# Product Recall and Liability

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Abstract

*This paper examines a firm's incentives to recall its product after learning that the product may harm consumers. It also discusses whether courts should protect consumers who do not comply with recalls. Under the "no duty to return" rule, the firm bears the same liability no matter whether it has made a recall or not. The firm then may not recall the product as often as socially desired or provide insufficient reimbursement for consumers' return costs. In contrast, the "full duty to return" rule denies the firm's future liabilities after it makes a recall. More consumers then return the product, which reduces the firm's incentives to recall the product. We show that the "full duty to return" rule may or may not generate more product recalls or higher social welfare. We also discuss the "partial duty to return" rule which partially reduces the firm's liability after it makes a recall.*

## 1. INTRODUCTION

After selling its product, a firm may learn of potential harm that the product might cause to consumers. The firm can choose to recall and repair (or replace) the product. However, not all consumers would return the products, even if firms provide reimbursement and consumers learned of the recalls.[2] For example, in 2000, when Firestone recalled the tires used in Ford Explorers, some consumers did not respond, even when they knew the product was recalled.[3] In 2003, the US Consumer Product Safety Commission issued a notice saying that many consumers continued to use products that have been recalled. This paper examines consumers' incentives to return the recalled products. It also considers a firm's private incentives to recall its product.

During a product recall, consumers do not consider the firm's costs and the firm may not provide sufficient reimbursement for consumers' return costs. The firm's incentives

to recall the product are distorted by consumers' inefficient returns. This paper examines whether courts should impose consumers' duty to return the recalled product and consider consumers' negligence when determining the firm's liabilities. Three liability rules are addressed: under the "no duty to return" rule, the firm bears the same liability to a harmed consumer, no matter whether it has recalled the product or not; in contrast, under the "full duty to return" rule, the firm bears no future liability after it recalls the product.[4] We will show that the "full duty to return" rule may not generate more product recalls or higher social welfare than the "no duty to return" rule, since the "full duty to return" rule leads more consumers to return the product and thus the firm may have less incentive to recall the product. Similar intuition applies to the "partial duty to return" rule which reduces the firm's liability but not fully denies it.

Courts have different practices about whether and to what extent consumers bear the duty to return the recalled product. For example, in J.H.O.C v. Volvo Trucks Inc., Court of App., 11th Circuit, 08-13868 (2008), the courts found contributory negligence in the plaintiff's failure to comply with the manufacturer's product recall and then denied the defendant's liability. In Smith v. Ontario Sewing Machine Co., Ga. App. A01A0837 (2001), although the trial court granted summary judgment in favor of the defendant since the plaintiff's employer did not comply with the recall made by the defendant, the Court of Appeals reversed the decision and argued that the defendant's duty was not relieved by the omissions of the plaintiff's employer.

Two issues lead to such different practices. First of all, in the United States, five states adopt the contributory negligence rule, which completely bars a plaintiff from

getting damage compensation even if the plaintiff has slight negligence. Thirty-three states adopt the "modified" comparative negligence rule, which completely bars a plaintiff from recovery if the plaintiff's negligence is not less than the defendant's fault. The remaining states adopt the "pure" comparative negligence rule, which awards a plaintiff damage compensation according to her relative fault. Appendix A provides details about these rules. The "full duty to return" rule resembles contributory negligence or modified comparative negligence with plaintiffs' negligence larger than defendants' fault. The "partial duty to return" rule is similar to pure comparative negligence.[5]

Second, it is subjective for the jury or the judge to decide whether a plaintiff's failure to comply with the recall should be considered as negligence or not, and if it is considered, to what extent. People have different views on whether a firm's recall fully explains the potential harm, whether a firm exercises sufficient care to contact consumers and fix the product, and whether consumers face constraints so that they could not return the products.[6] The "no duty to return" rule implies that courts set a very high standard of evidence to show consumers' negligence for not returning the recalled products; while the "full or partial duty to return" rule means that the standard of evidence is lower.

We formally consider a framework where, after selling its product, a firm may privately learn of the likelihood for consumers to be harmed by the product, while consumers privately know their heterogeneous damage levels. The firm decides whether to recall and repair the product. It can offer reimbursement for consumers' return costs. The firm's costs depend on how many consumers return the product. If a consumer complies with the recall, the firm will repair the product and there will be no harm. If a

consumer does not return the product and is harmed, the firm may or may not be found liable depending on the liability rules. The social optimum requires that the firm make a recall when the likelihood for consumers to be harmed is high and that only those consumers with high potential damage levels return the product.

We first examine the "no duty to return" rule, i.e. strict liability. The firm makes a recall only when the likelihood for consumers to be harmed is high enough. If the firm will be found liable for sure, consumers would not comply with the recall unless the firm offers full reimbursement for their return costs. Given that consumers are heterogeneous, the firm has lower incentives to recall the product than socially desired. Similarly, if the firm is very unlikely to be found liable or consumers' return costs are low, consumers have excessive incentive to return the recalled product. In this scenario, the firm does not offer reimbursement and does not recall the product as often as socially desired.

If the firm is highly likely (but not surely) to be found liable, or consumers' return costs are high, many consumers do not return the recalled product. In this scenario, there is no divergence between the firm's recall decision and what is socially desired.[7] However, the firm does not provide sufficient reimbursement for consumers' return costs, since it bears only imperfect strict liability and tries to reduce consumers' information rents. Correspondingly, fewer consumers return the product than socially desired.

