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THE CENTER FOR THE STUDY
OF INDUSTRIAL ORGANIZATION
AT NORTHWESTERN UNIVERSITY

Working Paper #0042

**Manufacturer Liability for Harms Caused by
Consumers to Others**

By

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and

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This paper investigates whether manufacturers should be liable if consumers, through the use of a product, cause harm to others. If consumers have deep pockets then consumer-only liability is socially desirable. With consumer insolvency, however, consumer-only liability leads to inadequate consumer precautions, inadequate safety features, and excessive economic activity. With homogeneous insolvent consumers, the best rule is "residual-manufacturer liability" where the consumer bears primary responsibility and the manufacturer bears the shortfall in damages. When consumers' willingness-to-pay is correlated with social harm they cause then residual-manufacturer liability distorts the market quantity. When consumers differ in their wealth then residual manufacturer liability creates an inefficient cross-subsidization and an overprovision of safety features. In both cases, consumer-only liability may be preferred to residual-manufacturer liability. Applications, including gun manufacturer liability, are discussed.

1. Introduction

Courts have been called upon in recent years to decide whether a manufacturer should be liable if a consumer, through the use of the manufacturer's product, causes injury to another person. The most salient example is the rash of lawsuits filed against firearms manufacturers, which seek to hold them liable for the deaths and injuries caused by the criminal use of guns. Such lawsuits have generally been unsuccessful, but the issue of the gun makers' liability is still hotly discussed in the legal and political arenas.²

This issue is by no means limited to guns. An automobile, for example, may hit a pedestrian, cyclist, or motorist; alcohol consumption increases this risk even further. Motorboat engines can lacerate swimmers. Lawnmowers fling projectiles, harming passersby. Pesticides may poison neighbors' pets and children. Cigarette lighters may burn down apartment buildings. And, even more dramatically, some ordinary crop fertilizers when mixed with gasoline become extraordinarily potent explosives; this is how the bomb that destroyed the Oklahoma City federal building was made. One can, of course, imagine many other products whose use by the consumer creates risks to others, raising the general question whether the manufacturer should be liable for such risks to nonconsumers.³

² By and large, the courts have refused to hold manufacturers liable for the injuries suffered by nonconsumers as a consequence of consumers' use of their products. This refusal has been especially pronounced in cases where the injuries are the result of negligent or criminal conduct by the consumer. The courts' stance has been that the consumer alone is responsible for such misbehavior. And even in cases where the accident was not the consumer's fault, the courts have generally been reluctant to hold the manufacturer liable to the nonconsumer, unless the product malfunctioned. (For example, if a car's brakes fail and a pedestrian is hurt, the pedestrian may be able to recover from the manufacturer, provided that the brake failure is not the consumer's fault.) These limitations on liability have been explicated, and frequently criticized, by legal commentators.

³ To take another example, violent movies or computer games may inspire individuals to commit murder. These, and each of the examples given in the preceding paragraph in the text, have led to lawsuits brought against manufacturers by nonconsumer victims of the product in question.

Manufacturer liability is undesirable when consumers have adequate financial resources and can be held personally liable for non-consumer injuries. In these circumstances, imposing strict liability on the consumers alone is the socially optimal liability rule.⁴ With consumer-only liability, consumers fully internalize the social harm caused by their product use: they bear the cost of their own injuries directly and pay in full for the injuries suffered by others. Consequently, they will take optimal precautions to reduce the probability of accidents, will demand appropriate safety features from the products' manufacturers, and will consume the socially optimal quantities.

When consumers lack the financial resources to fully compensate their victims (or are otherwise judgment proof) then consumer-only liability fails to achieve social optimality -- insolvent consumers will demand cheap, unsafe products and use them dangerously.⁵ When consumers are homogeneous (with identical demand curves, financial assets, and propensities to cause harm) the best strict liability rule holds the manufacturer responsible for the shortfall in

See *Houvenagle v. Wright*, 340 N.W.2d 783 (Ia. App. 1983) (automobile); *Dauphin Deposit Bank and Trust Co. v. Toyota Motor Corp.*, 596 A.2d 845 (Pa. Sup. 1991) (alcohol); *Fitzpatrick v. Madonna*, 623 A.2d 322 (Pa. Sup. 1993) (outboard motor); *Dugan v. Sears, Roebuck & Co.*, 447 N.E.2d 1055 (Ill. App. 1983) (lawnmower); *Mascarenas v. Miles, Inc.*, 986 F. Supp. 582 (W.D. Mo. 1997) (pesticide); *Curtis v. Universal Match Corp.*, 778 F. Supp. 1421 (E.D. Tenn. 1991) (cigarette lighter); *Gaines-Tabb v. ICI Explosives, USA, Inc.*, 160 F.3d 613 (10th Cir. 1998) (fertilizer); *Byers v. Edmondson*, 712 So.2d 681 (La. App. 199) (violent movie); *James v. Meow Media Inc.*, Civ. No. 5:99CV-00096 (W.D. Ky. 1999) (violent computer game).

⁴ Hamada (1976) points out that consumer liability for bystander harm works as well when the bystanders can sue the consumers for damages. Spence (1977) argues out that consumer liability is less desirable when consumers misperceive the product risks.

⁵ This so-called "judgment-proof problem" is formalized in Shavell (1986). One could try to give consumers a greater incentive to take care by using non-financial sanctions, such as greater use of criminal penalties for careless or malicious product use. (This strategy might include requirements that a consumer have a license and/or carry liability insurance, as is done with automobiles.) Note, however, that criminal penalties are costly, and frequently ineffective. Some individuals are undeterred by any feasible threat of criminal liability. But raising the price of products may restrain these "undeterrable" individuals, if only by placing some products out of financial reach. The working assumption in this paper is that the threat of direct liability (civil or criminal) is often insufficient to force consumers to take full account of risks to third parties.

non-consumer damages not covered by the financially-constrained consumer, a rule that we call "*residual-manufacturer liability*."⁶ Although consumers still take inadequate precautions when using risky products, manufacturers will design and produce safer products. Furthermore, the market price will necessarily rise to reflect both the additional investments in safety and the expected future manufacturer liability, leading consumers to choose the efficient level of economic activity.⁷ Residual-manufacturer liability may be undesirable, however, when consumers are heterogeneous.

Suppose that consumers have heterogeneous preferences and heterogeneous propensities to cause social harm. Residual-manufacturer liability leads to distortions when the consumers' elasticity of demand is systematically correlated with the expected social harm that they cause. If consumers with more elastic demands cause more harm on average, then the competitive market will oversupply the product. If consumers with less elastic demands cause more harm, then the competitive market will undersupply the product. Indeed, residual-manufacturer liability may depress the level of economic activity so much that society as a whole would be better off with consumer-only liability.

A numerical example provides intuition for this result. Suppose there is a population of consumers, each of whom demands at most one unit of the good. Each unit costs \$10 to produce. Suppose that 99% of the population causes no harm but 1% causes harm of \$300.

⁶ In a sense, the argument is loosely analogous to that for vicarious liability, i.e., holding employers liable for the negligence of their employees. Sykes, 1998, provides a survey. See also Mattiacci and Parisi, 2002. But unlike the vicarious liability situation, the manufacturer has little control over how the product is used after it is sold. Our approach in this paper is to analyze the significance of such consumer heterogeneity for the issue of manufacturer liability for dangerous products.

⁷ As shown by Shavell (1980), the higher price generally leads to more prudent product use. Shavell (1980) does not discuss residual-manufacturer liability or the heterogeneity issues discussed here.

