safer product are very stringent; the conditions that result in a more harmful product are much less stringent. Condition (14) in Proposition 3 implies a more harmful product if manufacturer and buyer care are strategic complements; if they are weak substitutes so that a dollar reduction in manufacturer care induces less than a dollar increase in consumer care; if they are perfect substitutes; and even if they are strong substitutes if $\widehat{\rho}' > 0$. In fact, reduced liability for the manufacturer can still result in a more harmful product if buyer and manufacturer care are even stronger substitutes than allowed by condition (14) as long as the effect of the manufacturer's care choice on the probability it has to accept all liability is not too large so that (15) is satisfied.

The necessary and sufficient conditions for reduced manufacturer liability to *not* result in a more dangerous product are that both (22) and (23) in the proof of Proposition 3 are satisfied. Manufacturer liability does not affect how harmful the product is if either (22) or (23) hold with equality, but these are special cases that we can ignore for the purposes of our discussion. In the absence of these special cases, Eq. (22) reveals that a less harmful product requires that the buyer considers its care and the manufacturer's care to be strong strategic substitutes so that a dollar reduction in the manufacturer's care choice motivates the buyer to increase its care choice by more than a dollar. In addition, the satisfaction of (23) and (17) reveal that a less harmful product requires that the manufacturer's care be increasing in its liability share to a sufficient degree. Thus, as the manufacturer's liability share is reduced, it reduces its level of care, but the buyer more than makes up for it by significantly increasing their level of care, resulting in lower expected harm per unit. Given the strong strategic response of the buyer, the manufacturer's reduction in care as its liability is reduced requires that the probability liability shifts entirely to the manufacturer be strictly increasing in the manufacturer's care choice to a sufficient degree. This is implied by condition (23). It bears emphasizing that the existence of some probability that liability will shift entirely to the manufacturer and that this probability increases with the manufacturer's care choice are necessary conditions for a reduction in the manufacturer's liability share to result in a less harmful product. If $\widehat{\rho}' \leq 0$, reducing the manufacturer's share of liability cannot lead to a safer product.

Our next proposition characterizes the distributional impacts of reducing manufacturer liability for public harm.

Proposition 4:   A reduction in the manufacturer's share of liability results in:

1. Lower combined expected per-unit costs of the consumer and manufacturer (i.e., expected per-unit market costs) and higher output.

2. Weakly higher expected per-unit and strictly higher total social costs.

3. Lower expected welfare.

Proof of Proposition 4:   From Eq. (6) in Proposition 1, in equilibrium the manufacturer's care is chosen to minimize the manufacturer's and buyer's combined expected per-unit costs of selling and using the product (i.e., the expected per-unit market costs). Therefore, as we have done earlier, we can use the envelope theorem to calculate the marginal effect of δ^m on the right side of (6) as $\widehat{H}(1 - \widehat{\rho}) > 0$, which reveals that the per-unit expected costs of selling and using the product fall as the manufacturer's liability is reduced. Since the consumer's demand for the product, $P(q)$, is strictly decreasing, output is higher. Thus, we have proven part 1 of Proposition 4.

To prove the second part of the proposition, we first show that the expected per-unit social cost of the product, $\widehat{SC} = \widehat{H} + \widehat{x}^m + \widehat{x}^b$, weakly increases as the manufacturer's liability share is decreased. Using $H(\widehat{x}^m, \widehat{x}^b)$ and (21), our goal is to show

$$\frac{\partial \widehat{SC}}{\partial \delta^m} = \left[\frac{\partial \widetilde{H}}{\partial x^m} + \frac{\partial \widehat{x}^b}{\partial x^m} + 1 \right] \frac{\partial \widehat{x}^m}{\partial \delta^m} \leq 0. \tag{24}$$

Recall the first order condition for determining the manufacturer's choice of care, Eq. (18). Using $\partial \widetilde{H}/\partial x^m$ as defined by (20), add and subtract $\partial \widetilde{H}/\partial x^m$ from the left side of (18), rearrange and collect terms to obtain

$$\frac{\partial \widetilde{H}}{\partial x^m} + \frac{\partial \widehat{x}^b}{\partial x^m} + 1 = \left[\frac{\partial \widetilde{H}}{\partial x^m}(1-\rho) - \widehat{H}\widehat{\rho}' \right] (1 - \delta^m - \delta^b). \tag{25}$$