We then examine the "full duty to return" rule and the "partial duty to return" rule. Under these rules, on one hand, the firm could deny or reduce future liabilities by making a recall. Such a direct effect increases the firm's incentives to recall the product. On the other hand, more consumers return the product. Such an indirect effect reduces the firm's

incentives to make a recall. Overall, there may be more or fewer recalls than socially desired. Furthermore, the firm may not provide reimbursement to consumers. It makes a recall when the likelihood for consumers to be harmed is large enough or small enough. If the firm bears perfect strict liability, or if it bears imperfect liability but consumers' return costs are high, the "full duty to return" rule causes more recalls than the "no duty to return" rule. However, if the firm bears imperfect liability and consumers' return costs are low, the "full duty to return" rule may even result in fewer recalls.

This paper provides policy implications. First, the "full duty to return" rule may or may not generate higher social welfare than the "no duty to return" rule. Suppose that the expected harm is always large enough, compared to consumers' return costs and the firm's costs of recalls. Then if the firm is very likely to be found liable, the "full duty to return" rule is more efficient than the "no duty to return" rule. Such a scenario may apply to products such as cars and consumer electronics. In contrast, if the expected harm is not always large and the firm is very likely to be found liable or consumers' return costs are too high, the "no duty to return" rule is socially more efficient. This may apply to some industrial machines and medical equipment with low expected harm but high return costs such as profit losses for corporate customers.

Second, suppose that courts could observe more information on the related factors such as consumers' return costs, the firm's costs of recalls, and the probability for the firm to be found liable. Then courts may design the "partial duty to return" rule. If consumers' return costs are extremely high, there is no need to impose consumers' duty. If consumer' return costs are reasonably high or if the firm is very likely to be found

liable when it does not make a recall, the optimal liability rule should reduce the firm's liability to a certain level (but not to zero).

This paper contributes to the literature on product safety and liabilities.[8] Welling (1991) shows that a firm makes recalls in order to build the firm's reputation in the market. Marino (1997) argues that mandatory recalls motivate firms to increase product safety before sales. Ben-Shahar (2005) considers that a product recall may cause consumers' awareness of potential harm and therefore trigger more lawsuits against firms. Correspondingly, firms have insufficient incentives to recall products. Spier (2008) analyzes a firm's incentives to buyback unsafe products. She shows that the firm offers a low buyback price than socially desired. Different from this literature, this paper considers a firm's decision to repair its product, and includes a firm's variable costs in recalls. More importantly, it addresses consumers' return costs and shows that imposing consumers' duty to return may even lead to fewer recalls or lower social welfare.[9]

Generally, this paper contributes to the literature on strict liability and negligence rules. Brown (1973) shows that strict liability does not induce victims to take care, while negligence rules may lead both injurers and victims to take optimal care. Green (1976), Emons (1990), and Emons and Sobel (1991) extend the comparison by considering heterogeneous injurers and victims. Rubinfeld (1987), Edlin (1994), and Bar-Gill and Ben-Shahar (2003) examine comparative negligence rules with bilateral due care. Shavell (1980) distinguishes levels of care from levels of activity. He shows that strictly liability leads victims to take excessive activities while negligence rules lead injurers to take excessive activities. This paper considers a few aspects not being addressed before: First,

the success of the firm's recall is fully contingent on consumers' returns, but the firm's costs are higher if more consumers take care to return the product. Second, the firm can offer reimbursement to affect consumers' returns but cannot observe heterogeneous consumers' damage levels. Finally, the firm's recall discloses useful information to consumers for their return decisions. Given these differences, the firm does not make excessive recalls under strict liability. And contributory negligence or other negligence rules may not cause more recalls or higher social welfare than strict liability.

This paper is also related to the literature on information disclosure. Daughety and Reinganum (1995) show that firms can signal their product quality through different prices. Daughety and Reinganum (2007) discuss how liability rules affect a firm's choice between signaling product safety through the price and directly revealing product safety by paying disclosure costs. Shavell (1994) and Polinsky and Shavell (2006) examine a firm's private incentives to acquire and disclose information about product safety before sales. Generally the literature on information disclosure discusses ex-ante information disclosure (Grossman, 1981; Milgrom, 1981; Mathews and Postlewaite, 1985), while this paper considers a firm's ex-post information disclosure after its product is sold.

The next section presents the model. The third section analyzes the firm's incentives to recall its product and consumers' incentives to comply with the recall under the "no duty to return" rule. The fourth section examines the "full duty to return" rule. The fifth section compares the above two liability rules and discusses the "partial duty to return" rule. It also provides policy implications. The last section offers concluding remarks. All proofs are in Appendix B.

## 2. THE MODEL

A firm has sold its product to consumers with density one. Each consumer's value from using the product is $V>0$. Assume that $V$ is large enough, so that consumers continue to use the product, even if the firm makes a recall but consumers do not return it. This assumption is valid for many durable products, including automobiles, electronics, industrial machines, and medical equipment. It may not fully apply to products of low values, such as food or toys. Consumers may simply stop using such products when the firm makes a recall or the firm may buy back the product rather than repair it.

The firm and consumers know that the likelihood for consumers to be harmed, $p$, follows a distribution $f(p)$ on [0,1] with a cumulative density function $F(p)$ . After the product is sold, the firm may privately learn whether the product is harmful and learn of $p$. Neither consumers nor any third party observes whether the firm has learned of $p$ or not.