Furthermore, suppose that the safe consumers value the product less than the harmful consumers: $v_L = \$12.99$ and $v_H = \$310.01$. All consumers are totally insolvent ex-post, while manufacturers have deep pockets. Finally, we assume that the manufacturers cannot discriminate among the different consumer types.⁸

Notice that both types of consumer "should" purchase the product in this example: 99% of the population creates a surplus of \$2.99 while 1% of the population creates a social value of a penny.⁹ With consumer-only liability, competition drives the price down to $p = \$10$, the manufacturers' marginal cost of production. The socially optimal outcome is obtained: all consumers -- safe and unsafe alike -- buy the product. Now consider residual-manufacturer liability. If both types of consumer purchased the product the price would be $p = \$13$, above safe consumers' valuation of \$12.99. So the safe consumers would be driven from the market and the price would subsequently rise to $p = \$310$, the marginal production cost of \$10 plus the expected social harm caused by harmful types, \$300. Only the harmful 1% of the population purchases the product, and, for these harmful consumers, the "social surplus" is just a penny. Social welfare has obviously fallen.¹⁰

Residual-manufacturer liability may also fail when consumers have identical harms and demands but have heterogeneous financial assets. With consumer-only liability, the *solvent* consumers would internalize the damages caused by their product use and would demand safety features and be prudent in their purchase decisions and product use. *Insolvent* consumers, on the other hand, would purchase unsafe products and take too little care. With residual-manufacturer

⁸ Alternatively, one could assume that there is a resale market making price discrimination infeasible: the low harm types could always resell the product to the high harm types.

⁹ The social surplus when the safe consumers purchase the product is $\$12.99 - \$10.00 = \$2.99$ while the social surplus for the unsafe consumers is $\$310.01 - \$10.00 - \$300.00 = \$.01$.

¹⁰ If the social surplus for the unsafe consumers was negative in this example then the market would cease to exist.

liability the solvent consumers may be driven out of the market. Furthermore, in the separating equilibrium the solvent consumers are supplied with excessively safe products. These distortions may be so severe that it is better to impose liability on the consumers alone rather than have the manufacturer bear the shortfall in non-consumer damages.

The issues raised here are distinct from the large literature that focuses on product injuries to consumers. Where injuries to consumers are involved, consumers and manufacturers jointly absorb the costs of such injuries (with the allocation depending on the contract struck between them), and so have a natural joint incentive to take optimal precautions against injury. To put it another way, product injuries to consumers are largely internalized in well-functioning markets (Hamada, 1976; Landes and Posner, 1984 and 1987).¹¹ Even without any manufacturer liability imposed by law, consumers would be willing to pay a premium for safer products that reduce their personal risk and to use risky products prudently. Consequently, the economic arguments for products liability for consumer injuries have focused on situations involving transactions costs and market imperfections. Manufacturer liability for consumer injuries may be desirable, for example, when consumers misperceive product risks (Spence, 1977; Epple and Raviv, 1978; Polinsky and Rogerson, 1983) or manufacturers have private information about the safety of their products or take unobservable actions that affect product safety (Daughety and Reinganum, 1995 and 1997).

The paper is organized as follows. Section 2 presents the basic framework with a representative consumer. Section 3 allows for heterogeneous demand curves and harm propensities, and shows how the desirability of residual-manufacturer liability depends on the correlation between these two factors. Section 4 considers the distortions associated with

¹¹ Early descriptive work includes Calabresi (1961) and McKean (1970).

heterogeneous solvency among consumers. Section 5 concludes. All proofs are given in the appendix.

2. The Basic Framework

We begin with the case of *representative consumer* purchasing a harmful product from a perfectly competitive market. The probability that a single unit of the good will cause an accident is $\pi(x, y)$, where $x \geq 0$ is the manufacturer's investments in product safety and $y \geq 0$ is the consumer's precaution level. The manufacturers' investments in product safety are perfectly observable to the consumer at the time that he makes his purchase decisions. The manufacturers have identical constant-returns-to-scale production technologies with marginal production cost x (we normalize the other production costs to zero). We assume that $\pi(x, y)$ is decreasing in each argument and is strictly convex.¹² Furthermore, we assume that the marginal return from the first dollar of investment is arbitrarily large, $\lim_{x \rightarrow 0} \pi_1(x, y) = -\infty$ and $\lim_{y \rightarrow 0} \pi_2(x, y) = -\infty$.¹³

Conditional upon an accident occurring, the social harm is $h + d$ where $h > 0$ is the harm borne by the consumer directly and $d > 0$ is the harm suffered by third parties.¹⁴ Consumers are said to be insolvent or "judgment-proof" when their future assets, w , are insufficient to cover the damages to third parties, d .¹⁵ In contrast to the consumers, manufacturers are assumed to

¹² If $\pi_{12}(x, y) > 0$ then the precautions are complements and if $\pi_{12}(x, y) < 0$ then the precautions are substitutes where $\pi_{12}(x, y)$ denotes the cross-partial derivative.

¹³ We adopt the notation that $\pi_1(x, y) = \partial \pi(x, y) / \partial x$ and $\pi_2(x, y) = \partial \pi(x, y) / \partial y$. The assumption in the text guarantees the existence of an interior solution.

¹⁴ If $d < 0$, so the activity creates social benefits, then liability will not help to encourage the activity. The "victims" (beneficiaries in this case) would have no incentive to sue. A better policy might be to subsidize the activity instead.

¹⁵ Note that the price that the consumers pay ex ante is not deducted from their future wealth. This assumption is made mostly for convenience, and is quite realistic when accidents are low

have deep pockets. The representative consumer receives a marginal benefit $P(q)$ from consuming the q^{th} unit of the good. This is the inverse demand curve net of any future accident costs and liability concerns.

We consider the class of strict liability rules, $\{\delta^c, \delta^m\}$, that allocate damages $\delta^c \leq w$ to the consumer and δ^m to the manufacturer.¹⁶ Note that this class does not include rules where the liability depends on the actual precautions taken by the manufacturer and the consumer. (Negligence rules, and alternative policies to strict liability, will be discussed in the conclusion.)

2.1 The Social Optimum

Social welfare, which is a function of the market quantity, q , and manufacturer and consumer precautions, x and y , is:

$$S(x, y, q) = \int_0^q [P(z) - \pi(x, y)(h + d) - x - y] dz. \quad (1)$$

Conditional on precautions x and y , the socially optimal quantity sold is $g(x, y)$ where:

$$P(g(x, y)) = \pi(x, y)(h + d) + x + y. \quad (2)$$

At this quantity, the private value of the marginal unit, $P(g(x, y))$, is exactly offset by the expected future harm, $\pi(x, y)(h + d)$, plus the precaution costs, $x + y$. Let $\{x^*, y^*, q^*\}$ be the first-best outcome.¹⁸

probability events. Similar results would be obtained in a world where consumers have deep pockets but there is a low probability of being held responsible for the damages. This may be due to difficulties in attributing harm.

¹⁶ The astute reader will notice that we are implicitly assuming that only one accident can occur for a given consumer. This is justified if accidents occur with a random arrival rate and economic activity ceases after the first accident.

¹⁷ Some may argue that the benefits to injurers from certain activities (e.g. rape) should not be included in the social welfare function. Formally, one could nullify this concern by adjusting the social harm (for example).

2.2 The Competitive Equilibrium

In a competitive market, precautions x and y and the market quantity q are chosen by private parties in the shadow of future liability. Manufacturers compete by offering price-safety pairs, $\{p, x\}$, to attract the representative consumer. They are the "leaders," choosing precautions first, while the consumers are the "followers," subsequently choosing their precautions. The competitive equilibrium, $\{\hat{x}, \hat{y}, \hat{q}\}$, maximizes consumer surplus subject to three constraints:

$$\begin{aligned} \underset{\{p, x\}}{\text{Max}} \quad & \int_0^q [P(z) - \pi(x, y)(h + \delta^c) - y - p] dz & (3) \\ \text{s.t.} \quad & -\pi_2(x, y)(h + \delta^c) - 1 = 0 \\ & P(q) = \pi(x, y)(h + \delta^c) + y + p \\ & p \geq x + \pi(x, y)\delta^m. \end{aligned}$$

The first constraint reflects the fact that consumers choose their precautions, y , to minimize their expected private costs associated with product use, $\pi(x, y)(h + \delta^c) + y$. (Under our assumptions the solution to the associated first-order condition is the unique maximum.) The second constraint reflects the fact that the representative consumer chooses to consume up to the point where his marginal value of consumption, $P(q)$, is exactly offset by his expected marginal cost, $\pi(x, y)(h + \delta^c) + y + p$. The final constraint simply reflects the fact that manufacturers must earn non-negative profit margins.