Now, take (17) and rearrange terms to obtain

$$-sgn\left(\frac{\partial \widehat{x}^m}{\partial \delta^m} \right) = sgn\left(\frac{\partial \widetilde{H}}{\partial x^m}(1-\widehat{\rho}) - \widehat{H}\widehat{\rho}' \right). \tag{26}$$

Eqs. (25) and (26) imply

$$-sgn\left(\frac{\partial \widehat{x}^m}{\partial \delta^m} \right) = sgn\left(\frac{\partial \widetilde{H}}{\partial x^m} + \frac{\partial \widehat{x}^b}{\partial x^m} + 1 \right),$$

which in turn implies (24). Note the very special case that (24) is zero if and only if $(\partial \widetilde{H}/\partial x^m)(1 - \widehat{\rho}) - \widehat{H}\widehat{\rho}' = 0$. Now, recall from part 1 of this proposition that output strictly increases as the manufacturer's share of liability is reduced. Expected total social costs strictly increase because per-unit expected social costs weakly increase and output strictly increases.

To prove the final part of the proposition denote expected social welfare evaluated at the equilibrium described in Proposition 1 as $\widehat{SW}$. Using (2) and (9) we can write

$$\widehat{SW} = \int_0^{\widehat{q}} P(z)dz - \widehat{SC}\widehat{q}. \tag{27}$$

Differentiate (27) with respect to δ^m to obtain

$$\frac{\partial \widehat{SW}}{\partial \delta^m} = \left[P(\widehat{q}) - \widehat{SC} \right] \frac{\partial \widehat{q}}{\partial \delta^m} - \int_0^{\widehat{q}} \frac{\partial \widehat{SC}}{\partial \delta^m} dz. \tag{28}$$

The second term on the right side of (28) is non-negative from part 2 of this proposition (see Eq. (24)). The first term is the change in expected social welfare that is due to the increase in the

equilibrium quantity of the good as the manufacturer's liability is reduced. To sign the first term of (28), recall that $P(\widehat{q}) = \widehat{MC} < \widehat{SC}$ (refer to Figure 1). Combining this with $\partial \widehat{q}/\partial \delta^m < 0$ from part 1 of the proposition reveals that the first term of (28) is strictly positive. Since the second term is non-negative, expected social welfare declines as the manufacturer's share of liability for public harm is reduced. $\square$

Perhaps the most important implication of Proposition 4 is that reducing manufacturer liability increases the welfare of market participants, but shifts the burden of expected harm from the market to the public. On a per-unit basis, the reduction in the expected costs of the market participants is outweighed by the increase in the uncompensated expected public harm, *even if the product is safer*. In total, market participants are better off because their per-unit expected costs are lower and output is higher, but this gain is made possible by shifting the burden of expected harm to the public. In fact, in a competitive market, the increase in expected public harm from reducing manufacturer liability is strictly greater than the benefit to market participants. Thus, tort reforms that reduce manufacturer liability in competitive markets but do not otherwise completely assign liability to buyers unequivocally reduce expected social welfare.[9]

4   Imperfectly competitive supply

However, if the market is instead imperfectly competitive, the increase in output that comes with reduced manufacturer liability can increase expected social welfare. The expected social cost of manufacturing and using the product would still increase with reduced manufacturer liability, but if this loss is lower than the increased gain from higher output, then expected social welfare may increase. In this subsection we explore the possibility that contingent incomplete liability and tort reform can lead to greater welfare under imperfect product competition. We present general results for generic deviations from perfectly competitive output, without assuming a particular form of imperfect competition. Since this may involve multiple firms, the representative firm in our model will now be referred to as manufacturers. Although our main results capture the general effects of deviations from perfect competition, we will illustrate some of the results with a model of monopoly supply.