Consumers are heterogeneous: consumers of density $g(H)$ suffer damages $H$ when they are harmed.[10] The damage level is bounded above by a fixed number $\overline{H}$ , which is normalized to be 1.[11] The cumulative density function is $G(H)$, which has a monotone hazard rate: $\frac{1-G(H)}{g(H)}$ is decreasing in $H$. Consumers privately know their potential damage levels. This assumption is realistic. A consumer knows more about how the product is important to her or what particular damages she would bear if she is harmed. The results hold in an equivalent model where the firm learns the uniform damage level, while consumers privately know their heterogeneous likelihoods to be harmed.[12]

The timing is as follows:

On date 1, the firm may learn of the likelihood for consumers to be harmed, p, and can decide whether to recall the product or not. If the firm makes a recall, the announcement credibly discloses $p$,[13] and the firm spends costs $C(R)$ to fix the returned product, where $R$ is the mass of consumers who return the product. $C(R)$ is continuous, differentiable, and increasing in $R$. Without loss of generalization, let $C(R) = cR$, where $c$ is fixed.[14] For simplicity, assume that the firm's fixed costs of the recall are zero. The firm can also choose to offer reimbursement $t$ to each consumer who returns the product. For example, when firms recall automobiles or medical equipment, they can cover return costs and offer consumers rental cars or equipment for temporary use.

When the firm recalls the product, on date 2, consumers decide whether to return the product. If a consumer returns the product, the firm would repair it and there is no future harm. However, the consumer's value would be changed to $V- k+ t$, where $k$ can be interpreted as the consumer's transportation and inconvenience costs, or corporate customers' re-installation costs and profit losses. $k$ can be observed by the firm and consumers, but cannot be verified ex-ante. For example, consumers' inconvenience or disutility when returning the product cannot be verified. Therefore, it is difficult for government agencies or courts to require the firm to fully compensate $k$.

On date 3, if a consumer is harmed, she will sue the firm.[15] If the firm has not made a recall, when a consumer is harmed, the firm will be found liable and fully compensate the consumer's damage $H$ with a probability $q \leq 1$. If the firm has made a recall, under the "no duty to return rule", the firm still bears the above expected liability. In contrast, under the "full duty to return rule", if the firm has made a recall, but this particular consumer

does not return the product, the firm will bear no liability. The "partial duty to return" rule reduces the firm's expected liability but not to zero after the firm recalls the product. If $q$=1, the firm bears perfect strict liability, while if $q$<1, the firm bears imperfect strict liability. This is consistent to the reality that consumers may not have enough evidence in litigation or there may be limited enforcement.

Since the potential damage level $H$ has been normalized to be between zero and one, this paper will focus mostly on the scenario where $c+k$ is also less than one.

Courts may not be able to verify the exact costs of returns and recalls. Still courts tried to consider such information in determining consumers' negligence. For example, in the lawsuit where a plaintiff sued Ontario Sewing Machine Co., which is mentioned in the introduction, the court of appeal observed high costs and profit loss for the plaintiff's employer to comply with the recall and used such information to the favor of the plaintiff. The literature on bilateral care has also addressed victims' costs of care[16].

In reality, not all consumers become aware of the product recall. The firm may not have a record of all consumers, or some consumers may have re-sold the product or simply not noticed the announcement. Also, the firm may not have incentives to make the recall announcement widespread. However, in the US, firm recall announcements are often monitored by government agencies. For example, the Food and Drug Administration (FDA) specifies a procedure that firms should follow in making recall announcements. Therefore, firms do not have much flexibility to affect the quality of recall announcements. The results in this paper still hold, even if some consumers exogenously do not become aware of the recall.

This model focuses on the firm's voluntary recalls. In practice, the government regulatory agencies such as the FDA and the US Consumer Product Safety Commission could also enforce mandatory recalls. However, the firm is more likely to learn of the relevant information about potential harm, costs of recalls, and consumers' return costs, than the government agencies.[17]

Furthermore, product recalls potentially can be used as evidence of the harm caused by the product. This changes consumers' incentives to file lawsuits and may mitigate firms' incentives to make recalls, as analyzed by Ben-Shahar (2005). In practice, courts often do not accept the use of product recalls as evidence, though they do not exclude the use of reports or data disclosed during product recalls.[18] This paper ignores this possibility of using product recalls as evidence in litigation.

Finally, in this model, the firm's fixed costs of making a recall are assumed to be zero. In reality, especially for products such as medical equipment and automobiles, when a firm makes a recall, its costs of repairing the product and offering reimbursement are typically larger than the costs of making recall announcements. If fixed costs are included, it would be efficient for the firm not to issue a recall when the harm level is small enough.

It is useful to derive the benchmark where a policy maker could make decisions on both recalls and returns, in order to maximize social welfare. When the likelihood for consumers to be harmed is $p$, a consumer should return the product if and only if the expected harm is higher than the total costs for both the firm and the consumer, i.e., $pH > c + k$ . Recall that $H$ has been normalized to be less than 1. The following proposition summarizes the socially optimal recall and return decisions.

**Proposition 1 (The social optimum benchmark):** To maximize social welfare, the firm should recall the product whenever $p > c + k$, and given a recall, only consumers with $H \geq H^{**} = \frac{c+k}{p}$ should return the product.