This program gives us important insights into the desirability of different liability rules. The first constraint suggests that the consumer under-invests in product safety when $\delta^c < d$ and

¹⁸ The first-order conditions are $-\pi_i(x^*, y^*)(h + d) - 1 = 0$ for $i = 1, 2$, and $q^* = g(x^*, y^*)$.

over-invests when $\delta^c > d$. All else equal, consumers should bear full responsibility for the third-party injuries that their product use causes. Second, when the last constraint binds (so manufacturers earn zero profits) then the second constraint implies that the market quantity will satisfy $P(q) = \pi(x, y)(h + \delta^c + \delta^m) + x + y$. Conditional on safety measures x and y , the market quantity (or level of economic activity) is socially optimal if and only if the third-party victim is compensated in full for his damages, $\delta^c + \delta^m = d$. In other words, when $\delta^c + \delta^m = d$ consumer's total cost of consumption reflects all of the ex post social costs, including the harm to third parties.

2.3 Welfare Analysis

Proposition 2.1: If the representative consumer is fully solvent ($w \geq d$) then the first-best market outcome is achieved by the perfectly competitive market if, and only if, the consumer alone pays for third-party damages ($\delta^c = d$ and $\delta^m = 0$). If the representative consumer is insolvent ($w < d$) then the strict liability rule that achieves the highest possible social welfare puts primary responsibility for third-party harm on the consumer and residual responsibility on the manufacturer, ($\delta^c = w$ and $\delta^m = d - w$).

The formal proof is given in the appendix. When consumers are fully solvent, *consumer-only liability* ($\delta^c = d$ and $\delta^m = 0$) leads the representative consumer to fully internalize the social cost of their product use. He demands the socially optimal safety features from manufacturers, invests optimally in precautions, and engages in the appropriate level of economic activity. Consumer-only liability fails to achieve desirable outcomes when the

representative consumer is insolvent: he takes too little care, demands too few safety features, and consumes too much.

A better rule -- indeed the best rule within the class of strict liability rules -- is *residual-manufacturer liability*. The manufacturer who produced the product is held liable for the shortfall in damages when the consumer who caused the accident has insufficient assets to compensate the third-party victim. More generally, this rule is given by $\delta^c = \min\{d, w\}$ and $\delta^m = d - \min\{d, w\}$. When consumers are insolvent, residual-manufacturer liability leads manufacturers to (1) choose appropriate manufacturer precautions and (2) set the price at a level where the market quantity is socially optimal in light of these investments.

2.4 Discussion

The basic model can be extended in number of ways without changing the conclusion. First, the harms caused by an accident can be stochastic instead of deterministic. The harm borne by the consumer, h , can simply be reinterpreted as the mean or expected harm and nothing in the expressions would change. Introducing noise to the third-party damages, d , complicates the analysis somewhat because the general liability rule would need to specify the allocation for each realization of damages, $\{\delta^c(d), \delta^m(d)\}$. Residual-manufacturer liability would still be the optimal rule, however: the consumer would pay for the third-party damages to the extent that his wealth allows, $\delta^c(d) = \min\{d, w\}$, and the manufacturer would bear the shortfall, $\delta^m(d) = d - \min\{d, w\}$.

Other policy instruments, such as taxation and mandatory insurance policies for consumers, will perform well on some -- but not all -- dimensions. These alternative instruments, if carefully chosen, will achieve the desirable level of economic activity. They will

not by themselves get consumers to take additional care or manufacturers to implement socially desirable safety features, however. These alternative instruments would need to be coupled with other instruments -- regulations or negligence-based liability rules perhaps -- in order to mimic all of the benefits of residual-manufacturer liability.

The optimality of residual-manufacturer liability is maintained with some forms of consumer heterogeneity. Importantly, the representative consumer's inverse demand curve $P(q)$ can be reinterpreted as representing a continuum of consumers who differ in the value they place on consuming a single unit of the good. Residual-manufacturer liability is socially desirable so long as the different consumer types all have the same solvency and the same propensity to cause social harm, h . The next two sections highlight why residual-manufacturer liability may be undesirable when these other forms of heterogeneity are introduced.

3. Heterogeneous Risk Posed by Consumers

This section focuses on the problem that arises when consumers differ in both their willingness to pay for the product and also in the social harm that their product use causes. In contrast to the last section, where consumers were homogeneous and residual-manufacturer liability led to socially desirable market outcomes, here we show that residual-manufacturer liability distorts the market quantity when consumers' willingness to pay and the expected social harm are correlated. Indeed, residual-manufacturer liability may create such large distortions in the level of economic activity that it would be better to have no manufacturer liability at all.

The firearms example provides intuition for this last idea. Suppose there are two types of gun buyers, criminals and law abiders, each of whom has unit demand. A gun creates more social harm in the hands of a criminal than in the hands of a law abider. Imagine that criminals

are willing to pay more for firearms than law abiders. Notice that the *marginal purchaser* (i.e. the consumer who is indifferent between buying the gun and not buying the gun at the going price) is more likely to be a law abider than the *average purchaser*. It follows that the marginal purchaser causes less social harm than the average purchaser of the product. Since the strict liability rule "taxes" manufacturers for the average social harm that their products cause (assuming they cannot distinguish the two consumer types), the market price will be inefficiently high and the market quantity inefficiently low. Taken to the extreme, guns will be driven off the market, even if the positive social surplus associated with the use of law abiders outweighs the social losses associated with criminal use.¹⁹ To put it differently, there is a cross-subsidy where low-risk consumers pay for dangers created by the high-risk consumers, and low-risk consumers will therefore be over-deterred from purchasing and using the product.²⁰

3.1 The Model

Suppose there are two types of customers, $i = H, L$. If a type i consumer purchases one unit of the product, the *expected social harm* to third parties is Δ_i .²¹ We assume that type H

¹⁹ Previous commentators have argued that manufacturer liability for gun misuse is optimal, because it will force criminals to internalize the cost of their activity. See Note, *Absolute Liability for Ammunition*, 108 Harv. L. Rev. 1679 (1995); Note, *Manufacturers' Strict Liability for Handgun Injuries: An Economic Analysis*, 73 Geo. L.J. 1437 (1985). The problem with that assertion is that liability will force *law-abiding* gun owners to bear much of the cost of criminal uses, since that cost will probably be built into the price of all guns. Liability will therefore overdeter law-abiding users. A critical question is whether that overdeterrent effect outweighs the benefits of liability. With the exception of Hay's (1999) informal analysis, this is unaddressed in the literature.

²⁰ If instead the consumers' private benefits of consumption were *negatively correlated* with the social harm -- if law abiders cause more social harm than criminals -- then the marginal purchaser causes more social harm than the average purchaser. In this case, residual-manufacturer liability would lead to a price that is too low and a quantity that is too high and is better than consumer-only liability.

²¹ This corresponds to πd from the last section.

consumers cause more social harm than type L consumers: $\Delta_H > \Delta_L > 0$. The inverse demand curve of type i consumers is $P_i(q)$ and we let the corresponding demand curve be $D_i(p)$. As in the simple example above, we assume that consumers do not suffer personal damages from product use ($h = 0$) and are all totally insolvent or judgment proof *ex post* ($w = 0$). Neither the manufacturer nor the consumers take precautions here: manufacturing costs are normalized to zero and there is no "moral hazard" problem for consumers.

Two liability rules will be compared here: *residual-manufacturer liability* and *consumer-only liability*. We will assume that it is impossible for manufacturers to distinguish between the two types of customers and therefore manufacturers *cannot price discriminate*. This is important because, under residual-manufacturer liability, manufacturers face higher expected liability costs when selling to a type H consumer. Indeed, if the consumers' types were observable to manufacturers then type H consumers would be forced to pay a higher price than their type L counterparts.