Due to our modeling choice to make expected per-unit harm and the costs of care independent

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[9]We noted earlier that Proposition 2 in Hay and Spier (2005) states that the second-best optimal strict liability rule when the buyer is judgment-proof pushes the residual liability to the manufacturer, thus maintaining $\delta^m + \delta^b = 1$. We confirm this finding with the proof of part 3 of Proposition 4. Given incomplete liability shares, we show that expected social welfare is monotonically increasing in the manufacturer's liability share. Thus, given that the consumer's liability share is constant at $\delta^b < 1$, expected social welfare is maximized by increasing the manufacturer's share so that $\delta^m + \delta^b = 1$. Note that we extend the Hay and Spier result to include the possibility that all liability shifts to the manufacturer.

of the level of output, per-unit care choices are not affected by whether the output market is per-fectly or imperfectly competitive. Thus, under contingent incomplete liability per-unit care choices remain $\widehat{x}^m$ and $\widehat{x}^b$, and expected per-unit social and market costs remain $\widehat{SC}$ and $\widehat{MC}$, respectively. However, the level of output will be different. Denote output under imperfect competition as $\overline{q}$. We assume that output is lower under imperfect competition so $\overline{q} < \widehat{q}$ throughout.

While imperfect competition likely results in lower output than perfect competition, output under imperfect competition and contingent incomplete liability may be higher or lower than first-best output q^*. Moreover, regardless of whether output under imperfect competition is higher or lower than first-best output, expected social welfare under imperfect product competition and contingent incomplete liability is strictly less than first-best expected welfare.

More interesting is whether imperfect competition can lead to higher expected social welfare than perfect competition under contingent incomplete liability. We have already specified expected social welfare under contingent incomplete liability (in other words, given $\widehat{x}^m$, $\widehat{x}^b$ and $\widehat{q}$) in (27). Under imperfect competition, expected per-unit social cost remains at $\widehat{SC}$ but output is $\overline{q}$. There-fore, expected social welfare under imperfect competition and contingent incomplete liability is

$$\overline{SW} = \int_0^{\overline{q}} P(z)dz - \widehat{SC}\overline{q}. \tag{29}$$

Use (27) and (29) to calculate

$$\widehat{SW} - \overline{SW} = \int_{\overline{q}}^{\widehat{q}} P(z)dz - \widehat{SC}(\widehat{q} - \overline{q}). \tag{30}$$

From (30) we can very quickly derive a sufficient condition for when imperfect competition leads to higher expected social welfare. Since $P(q) < P(\overline{q})$ for $q \in (\overline{q}, \widehat{q}]$, $\int_{\overline{q}}^{\widehat{q}} P(z)dz < P(\overline{q})(\widehat{q} - \overline{q})$. Therefore, $P(\overline{q}) \le \widehat{SC}$ is a sufficient condition for $\widehat{SW} - \overline{SW} < 0$. These cases include the special, but potentially important, case that output under imperfect competition and contingent incomplete liability is greater than first-best output. To see this, recall Figures 1a and 1b for $P(q^*) = SC^* < \widehat{SC}$. Then, $\overline{q} \ge q^*$ implies $P(\overline{q}) \le P(q^*)$, and consequently, $P(\overline{q}) \le SC^*$. Since $SC^* < \widehat{SC}$, we have $P(\overline{q}) < \widehat{SC}$. Therefore, if the combination of imperfect competition and contingent incomplete liability leads to higher output than first-best, then this outcome produces higher expected social welfare than under perfect competition. In this case, the fact that imperfect competition restricts output relative to perfect competition moves output closer to the first-best level of output.