## 3. NO DUTY TO RETURN

Under the "no duty to return" rule, if a consumer is harmed, no matter whether the firm has made a recall or not, the firm will be found liable with a probability $q \leq 1$. In this case, the firm has to fully compensate the consumer's damage $H$.

### 3.1 Perfect strict liability ($q$=1)

If the firm will be found liable for sure whenever consumers are harmed, consumers expect to always get full compensation and therefore would not comply with the recall unless the firm offers reimbursement $t \geq k$. Given a recall, there are more returns than socially desired, as shown in the following proposition.

**Proposition 2**: Under the "no duty to return" rule, if the firm bears perfect strict liability ($q$=1), the firm makes a recall and offers $t = k$ if and only if $p \geq \frac{c+k}{\int_0^1 HdG(H)}$. There are fewer recalls than socially desired. When there is a recall, all consumers return the product if and only if $t \geq k$, and there are more returns than socially desired.

Intuitively, under the "no duty to return" rule, if the firm bears perfect strict liability, consumers do not internalize future harm and the firm's costs when they decide whether to comply with the recall or not. Consumers' heterogeneity in potential damage levels would not make a difference in their return decisions. Either all consumers return the product, or no consumer does so. If the firm offers full reimbursement for consumers' return costs, consumers have excessive incentives to return the product, which in turn reduces the firm's incentives to recall the product. Note that, if consumers face the same potential damage level, consumers' returns would be socially efficient.

The above result is different from what in the literature. As discussed in the introduction, the literature shows that, under perfect strict liability, potential victims does not take any care and the injurer takes excessive care. In the literature, the injurer's care can reduce the probability of harm even if the potential victims do not take any care and the injurer's costs of care do not depend on the victims' actions. However, in this paper, differently, the success of the firm's recall is fully contingent on consumers' returns. Under perfect strict liability, the firm has to offer full reimbursement for consumers' return costs. Therefore, there are too many returns and the firm does not recall the product as often as socially desired.

### 3.2 Imperfect liability ($0<q<1$)

Now, suppose that the firm will be found liable with a limited probability when consumers are harmed. In this scenario, consumers internalize parts of future damages

when they decide whether to comply with the recall or not. Consider a particular consumer with potential damage level *H*. If this consumer returns the product, her utility will be *V-k+t*. If she does not return the product, she will be harmed with a probability *p* and her expected utility will be *V-pH+pqH*, since she will get full compensation *H* with a probability *q*. This comparison leads to the following lemma.

**Lemma 1:** Under the "no duty to return" rule, if the firm bears imperfect strict liability, only those consumers with potential damage levels $H \geq H_N = \min(1, \frac{k-t}{(1-q)p})$ return the product. The density of consumers who return the product, $R_N = 1 - G(H_N)$ increases in the likelihood for consumers to be harmed, *p*, and the reimbursement *t*. If $k > \frac{(1-q)}{q}c$, the reimbursement that can lead to socially efficient returns is $t^* = qk - (1-q)c$.

As shown in Lemma 1, consumers' heterogeneity in their potential damage levels affects their return decisions. The firm does not observe each consumer's potential damage level. If the firm makes a recall and offers reimbursement *t*>0, those consumers with high potential damage levels would return the product and get information rents.

The following analysis first derives the firm's optimal reimbursement in a recall and then discusses the firm's incentives to recall the product. Suppose that the firm recalls the product for sure, the firm's minimization problem would be

$$Min_t \ (t+c)(1-G(H_N)) + qp\int_0^{H_N} HdG(H),$$

The first term in the objective function represents the firm's costs of reimbursing consumers and repairing the product returned, while the second term reflects its expected liabilities to those consumers who do not return the product. If $H_N < 1$, the derivative of the objective function with respect to *t* is

$$(1-G(H_N))+\frac{g(H_N)}{(1-q)}[\frac{t+c}{p}-\frac{q(k-t)}{(1-q)p}],$$

The above derivative is strictly positive if the reimbursement *t* is equal to the consumers' return costs *k*. Therefore, the firm never offers full reimbursement for consumers' return costs. The following proposition shows that, when the firm makes a recall, it may not offer sufficient reimbursement, i.e., $t<t^*$.

**Lemma 2**: Suppose that the firm bears imperfect strict liability ($q<1$) no matter whether it has made a recall or not. Assume that the firm makes a recall. (1) If $k \le \frac{(1-q)}{q}c$, the firm offers no reimbursement, i.e., $t=0$. (2) If $k > \frac{(1-q)}{q}c$, the firm never offers sufficient reimbursement as socially desired, i.e., $t < t^* < k$. In particular, when $p \le c+k$, the firm offers no reimbursement; when $c+k < p \le \frac{k}{(1-q)}$, the firm offers positive reimbursement $t>0$; when $p > \frac{k}{(1-q)}$, $t \ge 0$. When $p > c+k$, the optimal reimbursement solves $H_N = \frac{k-t}{(1-q)p}$ and $H_N - \frac{1-G(H_N)}{g(H_N)}(1-q) = \frac{c+k}{p}$.

The above results are intuitive. First of all, given that the firm bears imperfect strict liability, the firm would never offer full reimbursement for consumers' return costs. Second, when consumers' return costs are low enough, or the firm is very unlikely to be found liable, most consumers have sufficient or even excessive incentives to return the product. In this scenario, the firm does not offer any reimbursement. In contrast, when consumers' return costs are high or the firm is very likely to be found liable, consumers do not have sufficient incentives to return the product and therefore the firm may have to offer reimbursement.