3.2 The Constrained Social Optimum

Suppose that a social planner can choose the market price, but cannot discriminate between the two different consumer types. The planner chooses the price to maximize social welfare:

$$D_H(p) \int_0^{D_H(p)} [P_H(z) - \Delta_H] dz + D_L(p) \int_0^{D_L(p)} [P_L(z) - \Delta_L] dz$$

Differentiating this expression with respect to the price, p , gives us:

$$\tilde{p} = \frac{\Delta_H D'_H(\tilde{p}) + \Delta_L D'_L(\tilde{p})}{D'_H(\tilde{p}) + D'_L(\tilde{p})} = MH(\tilde{p}) .$$

This equation has a nice interpretation: it says that the second-best market price, \tilde{p} , equals the incremental social harm associated with the sale of one additional unit, or the "marginal social harm," at that price, $MH(\tilde{p})$. Intuitively, suppose that price falls ever so slightly so that exactly one more unit is sold. With probability $D'_H(\tilde{p})/[D'_H(\tilde{p})+D'_L(\tilde{p})]$ the additional unit is sold to a type H consumer, and with probability $D'_L(\tilde{p})/[D'_H(\tilde{p})+D'_L(\tilde{p})]$ it is sold to a consumer of type L. Multiplying these probabilities by the associated social harms, Δ_H and Δ_L , we see that the second-best market price, \tilde{p} , equals the marginal social cost associated with the additional unit.

3.3 The Competitive Equilibrium

With *consumer-only liability*, competition drives the market price down to the marginal cost of production which we have normalized to zero: $p^C = 0$. Since consumers are insolvent *ex post*, the competitive market does not internalize the social harm to nonconsumers and the market quantity (or "level of economic activity") is too high.

With residual-manufacturer liability, the competitive equilibrium price will rise to reflect the manufacturers' future expected liability. Since a manufacturer cannot control who buys his product the manufacturer's expected liability for each unit sold is based on *market averages*. The *average harm* caused by each unit of the product sold when the market price reflects the total social harm, $TH(p) = \Delta_H D_H(p) + \Delta_L D_L(p)$, divided by the total quantity demanded, $D_H(p) + D_L(p)$. In the competitive equilibrium, the market price P^R reflects the manufacturer's expected liability associated with a sale:

$$P^R = \frac{\Delta_H D_H(P^R) + \Delta_L D_L(P^R)}{D_H(P^R) + D_L(P^R)} = AH(P^R).$$

Comparing this expression with the social planner's constrained optimum shows that residual-manufacturer liability will not generally achieve the second-best outcome. Since the average social harm may exceed the marginal social harm and vice versa, residual-manufacturer liability can lead to market quantities that are either too high or too low. Indeed, it may be the case the market quantity is distorted so much by residual-manufacturer liability that it would be better to have consumer-only liability instead.

3.4 Welfare Analysis

The relative desirability of residual-manufacturer liability hinges on the elasticities of demand for the two consumer types, $\varepsilon_H(p)$ and $\varepsilon_L(p)$. For the remainder of this section, we will assume that the two types of consumer can be ranked according to these elasticities, i.e.

either $\varepsilon_H(p) < \varepsilon_L(p)$ for all prices, p , or the reverse where $\varepsilon_i(p) = -\frac{pD'_i(p)}{D_i(p)}$.

Lemma 3.1: The average harm to third parties exceeds the marginal harm, $AH(p) > MH(p)$, if and only if the more harmful consumer group has a less elastic demand than the less harmful group, $\varepsilon_H(p) < \varepsilon_L(p)$.

This result is important for assessing the social desirability of manufacturer liability. If the two groups have the same elasticities, $\varepsilon_H(p) \equiv \varepsilon_L(p)$, then the relative proportions of the two consumer types among all purchasers is the same regardless of the market price. When the "marginal harm" and the "average harm" are the same, the competitive manufacturers appropriately internalize the harms that their products cause to nonconsumers. In this special

case, strict liability yields the second-best market outcome because the competitive market sets the correct market price. When $\varepsilon_H(p) \neq \varepsilon_L(p)$, however, then the marginal harm and the average harm will typically diverge and so the second-best is not obtained.

Proposition 3.2: The equilibrium market prices under consumer-only liability (p^C) and residual-manufacturer liability (p^R) may be ranked with respect to the constrained social optimum (\tilde{p}). When $\varepsilon_H(p) \equiv \varepsilon_L(p)$, we have $p^R = \tilde{p} > p^C$; when $\varepsilon_H(p) > \varepsilon_L(p)$ we have $\tilde{p} > p^R > p^C$; and when $\varepsilon_H(p) < \varepsilon_L(p)$ we have $p^R > \tilde{p} > p^C$.

When $\varepsilon_H(p) > \varepsilon_L(p)$ then the harmful consumers have a more elastic demand curve than the less harmful group. According to the lemma, the *average harm* is less than the *marginal harm*. The competitive market is being "under-taxed" (so to speak) for the product and so the equilibrium price is too low. Although the second-best outcome is not achieved, it is easy to see that residual-manufacturer liability is preferred to consumer-only liability. Although it does not achieve the first-best outcome, residual-manufacturer liability performs better than consumer-only liability.

When $\varepsilon_H(p) < \varepsilon_L(p)$, on the other hand, the more harmful consumer group has a less elastic demand curve than the less harmful group. The *average harm* exceeds the *marginal harm* in this case and so the manufacturers are being "over-taxed" under residual-manufacturer liability. The equilibrium market price is too high and the equilibrium market quantity is too low. To put it another way, the low risk consumers are being inefficiently driven out of the market because they are forced to subsidize their high-risk counterparts. The next proposition

states that consumer liability becomes more desirable (relative to residual-manufacturer liability) when the distance between the harm levels caused by the two types increases.

Proposition 3.3: If Δ_H rises and Δ_L falls while holding the average harm $AH(p)$ at price p^R fixed, then (i) social welfare under consumer-only liability rises if and only if $\varepsilon_H(p) < \varepsilon_L(p)$ and (ii) social welfare under residual-manufacturer liability is unchanged.

3.5 Discussion

We have seen that residual-manufacturer liability can have disastrous market consequences when the harmful consumers are less price sensitive than their less harmful counterparts. This is quite intuitive. When the harmful consumers have a relatively inelastic demand, the harm caused by the average consumer who purchases the product exceeds the harm caused by the marginal consumer. The residual-manufacturer liability rule induces the competitive manufacturers to raise the price above the socially optimal level, creating a chilling effect on economic activity. The consumers who cause the least social harm are the first to be driven from the market; the consumers who cause the most social harm are the ones more likely to remain. In these situations, consumer-only liability may be preferable because it keeps the less harmful consumers in the market.²²

Social welfare would of course be higher if an all-knowing social planner could fine-tune the policies to reflect the marginal harms instead. Damage multipliers could provide such an instrument: the multiplier would be less than one when consumers with less elastic demands

²² Consumer-only liability may, of course, have a host of unfortunate consequences as well. As shown in section 2, manufacturers will take insufficient safety precautions in designing their products and the consumers' level of economic activity will be too high.

cause more social harm and greater than one when the less elastic consumers cause less social harm. Alternatively, the social planner could impose a tax on the market to reflect the marginal social harm. Both policies would require that the court understand a host of market characteristics including the nature of demand curves, harm levels, and correlations, etc. Furthermore, both alternatives would compromise the desirable impact manufacturer liability has on the design of product safety features.

4. Heterogeneous Financial Assets

This section introduces a second kind of consumer heterogeneity: heterogeneous financial assets. Proportion θ of the consumer population, the "type 0" consumers, are completely insolvent following an accident ($w_0 = 0$). Proportion $1 - \theta$ of the consumer population, the "type 1" consumers, are fully solvent ($w_1 > d$). Following the notation from Section 2, the socially-efficient precautions are the same for the two groups, $x_0^* = x_1^* = x^*$ and $y_0^* = y_1^* = y^*$. Finally, we assume that the probability of an accident is additively separable in manufacturer and consumer precautions, or equivalently $\pi_{12}(x, y) = 0$. This assumption simplifies the analysis because a consumer's choice of precautions, y , is independent of the product's safety features, x .

As in Section 2, consumers care both about price and product safety features. We will characterize incentive-compatible pairs of product offerings, $\{p_0, x_0\}$ and $\{p_1, x_1\}$, where the judgment-proof consumers select the former product and the solvent consumers select the latter product. A pair of product offerings is a competitive equilibrium if no manufacturer can earn positive profits by deviating to a different price-safety combination. The equilibrium is said to be *pooling* when $\{p_0, x_0\} = \{p_1, x_1\}$ and *separating* otherwise.