To further understand the difference in expected social welfare under perfect and imperfect competition add $\widehat{MC}(\widehat{q} - \overline{q}) + \widehat{MC}(\overline{q} - \widehat{q}) = 0$ to the right side of (30) and collect terms to obtain

$$\widehat{SW} - \overline{SW} = \int_{\overline{q}}^{\widehat{q}} \left(P(z) - \widehat{MC} \right) dz - \left(\widehat{SC} - \widehat{MC} \right) (\widehat{q} - \overline{q}). \tag{31}$$

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The first term on the right side of (31) is the increase in expected market surplus of increasing output from the imperfectly competitive amount $\overline{q}$ to the perfectly competitive level $\widehat{q}$. The second term is the increase in the uncompensated expected public harm due to that increase in output. Thus, whether social welfare is higher or lower under imperfect competition when liability is not completely assigned and there is a chance liability can shift entirely to the manufacturers hinges on whether the extra expected market surplus at the competitive level of output is greater than or less than the extra uncompensated expected public harm at that level of output.

We illustrate this trade off in Figures 2a and 2b. Here we assume that $P(q)$ is linear so the exact calculation of (31) is

$$\widehat{SW} - \overline{SW} = \frac{\left(P(\overline{q}) - \widehat{MC}\right)(\widehat{q} - \overline{q})}{2} - \left(\widehat{SC} - \widehat{MC}\right)(\widehat{q} - \overline{q})$$
$$= \frac{(\widehat{q} - \overline{q})}{2}\left[\left(P(\overline{q}) - \widehat{MC}\right) - 2\left(\widehat{SC} - \widehat{MC}\right)\right]. \tag{32}$$

Eq. (32) reveals that, given a linear $P(q)$ and contingent incomplete liability, expected social welfare is higher under imperfect competition if and only if twice the per-unit expected uncompensated public harm, $\widehat{SC} - \widehat{MC}$, exceeds marginal expected market surplus at the imperfectly competitive level of output, $P(\overline{q}) - \widehat{MC}$.

In Figures 2a and 2b we also assume that imperfect competition in the output market is characterized by a monopoly supplier. The analogue to Eq. (7) when the manufacturer is a monopolist is

$$P(\overline{q}) + P'(\overline{q})\overline{q} = H(\widehat{x}^m, \widehat{x}^b)\left(\delta^m + \delta^b + (1 - \delta^m - \delta^b)\rho(\widehat{x}^m)\right) + \widehat{x}^m + \widehat{x}^b, \tag{33}$$

or rather, $P(\overline{q}) + P'(\overline{q})\overline{q} = \widehat{MC}$. We derive this result in the appendix.[10] Given that the consumer's marginal benefit function is linear, $P(q) + P'(q)q$ bisects the distance between the vertical intercept and $P(q)$. As before (see Figures 1a and 1b), output under perfect competition is $\widehat{q}$ such that $P(\widehat{q}) = \widehat{MC}$.

For Figure 2a we have set $P(\overline{q}) < \widehat{SC}$ so that expected social welfare is higher under monopoly than under perfect competition. The lined area in Figure 2a is the increase in expected market surplus as output is increased from the monopoly level to the perfect competition level. The shaded area is $\left(\widehat{SC} - \widehat{MC}\right)(\widehat{q} - \overline{q})$, the increase in expected uncompensated public harm of the increase in output from $\overline{q}$ to $\widehat{q}$. It is clear in the figure that expected social welfare under monopoly is higher than under perfect competition because the gain in expected market surplus at the perfectly

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[10]We should caution the reader that $P(q) + P'(q)q$ is not the monopolist's marginal revenue at the equilibrium level of output. Instead the monopolist's marginal revenue function is $p(q) + p'(q)q$, where $p(q)$ is the consumer's demand for the product net of its per unit expected costs of using the product; that is, $p(q) = P(q) - H(\widehat{x}^m, \widehat{x}^b)\delta^b(1 - \rho(\widehat{x}^m)) - \widehat{x}^b$.