More importantly, consumers privately know their heterogeneous damage levels, so the firm tries to reduce consumers' information rents and does not offer sufficient reimbursement as socially desired. This intuition is similar to that for the typical monopsony problem and Spier (2006) addresses similar effects when a firm tries to buyback its product. One difference in this paper is that the occurrence of insufficient reimbursement also hinges on imperfect liability and consumers' return costs.

The following analysis will examine the firm's incentives to recall the product. If the firm recalls the product, its total costs would be $(c+t)(1-G(H_N))+qp\int_0^{H_N} HdG(H)$, where *t* is determined as in Lemma 2. If the firm does not recall the product, its expected liability would be $qp\int_0^1 HdG(H)$. Therefore, the firm would make a recall if and only if $(c+t)(1-G(H_N)) < qp\int_{H_N}^1 HdG(H)$.

**Proposition 3**: Suppose that the firm bears imperfect strict liability ($q$<1) no matter whether it has made a recall or not.

(1) If $k < \frac{(1-q)}{q}c$ , there are fewer recalls than socially desired. There exist $p_N^2, p_N^1$ ( $p_N^2 \geq p_N^1 > c + k$ ) such that the firm recalls the product when $p > p_N^2$ and does not do so when $p < p_N^1$ . If consumers' potential damage levels follow the uniform distribution, then $p_N^2 = p_N^1$ . There are more returns than socially desired.

(2) If $k > \frac{(1-q)}{q}c$ , as socially desired, the firm recalls the product when $p \geq c + k$ . The firm offers insufficient reimbursement and there are fewer returns than socially desired.

(3) If $k = \frac{(1-q)}{q}c$ , or equivalently $q = \frac{c}{c+k}$ , the social optimum is achieved.

The above results are intuitive. When the likelihood for consumers to be harmed is small enough, the firm's expected liability is smaller than its costs of recalling the product. Therefore, the firm would not recall the product. In contrast, when the likelihood for consumers to be harmed is large enough, the firm would make a recall.

The comparison between the firm's private incentives to recall the product and what is socially desired is more subtle. If consumers' return costs are low or the firm is very unlikely to be found liable, consumers have excessive incentives to return the product, which increases the firm's costs of recalls. Correspondingly, the firm's incentives to recall the product are reduced.[19] If consumers' return costs are high, or the firm is very likely to be found liable, there is no excessive return and therefore, the firm's incentives

to make a recall are aligned with what is socially desired. [20] However, as shown in Lemma 2, the firm does not provide sufficient reimbursement, and therefore, there are fewer returns than socially desired.

In summary, if courts do not impose consumers' duty to return or put a very high standard of evidence in determining consumers' negligence, there are fewer returns than socially desired if consumers' return costs are high, and there are excessive returns otherwise. The firm has lower incentives to recall the product than socially desired if consumers' return costs are low or the firm is very unlikely to be found liable.

## 4. FULL DUTY TO RETURN

Under the "full duty to return" rule, the firm bears no future liability if it makes a recall. If the firm does not recall the product and a consumer is harmed, then it will be found liable with a probability $q$. As discussed in the introduction, this rule is equivalent to the contributory negligence or modified comparative negligence rule with the consumers' negligence larger than the firm's fault. Or this rule resembles the scenario where courts put a very low standard of evidence in determining consumers' negligence.

Suppose that the firm makes a recall and offers reimbursement $t$. For a particular consumer with potential harm level $H$, if she returns the product, her utility would be $V-k+t$; if she does not comply with the recall, her expected utility would be $V- pH$, since she would be harmed with a probability $p$ and, under the "full duty to return" rule, get no compensation. Therefore, the consumer will return the product if and only if

$$H \geq H_D = \min(1, \frac{k-t}{p})$$

Correspondingly, consumers' return rate is $R_D = 1 - G(H_D)$, which is zero when $p \leq k - t$. The firm's expected costs $(t+c)(1-G(H_D))$ strictly increase in *t*. Therefore, the firm does not offer any reimbursement. Consumers will return the product when $H \geq H_D = \min(1, \frac{k}{p})$, which is more than socially desired since $H^{**} = (c+k)/p$.

**Lemma 3**: Suppose that the firm bears no future liability if it makes a recall. The firm offers no reimbursement in any product recall, i.e. $t = 0$.

If the firm does not recall the product, its expected liability is $qp\int_0^1 HdG(H)$. Therefore, the firm will make a recall if and only if $c(1-G(H_D)) < qp\int_0^1 HdG(H)$. Note that both sides of this condition are increasing in *p*: When it is more likely for consumers to be harmed, more consumers will comply with the recall, which increases the firm's costs; at the same time, the firm can get rid of more future liabilities to those consumers who do not return the product. Such a trade-off implies that the firm's incentives to recall the product may not always increase with the likelihood for consumers to be harmed.

**Proposition 4**: Suppose that the firm bears no future liability if it makes a recall.
(1) Whenever there is a recall, there are weakly more returns than socially desired.
(2) Given *p*, the firm is more likely to recall the product if *q* is larger or *c* is smaller.