4.1 Example

To start, let's ignore precautions and assume that the probability of an accident is exogenously given and identical for solvent and insolvent consumers: $\pi = 1/3$. Suppose further that the consumers all have unit demands with valuation v (which we will vary). The consumers do not bear any direct harm from an accident, $h = 0$, but third-parties suffer damages in the event of an accident, $d = 12$. Finally, suppose that half of all consumers are insolvent ($\theta = 1/2$). We will see that both consumer-only liability and residual-manufacturer liability are inefficient and lead to very different economic distortions.

Let's start with the case of consumer-only liability. The competitive manufacturers drive the price down to marginal cost, normalized to zero. A solvent consumer internalizes all of the social harm that his product use causes and purchases when $v \geq \pi d = 4$, the socially efficient outcome. The insolvent consumers do not internalize the third-party harms, purchasing the product whenever $v > 0$. In other words, consumer-only liability leads to an efficient level of economic activity for the solvent consumers but an excessive level for the insolvent consumers.

Residual-manufacturer liability, on the other hand, leads to the efficient outcome for the insolvent consumers but insufficient quantities for the solvent consumers. To see why, suppose that both types of consumers are served in the competitive equilibrium. The equilibrium price would reflect the average manufacturer liability, or $p = \theta \pi d = 2$. The solvent consumers are willing to purchase the product when $v \geq \pi d + \theta \pi d = 6$. This decision rule is socially inefficient because consumers "should" purchase the product when $v > \pi d = 4$. Intuitively, a distortion arises because the solvent consumer pays twice for the third-party harm: through his own personal liability ex post, and also through the inflated price. If all of the solvent consumers are

driven out of the market, the market price rises to $p = \pi d = 4$ to reflect the liability cost associated with insolvent consumers only and the insolvent consumers subsequently make the efficient purchase decision.

This example suggests that residual-manufacturer liability will be preferred when there are many insolvent consumers in the population, but is inferior when the proportion is low. The next sub-sections extend this basic insight to the more general case where the precautions of the manufacturers and consumers are choice variables and demand curves are downward sloping.

4.2 Consumer-Only Liability

With consumer-only liability consumers are responsible for third-party injuries to the extent that their wealth allows. The third-party victim is made whole when the consumer is fully solvent, $\{\delta_1^c, \delta_1^m\} = \{d, 0\}$, but goes uncompensated when the consumer is insolvent, $\{\delta_0^c, \delta_0^m\} = \{0, 0\}$.

As a benchmark, suppose that there is complete information about the consumers' types. From Section 2 we know that, for the solvent consumers, the precaution levels (x^*, y^*) minimize the total social costs associated with a sale, $\pi(x, y)(h + d) + x + y$. The precaution levels for the insolvent consumers, on the other hand, would minimize the total private costs associated with a sale, $\pi(x, y)h + x + y$ and so the equilibrium precautions, $(\underline{x}, \underline{y})$, are too low. The next proposition states that this outcome is obtained with incomplete information as well.

Proposition 4.1: In the unique competitive equilibrium with consumer-only liability, the solvent consumers purchase $\{p_1^C, x_1^C\} = \{x^*, x^*\}$ and the insolvent consumers purchase

$\{p_0^C, x_0^C\} = \{\underline{x}, \underline{x}\}$ where $\underline{x} < x^*$. The solvent consumers take the efficient precautions, $y_1^C = y^*$, and consume the right amount, $q_1^C = g(x^*, y^*)$. The insolvent consumers underinvest in precautions, $y_0^C = \underline{y} < y^*$, and consume too much, $q_0^C = g(\underline{x}, \underline{y})$.

The insolvent customers do not care enough about safety and the competitive market gives them exactly what they want: a cheap and relatively dangerous product. They subsequently put in too little care to avoid accidents and consume too much. The fully solvent consumers, on the other hand, are held personally accountable for any third-party damages and therefore demand safer products from the manufacturers, $x_1^C = x^*$, and use them prudently, $y_1^C = y^*$. The competitive market supplies the solvent consumers "efficiently." When $\theta = 0$ all consumers are fully solvent and consumer liability alone achieves the first-best market outcome. Social welfare is clearly falling in θ , the proportion of insolvent consumers.

4.3 Residual-Manufacturer Liability

Suppose instead that the manufacturer is responsible for the shortfall in damages not paid by the insolvent consumer. The third-party victim is compensated in full by the consumer if the consumer is fully solvent, $\{\delta_1^c, \delta_1^m\} = \{d, 0\}$, and is compensated in full by the manufacturer if the consumer is insolvent, $\{\delta_0^c, \delta_0^m\} = \{0, d\}$. As a benchmark, suppose that there is full information and that the competitive manufacturers can discriminate between the two consumer types, setting a different safety-price pair for each.

Lemma 4.2: Suppose the consumers' *types are observable*. With residual-manufacturer liability, the market offers $\{p_1^R, x_1^R\} = \{x^*, x^*\}$ to the solvent consumers and $\{p_0^R, x_0^R\} = \{x^* + \pi(x^*, \underline{y})d, x^*\}$ to the insolvent consumers. The fully solvent consumers take the efficient level of precautions, $y_1^R = y^*$, while the insolvent consumers take too few precautions, $y_0^R = \underline{y} < y^*$. Conditional on the precautions levels, the efficient market quantities are obtained.

With full information and residual-manufacturer liability, the competitive firms choose the socially optimal precautions, $x_0^R = x_1^R = x^*$, but set different prices for the two groups. The fully solvent consumers are cheap to serve because there is no future "shortfall" for the manufacturers to pay. Consequently, p_1^R reflects the marginal production cost only. Insolvent consumers, on the other hand, are expensive to serve since the manufacturer is liable for the social harm that the insolvent consumers cause. The price that the insolvent consumers must pay, $x^* + \pi(x^*, \underline{y})d$, includes a premium to reflect the anticipated future liability of the manufacturer. To put it somewhat differently, solvent consumers pay *ex post* for the harm that they cause while the insolvent consumers pay *ex ante* through a *higher market price*.

This full-information benchmark is not sustainable when the consumers' types are unobservable. Since the insolvent consumers pay a higher price than their solvent counterparts, $p_0^R > p_1^R$, the insolvent consumers would obviously *pretend* to be solvent in order to secure the lower price. In other words, the full-information outcome in Lemma 4.2 is not incentive compatible.

Lemma 4.3: Suppose the consumers' types are not observable. A pooling equilibrium does not exist with residual-manufacturer liability.

This result is quite intuitive. If a pooling equilibrium did exist, the market price would have to be inflated to reflect the manufacturers' liability associated with the insolvent consumers. Consumers who are solvent face personal liability of third-party harm, and therefore place greater weight on product safety than their insolvent counterparts. A clever manufacturer could skim off these safety-sensitive consumers in the following way: *offer a safer product at a price that only the solvent consumers would prefer*. The manufacturer would then avoid future liability himself and earn a positive profit margin.

This intuition is applicable in understanding the separating equilibrium as well. The market supplies a product with optimal built-in manufacturer precautions to the insolvent consumers who pay for manufacturers' future liability up front through an inflated price. If the solvent consumers purchased this product, too, they would effectively have to pay twice for liability: once up front through the market price and then later on when a third party is suffers damages. But the competitive market supplies the solvent consumers with a very different product -- a safer product at a higher price. This ultra-safe product is priced "fairly" -- the solvent consumers are only paying the manufacturing costs and so their purchase decisions are efficient given the safety measures. But the safety measures themselves are inefficiently high.

Proposition 4.4: Suppose that consumers' types are unobservable. With residual-manufacturer liability there exists a unique separating equilibrium when θ , the proportion of insolvent consumers, is not too small. The fully solvent consumers purchase $\{p_1^R, x_1^R\} = \{\bar{x}, \bar{x}\}$ where

$\bar{x} > x^*$ and the insolvent consumers purchase $\{p_0^R, x_0^R\} = \{x^* + \pi(x^*, \underline{y})d, x^*\}$.²³ The fully solvent consumers take the efficient precautions, $y_1^R = y^*$, while the insolvent consumers take too few precautions, $y_0^R = \underline{y} < y^*$. Conditional on the precaution levels, the efficient market quantities are obtained.

When θ , the proportion of insolvent consumers, is small then a competitive equilibrium fails to exist. The reason is simple: a clever manufacturer could profitably deviate from the separating equilibrium and offer a product with optimal safety features (x^*) and a relatively low price that both consumer types would prefer. This is analogous to Rothschild and Stiglitz's (1976) famous result that competitive insurance markets may have no equilibrium.