competitive outcome is strictly less than the increase in expected uncompensated public harm. Observe that this will always be true if $P(\overline{q}) \leq \widehat{SC}$ as we noted earlier.
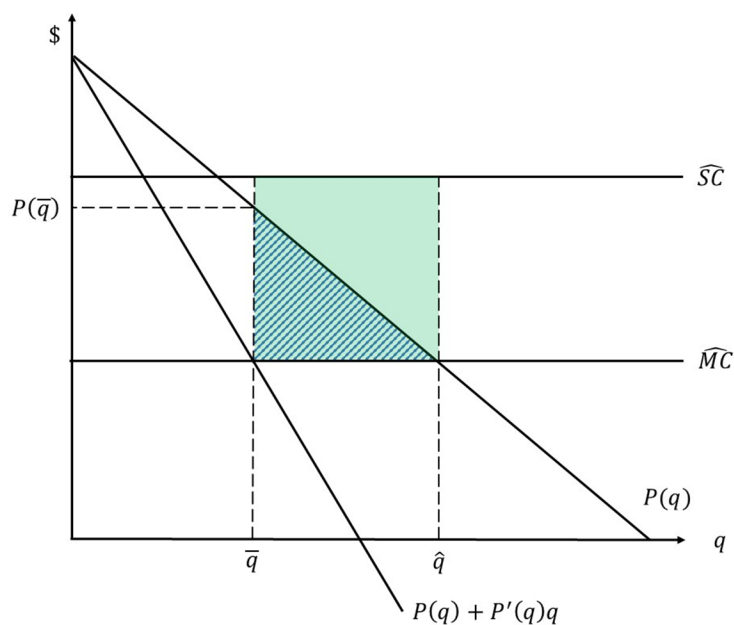
(a) Expected social welfare under perfect and imperfect competition when $P(\overline{q}) \leq \widehat{SC}$.
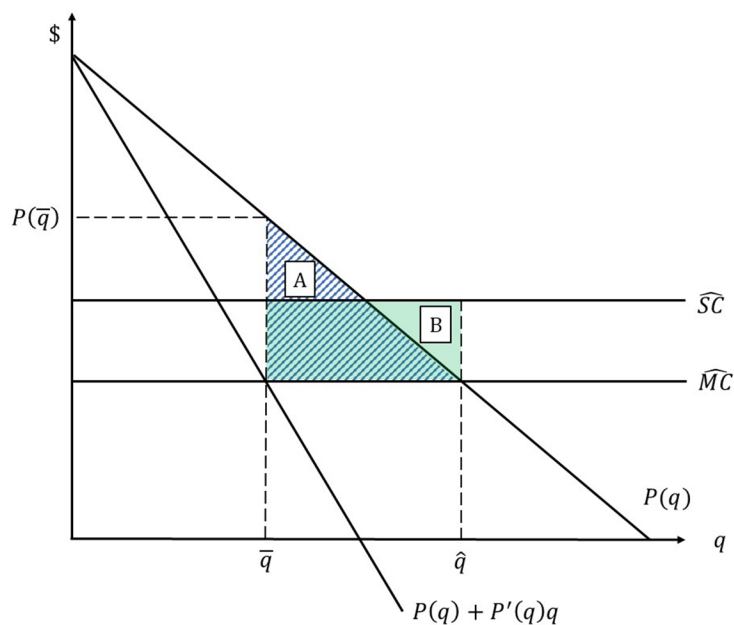
(b) Expected social welfare under perfect and imperfect competition when $P(\overline{q}) > \widehat{SC}$.

Figure 2: Differences in expected social welfare under monopoly and perfect competition

Figure 2b illustrates the case in which $P(\overline{q}) > \widehat{SC}$. In this case it is not clear from the figure

whether the increase in market surplus (the lined area) at the competitive outcome is greater than or less than the reduction in uncompensated public harm (the shaded area). Whether expected social welfare is higher or lower under monopoly supply depends on the relative values of areas A and B. Eq. (32) tells us that social welfare is higher under monopoly – that is, area B is greater than area A – if and only if $P(\bar{q}) - \widehat{MC} < 2\left(\widehat{SC} - \widehat{MC}\right)$.