(3) There exist $p_D^2, p_D^1$ ( $p_D^2 > p_D^1 > k$ ) such that the firm recalls the product when $p > p_D^2$ or $p < p_D^1$. Suppose that for any *H*, $g(H)$ is upper-bounded by a fixed number *M*, there exists $\bar{k}$ such that if $k \geq \bar{k}$, the firm always makes a recall, i.e., $p_D^1 = p_D^2$. In particular, assume that consumers' damage levels follow the uniform distribution on [0,1]. Then, if $k < \frac{c}{2q}$ and $\frac{c - \sqrt{c^2 - 2qck}}{q} < 1$, there exist $p_D^2, p_D^1$ such that the firm makes a recall if and only if $p < p_D^1$ or $p > p_D^2$; otherwise the firm always makes a recall.

Proposition 4 shows, under the "full duty to return" rule, the firm may conduct an unnecessary recall when the likelihood for consumers to be harmed is very small. This is intuitive since the firm can get rid of future liabilities and there would not be many returns given the small harm level. However, since there are still more returns than socially desired, such an unnecessary product recall would reduce social welfare.

Under the "full duty to return" rule, the firm's incentive to recall the product increases in *q*, the probability for the firm to be found liable. As shown in Section 3, this may not be true under the "no duty to return" rule. When *q* changes, the firm may adjust the reimbursement for consumers' return costs under the "no duty to return" rule but does not do so under the "full duty to return" rule.

More importantly, the "duty to return" rule has two conflicting effects on the firm's recall decision. On the one hand, the firm would like to recall the product more often in order to reduce future liabilities. On the other hand, more consumers would return the recalled product since they would not get any damage compensation otherwise, which in

turn reduces the firm's incentives to recall the product. When consumers' return costs are low, the second effect is large. Correspondingly, there exists a range of $p$ where the firm does not recall the product. In contrast, when consumers' return costs are high, the over-return problem is less severe and therefore the firm always recalls the product.

**Corollary 1:** Suppose that the firm bears no future liability after it makes a recall. There exists $\hat{k}$ ($0 < \hat{k} < \bar{k}$) such that, if $k < \hat{k}$, there are weakly fewer recalls than socially desired. If $k > \bar{k}$, there are weakly more recalls than socially desired.

In summary, the "full duty to return" rule motivates more consumers to comply with a recall. However, there may be too many returns, which would reduce the firm's incentives to recall the product. The firm may have insufficient or excessive incentives, depending on consumers' return costs and the firm's liability. These results imply that the contributory negligence rule or the modified comparative negligence rule could not achieve social optimum.

## 5. PARTIAL DUTY TO RETURN AND THE COMPARISON OF THE LIABILITY RULES

The previous sections show that both the "no duty to return" rule and the "full duty to return" rule may cause inefficiency. This section will first compare these two rules and then discuss the "partial duty to return" rule which reduces but not fully deny the firm's liability after the firm recalls the product.

### 5.1 Comparison between no duty to return and full duty to return

According to Propositions 3 and 4, there would be more product returns if negligent consumers are not protected. Intuitively, under the "full duty to return" rule, consumers have more incentives to comply with the recall since they would not receive any future damage compensation from the firm.

**Proposition 5:** Given the same likelihood for consumers to be harmed $p$, if the firm recalls the product, more consumers will comply with the recall under the "full duty to return" rule than under the "no duty to return" rule. That is, $R_N(p) \le R_D(p)$.

The following proposition shows that the "full duty to return" rule may or may not lead to more product recalls than the "no duty to return" rule.

**Proposition 6:**

(1) Suppose $q = 1$. The "full duty to return" rule leads to more product recalls than the "no duty to return" rule.

(2) Suppose $q < 1$. There exists $\tilde{k}$ such that, if $k > \tilde{k}$, the "full duty to return" rule causes more recalls than the "no duty to return" rule; if $k \le \tilde{k}$, the "full duty to return" rule may cause more or fewer recalls than the "no duty to return" rule. In particular, suppose that both $H$ and $p$ are uniformly distributed on [0,1] and $2c \le q$. Then if $2c < q \le 1/2$, the "full duty to return" rule causes more recalls than the "no duty to return" rule. If

$1/2 < q < 1$, there exists $\tilde{k} > 0$ such that if $k > \tilde{k}$ there are more recalls under the "full duty to return" rule; if $k < \tilde{k}$, there are fewer recalls under the "full duty to return" rule.

Intuitively, as shown in Section 4, given a fixed return rate, the "full duty to return" rule provides the firm more incentives to make a recall than the "no duty to return" rule. However, the "full duty to return" rule also leads more consumers to return the product, which reduces the firm's incentives to recall the product. When consumers' return costs are low and the firm bears imperfect but high liability, the "full duty to return" rule has a large impact on increasing consumers' returns and therefore the firm tends not to make a recall as often as under the "no duty to return" rule.

For the effects on social welfare, the comparison between these two legal rules is ambiguous, as shown in the following proposition.

**Proposition 7:** The "full duty to return" rule may or may not generate higher social welfare than the "no duty to return" rule. Assume that for any *H*, $g(H)$ is upper-bounded.

(1) Suppose that $f(p) > \delta$ for any $p>0$ where $\delta$ is a positive and fixed number. Given any $k > \max(\bar{k}, \frac{(1-q)}{q}c)$,[21] there exists $\hat{q} < 1$ such that for any $q \in (\hat{q},1)$, the "no duty to return" rule generates higher social welfare than the "full duty to return" rule.