Many authors have suggested changes to the Rothschild-Stiglitz timing that serve to restore the existence of equilibrium. Riley (1979) proposed a dynamic adjustment process where firms could modify their product offerings in light of a deviation. Our separating equilibrium in Proposition 4.4 is a so-called "Reactive Equilibrium" when θ is low as well. The idea behind this is that if a deviator did indeed make an offer that both types of consumer preferred, then another firm could react to this deviation and skim off the solvent consumers along the lines of Lemma 4.3. The robustness of the separating equilibrium for low θ is sensitive to the particular dynamic process, however. Indeed, Wilson (1977) restored the existence of a pooling equilibrium in Rothschild-Stiglitz by allowing the non-deviating firms to withdraw, but not modify, their offers in light of a deviation. These extensions, and other refinements, are surveyed in Riley (2001).

²³ The value \bar{x} is endogenous and implicitly defined by $x^* + \pi(x^*, \underline{y})(h + d) = \bar{x} + \pi(\bar{x}, \underline{y})h$. The proof is given in the appendix.

4.4 Discussion

We end this section by comparing the outcomes in Propositions 4.1 and 4.4. With consumer-only liability the competitive market provided the solvent consumers with efficient safety features, $x_1^C = x^*$, but the insolvent consumers with inefficiently low levels of safety features, $x_0^C = \underline{x}$. On the other hand, with residual-manufacturer liability the market supplies efficient safety features to the insolvent consumers, $x_0^R = x^*$, but excessive safety features to the solvent customers, $x_1^R = \bar{x}$. Not surprisingly, the former outcome is preferred when there are sufficiently many solvent consumers in the population but not when the population is dominated by insolvent consumers.

Proposition 4.5 There exists a cutoff, $\theta'' \in (0, 1)$. If the proportion of insolvent consumers is above this cutoff, $\theta > \theta''$, then the separating outcome with residual-manufacturer liability is strictly preferred to the equilibrium with consumer-only liability. If the proportion of insolvent consumers is below this cutoff, $\theta \leq \theta''$, then consumer-only liability is preferred.

5. Conclusion

There are sound economic reasons to hold manufacturers liable for the injuries that their products cause to non-consumers. Since consumers typically cannot be held responsible for 100% of the harms that they cause, placing liability on consumers alone will lead to the over-consumption of products with inadequate safety features. In a representative-consumer framework, the best strict liability rule holds the consumer liable for third-party damages up to

the point that their financial assets allow, and then holds the manufacturer liable for the shortfall in damages.²⁴ However, when consumers are heterogeneous, residual-manufacturer liability can lead to undesirable distortions in the market quantities and safety features.

The formal analysis in this paper ignored the costs of the legal system and assumed that victims were automatically compensated for their losses. Holding manufactures liable would only make practical sense if the shortfall in damages not paid by consumers (and the associated benefits of manufacturer liability) was large enough to justify the added expense and transactions costs associated with the litigation process. Residual-manufacturer liability may also backfire if overly-sympathetic juries grant astronomical jury awards, chilling the economic activity. (Note, however, that damage caps may control runaway jury awards and restore the proper market outcomes.)

As mentioned earlier, taxes may be a viable alternative to residual-manufacturer liability.²⁵ The optimal tax, which would reflect the marginal social harm, could be imposed on either the manufacturers or the consumers. Although taxation may have lower transactions costs than residual-manufacturer liability, it has several important drawbacks. First, the planner would require both the time and the ability to fine-tune the taxes on a market-by-market basis. Second, a tax by itself would provide inadequate incentives for manufacturers to design safer products. A negligence rule that holds manufacturers liable if their safety features fall short of acceptable levels -- or regulations geared at product safety directly -- may prove useful supplements to taxation. Note, however, that liability has the advantage of putting responsibility for safety in

²⁴ The asymmetry in the treatment comes from the assumption that consumers observe product attributes at the time of purchase but manufacturers cannot observe or control consumer care.

²⁵ See Carlton and Loury, 1980 and Hamilton, 1998, for discussions of Pigouvian taxation in the liability context.

the hands of experts -- manufacturers are surely better informed about the feasibility of product modifications than regulators.

Alternatively, consumers of risky products could be forced to hold insurance policies. If insurance providers cannot discriminate among the different types of consumers, then the competitive insurance premiums would reflect the average rather than the marginal harm and the market quantity would be distorted. Furthermore, in the absence of manufacturer liability and other regulations product safety regulations, manufacturers would have insufficient incentives to produce safer products. In sum, mandatory insurance leads to the same distortions as taxation.

The results of this paper raise the natural question -- and concern -- about where the chain of corporate responsibility should end. The model assumed a single manufacturer, but harmful activities will often involve multiple products and multiple suppliers. Guns, for example, are especially dangerous when they are loaded with bullets. Should the ammunition manufacturer be held liable for deaths and injuries as well? Timothy McVeigh created the bomb that destroyed the Oklahoma City Federal Building by loading a mixture of fertilizer with diesel fuel -- purchased at a Conoco service station -- into a rented Ryder truck. Should Conoco and Ryder be held responsible for the 168 lives that were lost?

A stark implication from the formal analysis is that -- absent supplier incentive and consumer heterogeneity issues -- the level of the harmful activity will be optimal when *the sum of the expected liabilities* of all contributing components is equal the expected harm.²⁶ But clearly incentives are important. All else equal, a greater share should be borne by those who are in a better position to reduce the probability or the magnitude of social harm. Manufacturers should be given the incentive to design and produce safer products. Retailers of dangerous

²⁶ Also, placing liability on a smaller number of suppliers should reduce the administrative costs associated with liability.

products need incentives to conduct customer background checks, institute waiting periods, and the like. Consumer heterogeneity is also important. If a key component of a harmful activity is a product that is particularly valuable only for that one harmful activity, then suppliers of that component should bear the burden of liability.²⁷

Even when incentive issues are absent, the problem of optimally assigning liability to products and services which may jointly be used to conduct harmful activities is complicated and analogous to an optimal tax problem. The social planner would like to "tax" the harmful activity directly, but the activity can only be proxied by a bundle of necessary components. The tax burden should then be allocated to minimize the deadweight loss in the respective markets.²⁸ In the fertilizer bomb example above, placing primary responsibility on fuel companies would probably be a policy mistake. The burden of liability would fall on the legitimate diesel fuel users whose durable equipment is dedicated to diesel fuel use -- the deadweight loss would be large. Placing liability on ammonium nitrate manufacturers, on the other hand, may make more sense. As the price of ammonium nitrate rises, the primary users -- farmers and landscapers -- may tend to substitute to harmless alternatives (such as ammonium sulfate). If the harmless alternative is a good substitute, then the deadweight loss associated with residual-manufacturer

²⁷ The Black Talon, for example, is an exploding bullet designed for the purpose of maiming victims. In one case, suburban commuters were shot by a deranged individual named Colin Ferguson. The victims sued the bullet's manufacturer, claiming that the product was excessively dangerous. The court threw the case out on the pleadings, explaining: "The very purpose of the Black Talon bullet is to kill or cause severe wounding. Here, plaintiffs concede that the Black Talons performed precisely as intended by the manufacturer." *McCarthy v. Olin Corp.*, 119 F.3d 148, 155 (2d Cir. 1997).

²⁸ At the optimum, it is not necessarily the case that the level of the harmful activity will be socially optimal. The social planner has to trade off the need to chill the harmful activity against the costs of distorting the safe activity.

liability will be small.²⁹ These, and other extensions of the basic analysis, remain fruitful areas for further research.

²⁹ The Philippines recently outlawed the import of ammonium nitrate. See "'Explosive' Fertilizer Material Banned," *Philippine Daily Inquirer*, November 26, 2002. There is some concern about the fate of the mango fruit industry, the main legitimate consumer of the ammonium nitrate. Proponents of the ban argue that farmers can easily substitute to ammonium sulfate instead.

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7. Appendix

Proof of Proposition 2.1: As a benchmark, suppose a social planner could *directly* choose manufacturer precautions, x , the market quantity, q , and the consumer's liability, δ^c . The representative consumer remains free to choose his own precautions, y , and does so to minimize his expected costs: $\pi(x, y)(h + \delta^c) + y$. Later, we will show that the competitive market achieves this benchmark.