We complete our analysis by considering tort reform that reduces the liability for public harm of imperfectly competitive manufacturers while holding the buyer's liability share fixed. Given expected social welfare under imperfect competition $\overline{SW}$ given by (29), we can obtain

$$\frac{\partial \overline{SW}}{\partial \delta^m} = \left[P(\bar{q}) - \widehat{SC}\right] \frac{\partial \bar{q}}{\partial \delta^m} - \int_0^{\bar{q}} \frac{\partial \widehat{SC}}{\partial \delta^m} dz. \tag{34}$$

(This is a rewrite and modification of (28) to the imperfect competition situation.) Recall from part 2 of Proposition 4 that the second term of (34) is negative except in a very special case in which it could be zero. This term indicates that reducing the manufacturers' liability increases the total expected social cost of the product, holding the level of output constant. The first term of (34) is the output effect on social welfare due to tort reform. We make the reasonable assumption that $\partial \bar{q}/\partial \delta^m < 0$ under generic imperfect competition so that a reduction in the manufacturers' liability leads to an increase in output as it does under perfect competition (Proposition 4 part 1) and is easily shown to be true under monopoly. We see that this output effect of tort reform works to further reduce expected social welfare when $P(\bar{q}) < \widehat{SC}$. Recall that in these cases, expected social welfare under imperfect competition is higher than under perfect competition. Therefore, there are cases in which imperfect competition produces higher expected social welfare, but a reduction in manufacturers' liability for public harm would reduce expected social welfare.

On the other hand, if $P(\bar{q}) > \widehat{SC}$ then the increase in output from reducing the manufacturers' liability under imperfect competition serves to increase expected social welfare. If the output effect in this case outweighs the increase in expected social costs, then expected social welfare increases. It is only in this case that tort reform can improve social welfare. We must emphasize, however, that this possible net gain in expected social welfare under imperfect competition can arise only by shifting spillover harm to the public. This stark redistribution of welfare from public to private parties is undoubtedly at the heart of public objections to tort reform.

5 Conclusion

Our analysis began with the observation that a surprisingly diverse array of US manufacturers enjoy immunity from liability for public harm as a result of tort reforms intended to reduce legal uncertainty; promote economic growth; and to incentivize care-taking by buyers who, arguably,

are the closest proximate cause of public harm. One example we noted is the 2005 US federal law that immunizes manufacturers of firearms for armed criminal actions committed with their products. Another example is the presence of commonsense consumption acts in roughly half of the US states that immunize the fast food and sugar-sweetened beverage industries from liability for buyer health damages that may exceed private ability to pay and be passed to public health insurance funds. The tort reform argument in favor of such laws is that firearm and fast food manufacturers are far removed from—and therefore not reasonably culpable for—the appropriate acquisition, use, and (in the case of firearms) secure storage of such products. The implicit argument follows that if buyers know that manufacturers are immunized from liability, they will take more precaution (perhaps even socially optimal precaution) and the resulting expected public harm and expected social welfare may be first-best. Indeed, recent tort reform emphasis upon buyer care over manufacturer care in the firearms context is illustrated by the relatively recent discussion by Anderson and Sabia (2018) of how 17 US states and the District of Columbia passed relatively impactful child access prevention laws over the 1993-2013 time period that includes the signing of the aforementioned 2005 federal law that immunized gun manufacturers from liability. And in the fast food context, Carpenter and Tello-Trillo (2015) indicate that the stated purpose of commonsense consumer act tort reforms is to incentivize consumers to take more care of their health, and they find evidence of this occurring in the fast food market in states that have CCAs.

Our concern at the start of this project, however, was that the above argument may not follow in the presence of one or more distortions, and that observed increases in buyer care when tort reforms reduce manufacturer liability may not imply increases in social welfare and therefore successful tort reform. The goal for our project was to closely examine the roles of two relatively overlooked distortions: (1) liability shares may not be completely assigned when only one party's liability is adjusted and (2) manufacturers may face a positive probability that the immunity from liability that they currently enjoy may be reversed, and this probability could be affected by the observable care they take. We refer to the combination of these two features as contingent incomplete liability. These distortions strike us as poignant because the real world is indeed characterized by incomplete liability shares and public commentary and protests increasingly call for a reversal of the immunity enjoyed by several manufacturers/principals.