(2) Suppose that $f(p) > \delta$ for any $p>0$ where $\delta$ is a positive and fixed number. Given any $q \in (c,1)$, there exists $k' < 1-c$ such that for any $k \geq k'$, the "no duty to return" rule generates higher social welfare than the "full duty to return" rule.

(3) If the expected harm level always satisfies $pH > c + k$, there exists $\tilde{q} < 1$ such that if $\tilde{q} < q \leq 1$, the "no duty to return" rule generates lower social welfare than the "full duty to return" rule.

Intuitively, under the "full duty to return" rule, consumers may return the recalled product more often than socially desired. As in part (1) of Proposition 7, the above social loss is fixed and strictly positive. In contrast, under the "no duty to return" rule, if consumers' return costs are not too small and the firm is likely to be found liable, the firm's recall decision is socially efficient and fewer consumers return the product than socially desired. This social loss diminishes arbitrarily close to zero when $q$ is close to 1.[22] Therefore, in this scenario, the "no duty to return" rule is socially more efficient.

The similar intuition applies to part (2) in Proposition 7. When consumers' return costs become larger and arbitrarily close to $1 - c$, under the "no duty to return" rule, the social loss of having insufficient returns diminishes arbitrarily close to zero; while under the "full duty to return" rule, there is still a non-trivial social loss from the firm's recall and consumers' excessive returns as long as $q$ is not too small.

Part (3) in Proposition 7 is also intuitive. If the expected harm level is always large enough, the social optimum requires that the firm should recall the product and consumers should always return the product. This is achieved under the "full duty to return" rule, as long as the firm is very likely to be found liable.

The above comparisons provide policy implications. Many states use modified comparative negligence or contributory negligence. However, when the expected harm is

not always large, consumers' return costs are high, and the firm is very likely to be found liable, it might be better to use strict liability or courts should set a very high standard of evidence in determining consumers' negligence.

In practice, for some industrial machines and medical equipment, the expected harm may not always be large but the return costs for customers could be relatively high. For example, corporate customers may have large costs to shut down production lines or reinstall machines, and have profit losses. Furthermore, if such machines and equipment have standard ways to be used, it is unlikely that the customers would operate incorrectly. Therefore it is likely for the manufacturers to be found liable when there is harm. For these products, the "no duty to return" rule could be more efficient than the "full duty to return" rule and courts may set a high standard of evidence in determining customers' negligence. However, this conclusion may not apply to automobiles. These products are used by individual consumers and the manufacturers often have large distribution channels for consumers to return the recalled product. Therefore, the expected harm could be always large comparing to return costs and costs of recalls. In such scenarios, courts may set a low standard of evidence in determining consumers' negligence.

### 5.2 Partial duty to return

Now suppose that courts have more information and can adopt the following "partial duty to return" rule: if the firm does not recall the product, the firm will pay full damage compensation to the harmed consumer once the firm is found liable; if the firm has

recalled the product, the firm, once it is found liable, will only pay partial compensation $\alpha H < H$ to the harmed consumers. This is similar the pure comparative negligence rule.

If courts impose more of consumers' duty to return or set a lower standard of evidence in determining consumers' negligence, $\alpha$ is lower. The following proposition characterizes the optimal "partial duty to return" rule which could achieve the social optimum under certain conditions.

**Proposition 8:** If $q \geq \frac{c}{c+k}$ or, equivalently, $k \geq \frac{(1-q)}{q}c$, the following "partial duty to return" rule achieves the social optimum: When the firm is found liable, if the firm has not recalled the product, the firm will pay full damage compensation to the harmed consumer; if the firm has recalled the product, the firm will pay partial damage compensation $\alpha H$, where $\alpha = \frac{c}{(c+k)q} \leq 1$. If $q < \frac{c}{c+k}$ or, equivalently, $k < \frac{(1-q)}{q}c$, the "partial duty to return" rule could not achieve social optimum.

The above results are intuitive and provide further policy implications. First, suppose that the firm is not likely to be found liable or consumers' return costs are low such that $k < \frac{1-q}{q}c$. When courts impose consumers' duty to return even partially, there would be more returns, which may reduce the firm's incentives to recall the product. The comparison of liability rules becomes ambiguous.[23]

Second, suppose that the firm is very likely to be found liable or consumers' return costs satisfy $1-c>k\geq\frac{1-q}{q}c$. Strict liability, contributory negligence, or modified comparative negligence might not lead to socially optimal recalls and returns. The optimal liability rule should impose "partial duty to return", i.e., pure comparative negligence

Finally, if consumers' return costs are too high such that $c+k\geq 1$, it is not socially efficient to return the product at all and consumers do not have incentives to comply with recalls. Imposing consumers' duty to return does not affect social welfare. However, although not modeled in this paper, in practice the recall announcement may have fixed costs or the firm can make investments to improve product safety before selling the product. If the firm anticipates that consumers' return costs are very high and the firm could reduce its liability after the recall, the firm would make unnecessary recalls or take insufficient ex-ante investments. Therefore, when consumers' return costs are too high, courts should not impose consumers' duty to return, or alternatively set a very high standard in determining consumers' negligence.

The above results assume that courts could observe consumers' return costs, the firm's costs of recalls, and the probability that the firm will be found liable. In practice, courts may not be able to observe the above information precisely but can still try to identify the relative level of these factors.