Our earlier assumptions guarantee a unique interior solution for the representative consumer's optimization problem. Consumer precautions may be written as an implicit function of the manufacturer precautions, x , and the liability rule, δ^c : $y = f(x, \delta^c)$. Our assumptions also imply that $f_{\delta}(x, \delta^c) > 0$ (i.e. the consumer takes more care when his personal liability is higher). Holding x fixed, if $\delta^c < d$ ($\delta^c > d$) then the consumer under-invests (over-invests) in precautions relative to what a social planner would do. Therefore the best liability rule in this benchmark case has $\delta^c = \min\{d, w\}$. Substituting this into the social welfare function in (1), the social planner would choose x and q to maximize:

$$\int_0^q [P(z) - \pi(x, f(x, \min\{d, w\}))(h + d) - x - f(x, \min\{d, w\})] dz .$$

The solution, $\{x^{**}, y^{**}, q^{**}\}$, satisfies:

$$x^{**} = \arg \min_x \pi(x, f(x, \min\{d, w\}))(h + d) + x + f(x, \min\{d, w\}), \quad (3')$$

$$y^{**} = f(x^{**}, \min\{d, w\}),$$

$$P(q^{**}) = \pi(x^{**}, y^{**})(h + d) + x^{**} + y^{**}.$$

Now we will compare this benchmark solution, $\{x^{**}, y^{**}, q^{**}\}$, to the competitive equilibrium defined by the program in (3), $\{\hat{x}, \hat{y}, \hat{q}\}$.

Claim: $\{\hat{x}, \hat{y}, \hat{q}\} = \{x^{**}, y^{**}, q^{**}\}$ if and only if $\delta^c = \min\{d, w\}$ and $\delta^m = d - \min\{d, w\}$.

Proof of claim: It is clear that the last constraint in program (3) binds, $p = x + \pi(x, y)\delta^m$. Since consumer surplus is falling in p , the market price, the competitive manufacturers' profit margins are driven to zero. We can substitute this zero-profit condition and the constraint that $y = f(x, \delta^c)$ (which is equivalent to the first constraint in (3)) into the objective function. The new program is:

$$\begin{aligned} \text{Max}_x \int_0^q [P(z) - \pi(x, f(x, \delta^c))(h + \delta^m + \delta^c) - x - f(x, \delta^c)] dz & \quad (3'') \\ \text{s.t.} \quad P(q) = \pi(x, y)(h + \delta^c + \delta^m) + x + f(x, \delta^c) & \end{aligned}$$

Since quantity q is chosen optimally given x and y , the envelope theorem tells us that we can disregard the affect on quantity q when looking for the manufacturer's precaution choice, x . The competitive equilibrium, $\{\hat{x}, \hat{y}, \hat{q}\}$, is therefore the solution to the following system of equations:

$$\begin{aligned} \hat{x} &= \arg \min_x \pi(x, f(x, \delta^c))(h + \delta^c + \delta^m) + x + f(x, \delta^c) & (3''') \\ \hat{y} &= f(\hat{x}, \delta^c) \\ P(\hat{q}) &= \pi(\hat{x}, \hat{y})(h + \delta^c + \delta^m) + \hat{x} + \hat{y}. \end{aligned}$$

$\{\hat{x}, \hat{y}, \hat{q}\}$ corresponds to the benchmark outcome $\{x^{**}, y^{**}, q^{**}\}$ defined above if and only if $\delta^c = \min\{d, w\}$ and $\delta^m = d - \min\{d, w\}$. Finally, if $\delta^c = d$ and $\delta^m = 0$ then the first-best is obtained: $(\hat{x}, \hat{y}, \hat{q}) = (x^{**}, y^{**}, q^{**}) = (x^*, y^*, q^*)$.

Q.E.D.

Proof of Lemma 3.1: $AH(p) > MH(p)$ is true if and only if:

$$\frac{\Delta_H D_H(p) + \Delta_L D_L(p)}{D_H(p) + D_L(p)} > \frac{\Delta_H D'_H(p) + \Delta_L D'_L(p)}{D'_H(p) + D'_L(p)}. \quad \text{Cross multiplying (and recognizing that}$$

$D'_H(p) + D'_L(p) < 0$) gives:

$$[\Delta_H D_H(p) + \Delta_L D_L(p)][D'_H(p) + D'_L(p)] < [\Delta_H D'_H(p) + \Delta_L D'_L(p)][D_H(p) + D_L(p)].$$

Rearranging terms:

$$[\Delta_H - \Delta_L]D_H(p)D'_L(p) < [\Delta_H - \Delta_L]D'_H(p)D_L(p).$$

The $[\Delta_H - \Delta_L]$ term is positive (by assumption) and cancels. Dividing both sides by $D_H(p)D_L(p)$ and multiplying by $-p$ gives:

$$-\frac{pD'_L(p)}{D_L(p)} > -\frac{pD'_H(p)}{D_H(p)},$$

and so we have $\varepsilon_L(p) > \varepsilon_H(p)$.

Q.E.D.

Proof of Proposition 3.3: With no liability, the market price is $p^C = 0$ regardless of the social harm. The social welfare at this price does depend on the social harm, however. Differentiating the social welfare function with respect to Δ_H and recognizing that Δ_L is an implicit function of Δ_H gives us:

$$\frac{d\Omega(p^C)}{d\Delta_H} = -D_H(p^C) - \left(\frac{d\Delta_L(\Delta_H)}{d\Delta_H} \right) D_L(p^C).$$

Since the average harm is constant, total differentiation gives us

$$\frac{d\Delta_L(\Delta_H)}{d\Delta_H} = -\frac{D_H(p^R)}{D_L(p^R)}.$$

Substituting this expression, $\frac{d\Omega(p^C)}{d\Delta_H} > 0$ if and only if $-D_H(p^C) + \left(\frac{D_H(p^R)}{D_L(p^R)} \right) D_L(p^C) > 0$,

which is true if and only if $\frac{D_H(p)}{D_L(p)}$ is increasing in price. Differentiating this expression shows

that this is true when $\varepsilon_H(p) < \varepsilon_L(p)$ everywhere. Finally, since the average harm at price p^R does not change, the competitive market quantity and price will not change. It follows that total social cost remains unchanged as well. Therefore $\Omega(p^R)$ is unchanged.

Q.E.D.

Proof of Proposition 4.1: Suppose there is full information. It follows from Proposition 2.1 that the solvent consumers will be efficiently supplied, $\{x_1^C, y_1^C, q_1^C\} = \{x^*, y^*, q^*\}$. The insolvent

consumers demand precautions where $\pi_i(x, y)h + 1 = 0$, so $x_0^C = \underline{x} < x^*$ and $y_0^C = \underline{y} < y^*$. The market price is x^* for the solvent consumers and \underline{x} for the insolvent consumers. Since incentive compatibility is satisfied, this is also the equilibrium when there is incomplete information.