We first analyze the market and welfare distortions caused by contingent incomplete liability. We next find it is possible for product safety to improve as the manufacturer's share of liability for public harm falls as a consequence of tort reform; however, the conditions under which this goal of tort reform obtains appear to be relatively strict. In particular, buyer and manufacturer care choices must be sufficiently strong strategic substitutes and the probability that the manufacturer loses its immunity must be strictly increasing in its care choice to a sufficient degree. If either of these conditions fail to hold, reducing manufacturer liability for public harm leads to less safe products.

Regardless of whether reducing the manufacturer's liability share leads to more or less product safety, we demonstrate that even as market participants are better off with tort reform, expected harm borne by the public strictly increases. Moreover, expected social welfare strictly declines with reduced manufacturer liability for public harm in competitive product markets. This effect may not hold in imperfectly competitive markets; lower output from market power is to some degree offset by tort reform's propensity to raise output. Consequently, there are limited circumstances under which tort reform can increase expected social welfare under imperfect competition. However, regardless of market structure, tort reform favors markets participants at the expense of burdening the public with a greater amount of harm. Taken together, these results provide important caveats for pro-tort-reform intuition that relaxing the manufacturer's liability share will, ceteris paribus, raise care-taking by buyers and lead to higher social welfare.

Notwithstanding the increasing prevalence of tort reforms that restrict if not fully immunize manufacturers from public harm, there is a surprisingly thin economic literature that formally explores the conditions under which tort reform may lead to higher social welfare. In addition to extending Hay and Spier (2005) in multiple directions described herein, our results also complement those of Daughety and Reinganum (2006) who caution on their p. 318 that in the presence of substantial spillovers of harm to third-parties "...sweeping undifferentiated tort reform is unlikely to be uniformly welfare enhancing." Their model has significant differences from ours–namely, their model features care-taking only by manufacturers whereas we have bilateral care-taking, and they do not consider the case in which manufacturers face a positive probability that immunity from liability is reversed and that this probability can be increasing in the observable care the manufacturer takes. We show how these real-world differences in our models nevertheless reinforce their words of caution. Our results may encourage courts and legislatures to revisit some aspects of tort reform and ensure that the full range of distortions is taken into account in policy design. We do not maintain that rolling back tort reform in and of itself is a panacea, but we are concerned that tort reform may be inefficient and unduly burden the public unless liability shares are complete.

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Appendix

Proof of Proposition 1:   Substitute (3) into the consumer's utility function (1) to obtain

$$U(q,x^b) = \int_0^q P(z)dz - \left[H(x^m,x^b)\delta^b(1-\rho(x^m))+x^b+p \right] q + w. \tag{35}$$

Eq. (5) of Proposition 1 follows because maximizing (35) with respect to the consumer's choice of care, given the manufacturer's care, requires minimizing $H(x^m,x^b)\delta^b(1-\rho(x^m))+x^b$ with respect to x^b. The solution to this minimization problem is the consumer's strategic best-response to the manufacturer's care choice. Given the strict convexity of $H(x^m,x^b)$, the consumer's best-response to the manufacturer's choice of care is unique. It is useful for the purposes of this proof to define the consumer's best-response function as

$$x^b = f(x^m,\delta^b). \tag{36}$$

Maximizing (35) with respect to q gives us the consumer's inverse demand for the product,

$$p = P(q) - H(x^m,x^b)\delta^b(1-\rho(x^m)) - x^b. \tag{37}$$

Now turn to the manufacturer. In a competitive equilibrium the price of the product is equal to the firm's expected marginal cost so that

$$p = H(x^m,x^b)(\delta^m + (1-\delta^m)\rho(x^m)) + x^m, \tag{38}$$

which is the representative manufacturer's inverse supply of the product. Combine this with the buyer's inverse demand (37) to obtain

$$P(q) = H(x^m,x^b)\left(\delta^m + \delta^b + (1-\delta^m-\delta^b)\rho(x^m) \right) + x^m + x^b,$$

which demonstrates (7) of Proposition 1.