Q.E.D

Proof of Lemma 4.2: As with consumer only liability, the solvent consumers will be efficiently supplied, $\{x_1^R, y_1^R, q_1^R\} = \{x^*, y^*, q^*\}$. The insolvent consumers take the same low level of precautions as before, $y_0^R = \underline{y} < y^*$, and the manufacturer precautions come from expression (3'),

$$\text{Max}_x \int_0^q [P(z) - \pi(x_0^R, \underline{y})(h + d) - x_0^R - \underline{y}] dz . \text{ Therefore } x_0^R = x^* \text{ and the zero-profit conditions}$$

$$\text{gives } p_0^R = x^* + \pi(x^*, \underline{y})d .$$

Q.E.D

Proof of Lemma 4.3: Suppose a pooling equilibrium, $\{\hat{p}, \hat{x}\}$, did exist and let $\hat{\theta}$ be the proportion of insolvent types. The zero-profit condition for the manufacturers implies that

$$\hat{p} = \hat{x} + \hat{\theta}\pi(\hat{x}, \underline{y})d .$$

In other words, the market price covers the costs of production, \hat{x} , plus the future expected liability associated with the insolvent consumers. Consider the following deviation: $\{\tilde{p}, \tilde{x}\}$ where $\tilde{p} = \hat{p} + \rho$ and $\tilde{x} = \hat{x} + \varepsilon$ where $\rho > 0$ and $\varepsilon > 0$. The insolvent consumer prefers $\{\hat{p}, \hat{x}\}$ to $\{\tilde{p}, \tilde{x}\}$ and the solvent consumer prefers $\{\tilde{p}, \tilde{x}\}$ to $\{\hat{p}, \hat{x}\}$ when

$$[\pi(\hat{x}, \underline{y}) - \pi(\hat{x} + \varepsilon, \underline{y})]h < \rho < [\pi(\hat{x}, y^*) - \pi(\hat{x} + \varepsilon, y^*)](h + d) .$$

Additive separability implies that $\pi(\hat{x}, \underline{y}) - \pi(\hat{x} + \varepsilon, \underline{y}) = \pi(\hat{x}, y^*) - \pi(\hat{x} + \varepsilon, y^*)$. For any $\varepsilon > 0$ this condition is satisfied by a range of positive ρ 's. The manufacturer offering this new product would receive positive profits when $\tilde{p} > \tilde{x}$, which after substituting \tilde{p} and \tilde{x} gives:

$$\rho > \hat{x} + \varepsilon - \hat{p} ,$$

and substituting for \hat{p} gives us:

$$\rho > \varepsilon - \hat{\theta}\pi(\hat{x}, \underline{y})d$$

When ε is sufficiently small then this condition is satisfied for any $\rho > 0$, and therefore holds for the range identified earlier.

Q.E.D.

Proof of Proposition 4.4:

Claim: In any separating equilibrium the firms earn zero profits, or equivalently $\{p_1^R, x_1^R\} = \{x_1^R, x_1^R\}$ and $\{p_0^R, x_0^R\} = \{x_0^R + \pi(x_0^R, \underline{y})d, x_0^R\}$.

Proof of claim: First, suppose $p_0^R > x_0^R + \pi(x_0^R, \underline{y})d$. A profitable deviation exists. Suppose a manufacturer deviates and offers a slightly lower price: $\{p_0^R - \rho, x_0^R\}$. All insolvent consumers prefer this new contract and so the deviator captures the entire type 0 market. If the solvent consumers prefer it, too, then all the better since the cost of serving a solvent consumer is lower.

Second, suppose that $p_1^R > x_1^R$. The incentive compatibility constraint for the insolvent consumer holds that: $p_0^R + \pi(x_0^R, \underline{y})h \leq p_1^R + \pi(x_1^R, \underline{y})h$. Consider a deviation where a manufacturer offers a slightly higher price and quantity, $\{p_1^R + \rho, x_1^R + \varepsilon\}$, that gives the insolvent consumer the same value as $\{p_1^R, x_1^R\}$, $p_1^R + \rho + \pi(x_1^R + \varepsilon, \underline{y})h = p_1^R + \pi(x_1^R, \underline{y})h$, or

$$\rho = [\pi(x_1^R, \underline{y}) - \pi(x_1^R + \varepsilon, \underline{y})]h.$$

The solvent consumers prefer this deviation when

$$p_1^R + \rho + \pi(x_1^R + \varepsilon, y^*)(h + d) < p_1^R + \pi(x_1^R, y^*)(h + d), \text{ or}$$

$$\rho < [\pi(x_1^R, y^*) - \pi(x_1^R + \varepsilon, y^*)(h + d)].$$

The value of ρ above and the assumption of additive separability guarantees that this is true.

Claim: $x_0^R = x^*$.

Proof of claim: As we showed earlier, $\{p_0^R, x_0^R\} = \{x^* + \pi(x^*, \underline{y})d, x^*\}$ creates the highest social

welfare for the insolvent consumers subject to the zero profit constraint. If $\{p_0^R, x_0^R\}$ did not have this form, then a profitable deviation would exist. $\{x^* + \pi(x^*, \underline{y})d, x^*\}$ would attract all of the insolvent consumers (and possibly the solvent ones, too -- a good thing).

Claim: $x_1^R = \bar{x} > x^*$ where \bar{x} is the implicit solution to: $x^* + \pi(x^*, \underline{y})(h+d) = \bar{x} + \pi(\bar{x}, \underline{y})h$.

Proof of Claim: Given the two claims proved earlier, the IC constraints for the two types are:

$$(IC_0): \quad x^* + \pi(x^*, \underline{y})(h+d) \leq x_1^R + \pi(x_1^R, \underline{y})h,$$

$$(IC_1): \quad x_1^R + \pi(x_1^R, y^*)(h+d) \leq x^* + \pi(x^*, \underline{y})d + \pi(x^*, y^*)(h+d).$$

(IC₀) implies that $x_1^R > x^*$. If (IC₀) were slack, then the solvent consumers could be made better off by lowering x_1^R closer to x^* . It is not hard to see that if (IC₀) binds then (IC₁) is slack.

Rewriting a binding (IC₀) as $x^* + \pi(x^*, \underline{y})d = x_1^R + [\pi(x_1^R, \underline{y}) - \pi(x^*, \underline{y})]h$ and substituting into the right hand side of (IC₁) gives $x_1^R + \pi(x_1^R, y^*)(h+d) \leq x_1^R + [\pi(x_1^R, \underline{y}) - \pi(x^*, \underline{y})]h + \pi(x^*, y^*)(h+d)$, and rearranging terms we have

$$[\pi(x^*, \underline{y}) - \pi(x_1^R, \underline{y})]h \leq [\pi(x^*, y^*) - \pi(x_1^R, y^*)(h+d)].$$

The two large terms in brackets are equal with additive separability, so (IC₁) is indeed slack and $x_1^R = \bar{x}$ as defined in the claim.

Claim: When θ is sufficiently large there does not exist a pooling deviation that both solvent and insolvent consumers prefer.

Proof of claim: Consider a deviation from the proposed separating equilibrium, $\{\tilde{p}, \tilde{x}\}$, that is preferred by both consumer types and let $\tilde{\theta}$ be the proportion of insolvent types at that deviation. Positive profits for the deviator implies $\tilde{p} \geq \tilde{x} + \tilde{\theta}\pi(\tilde{x}, \underline{y})d$. The deviation is preferred by the insolvent consumers when $\tilde{p} + \pi(\tilde{x}, \underline{y})h \leq x^* + \pi(x^*, \underline{y})(h+d)$. Taken together, we have

$\tilde{x} + \theta\pi(\tilde{x}, \underline{y})d + \pi(\tilde{x}, \underline{y})h \leq x^* + \pi(x^*, \underline{y})(h+d)$. When $\theta=1$ then $\tilde{\theta}=1$ as well so this becomes $\tilde{x} + \pi(\tilde{x}, \underline{y})(h+d) \leq x^* + \pi(x^*, \underline{y})(h+d)$ which is only satisfied when $\tilde{x} = x^*$ and $\tilde{p} = x^* + \pi(x^*, \underline{y})d$. We have already seen that the solvent consumers would prefer $\{p_1^R, x_1^R\}$, a contradiction. Continuity guarantees that this is also true when θ is sufficiently large.

Q.E.D.

Proof of Proposition 4.5: Let $S_i^j = S(x_i^j, y_i^j, q_i^j)$ be the social welfare associated with liability regime j for consumers of type i . Social welfare under consumer only liability is $\theta S_0^C + (1-\theta)S_1^C$, and social welfare under residual-manufacturer liability is $\theta S_0^R + (1-\theta)S_1^R$. Consumer-only liability is strictly preferred if and only if

$$(1-\theta)(S_1^C - S_1^R) > \theta(S_0^R - S_0^C).$$

On the left hand side we have $S_1^C = S(x^*, y^*, q^*) > S_1^R$. In other words, the solvent consumers are served efficiently under consumer-only liability but not under residual-manufacturer liability.

On the right hand side, $S_0^R > S_0^C$ because although consumers make the same inefficient precautions, $y_0^C = y_0^R = \underline{y} < y^*$, the manufacturers supply efficient safety features to the insolvent consumers under residual-manufacturer liability, $x_0^R = x^* > x_0^C = \underline{x}$ (and, furthermore, the price rises to the point where consumers purchase the right quantity given the investments). The result follows.

Q.E.D.