Finally, since the manufacturer chooses its level of care in anticipation of the buyer's choice of care and the equilibrium of the market, we may substitute (36) and (37) into the firm's profit function (4) to obtain

$$B(q,x^m) = \left[P(q) - H(x^m,f(x^m,\delta^b))\left(\delta^m + \delta^b + (1-\delta^m-\delta^b)\rho(x^m) \right) - x^m - f(x^m,\delta^b) \right] q. \tag{39}$$

Maximizing profit (39) with respect to x^m is the solution to

$$min_{x^m}\ H(x^m, f(x^m, \delta^b)) \left(\delta^m + \delta^b + (1 - \delta^m - \delta^b)\rho(x^m) \right) + x^m + f(x^m, \delta^b), \qquad (40)$$

which gives us (6) of Proposition 1. □

Proof of Proposition 2: From (2) the first-order conditions that uniquely determine (x^{m*}, x^{b*}, q^*) are:

$$\frac{\partial SW}{\partial x^i} = -\frac{\partial H}{\partial x^i} - 1 = 0, i = m, b; \qquad (41)$$

$$\frac{\partial SW}{\partial q} = P - H - x^m - x^b = 0. \qquad (42)$$

In this proof we drop the function arguments to reduce clutter. From (5), the consumer's equilibrium choice of care $\widehat{x}^b$ is determined from the first-order condition

$$-\frac{\partial H}{\partial x^b} \delta^b (1 - \rho) - 1 = 0. \qquad (43)$$

We see that (43) matches $\partial SW / \partial x^b = 0$ if and only if $\delta^b = 1$ and $\rho = 0$.

From (6), the first-order condition for the manufacturer's equilibrium choice of care can be written as

$$\left(\delta^m + \delta^b + (1 - \delta^m - \delta^b)\rho \right) \left(\frac{\partial H}{\partial x^m} + \frac{\partial H}{\partial x^b} \frac{\partial \widehat{x}^b}{\partial x^m} \right) + \frac{\partial \widehat{x}^b}{\partial x^m} + 1 + H(1 - \delta^m - \delta^b)\rho' = 0. \qquad (44)$$

If $\delta^b = 1$ and $\delta^m = 0$, (44) becomes

$$\frac{\partial H}{\partial x^m} + 1 + \left(\frac{\partial H}{\partial x^b} + 1 \right) \frac{\partial \widehat{x}^b}{\partial x^m} = 0. \qquad (45)$$

Since $\partial H / \partial x^b + 1 = 0$ if and only if $\delta^b = 1$ and $\rho = 0$, (45) matches $\partial SW / \partial x^m = 0$ if and only if $\delta^b = 1$, $\delta^m = 0$ and $\rho = 0$.

Finally, we note that the equilibrium level of output given by (7) matches the first-best level of output given by (42) if $\delta^b = 1$ and $\delta^m = 0$.□

Derivation of Eq. (33) First explicitly write the price at which the product trades as a function of the quantity traded, $p = p(q)$. In addition, denote the marginal revenue to the firm as $mr(q)$. Given the equilibrium care choices, $\widehat{x}^b$ and $\widehat{x}^m$, recall from (37) that the consumer's inverse demand

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for the product is

$$p(q) = P(q) - H(\widehat{x}^m, \widehat{x}^b)\delta^b(1 - \rho(\widehat{x}^m)) - \widehat{x}^b.$$

Marginal revenue to the firm is then

$$
\begin{aligned}
mr(q) &= \frac{d}{dq}\left[\left(P(q) - H(\widehat{x}^m, \widehat{x}^b)\delta^b(1 - \rho(\widehat{x}^m)) - \widehat{x}^b\right)q\right] \\
&= P'(q)q + P(q) - H(\widehat{x}^m, \widehat{x}^b)\delta^b(1 - \rho(\widehat{x}^m)) - \widehat{x}^b.
\end{aligned}
\tag{46}
$$

Given $\widehat{x}^b$ and $\widehat{x}^m$, the manufacturer's per-unit expected cost of the product is

$$H(\widehat{x}^m, \widehat{x}^b)(\delta^m + (1 - \delta^m)\rho(\widehat{x}^m)) - \widehat{x}^m. \tag{47}$$

In choosing output $\bar{q}$ the monopolist equates (46) and (47), which gives us (33).