## 6. CONCLUSIONS

This paper has examined a firm's private incentives to recall its product and consumers' incentives to comply with the recall. It also discusses whether courts should impose consumers' duty to comply with product recalls and whether the firm's liability should be reduced or denied after it makes a recall.

Under the "no duty to return" rule, i.e. strict liability, if the firm will be found liable for sure, there are fewer recalls than socially desired. If the firm is very unlikely to be found liable, or consumers' return costs are low, there are more returns than socially desired. Therefore, the firm provides no reimbursement for consumers' return costs and recalls the product less often than socially desired. If the firm is very likely (but not surely) to be found liable, or consumers' return costs are high, the firm makes recalls as socially desired but does not offer sufficient reimbursement, so that fewer consumers return the product than socially desired.

In contrast, the "full duty to return" or "partial duty to return" rule allows the firm to deny or reduce future liabilities by making a recall. Given a fixed return rate, the "duty to return" rules increase the firm's incentives to recall the product. However, they also increase consumers' returns, which may reduce the firm's incentives to recall the product. Overall, the "full duty to return" rule may even lead to fewer recalls than the "no duty to return" rule if consumers' return costs are low and the firm bears imperfect liability; otherwise the "full duty to return" rule leads to more product recalls.

In choosing liability rules or determining consumers' negligence, courts should consider how different rules affect consumers' returns, which in turn affect the firm's incentives to recall the product. The "full duty to return" rule is equivalent to contributory

negligence or modified comparative negligence with the plaintiff's negligence larger than the defendant's fault. These rules may result in lower social welfare than the "no duty to return" rule, i.e., strict liability, when the expected harm is not always large, consumers' return costs are high, and the firm is very likely to be found liable. If the expected harm of the product is so large that it is always socially efficient for consumers to return the product and if the firm is very likely to be found liable, the "full duty to return" rule is more efficient than the "no duty to return" rule.

Furthermore, if the firm is very likely to be found liable, imposing consumers' partial duty to return, i.e., pure comparative negligence, can achieve social optimum: after the recall, the firm's liability should be reduced to a certain level depending on consumers' return costs, the firm's costs of recalls, and the probability for the firm to be found liable. However, this rule requires courts to take more effort identifying the above factors.

There are fruitful topics on product recalls for future research. First, empirical tests on how different liability rules affect firms' recall decisions and consumers' returns will provide more policy implications. Second, in many product recalls, firms not only repair or replace the products that have been sold, but also make decisions on continuing sales. Government agencies, such as the FDA, often get involved in making decisions on continuing sales. It would be important to discuss the linkage between product recalls and continuing sales. Thirdly, when consumers buy products, firms and consumers may make effort to increase consumers' ex-post access to recall announcements. Different liability rules would certainly affect such ex-ante effort.

## APPENDIX A

*Negligence rules used in the United States*

1. Contributory negligence: Alabama, District of Columbia, Maryland, North Carolina, Virginia
2. Modified Comparative Negligence: Arkansas, Colorado, Connecticut, Delaware, Georgia, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Maine, Massachusetts, Michigan, Minnesota, Montana, Nebraska, Nevada, New Hampshire, New Jersey, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Vermont, West Virginia, Wisconsin, Wyoming
3. Pure Comparative Negligence: Alaska, California, Florida, Kentucky, Louisiana, Mississippi, Missouri, New Mexico, New York, Rhode Island, South Dakota, Washington

**Source:** http://www.mwl-law.com/PracticeAreas/Contributory-Neglegence.asp

## APPENDIX B

*Proof of Proposition 2*: Given $q$, if the firm recalls the product and offers $t = k$, all consumers would return the product and the firm's total costs are $c + k$. If the firm does not make a recall, its expected liability is $p\int_0^1 HdG(H)$. Therefore, the firm would recall if $p \geq \frac{c+k}{\int_0^1 HdG(H)}$. However, according to Proposition 1, to maximize social welfare, the

firm should recall whenever $p \geq c + k$ and the socially efficient return should satisfy $H \geq H^{**} = \frac{c+k}{p}$. *Q.E.D.*

*Proof of Lemma 2*: Define the sum of the firm's total costs and the expected liabilities as $L = (t+c)(1-G(H_N)) + qp\int_0^{H_N} HdG(H)$. If $H_N = \frac{k-t}{(1-q)p} < 1$, we have

$$\frac{dL}{dt} = (1-G(H_N)) + \frac{(t+c)g(H_N)}{(1-q)p} - \frac{qpH_N g(H_N)}{(1-q)p}$$

$$= (1-G(H_N)) + \frac{g(H_N)}{(1-q)}[\frac{t+c}{p} - \frac{q(k-t)}{(1-q)p}]$$

(1) Suppose that $k \leq \frac{(1-q)}{q}c$. Then $\frac{dL}{dt}$ is always positive and therefore, *t*=0.

(2) Suppose that $k > \frac{(1-q)}{q}c$. According to Lemma1, the socially efficient reimbursement is $t^* = qk - (1-q)c$. If $t \geq t^*$, $\frac{dL}{dt} > 0$. Therefore, $t < t^*$.

When $p \leq c + k$, given $t < t^*$, $H_N = 1$ and the firm sets *t*=0.

When $c + k < p \leq \frac{k}{(1-q)}$, if $t = 0$, then $H_N = 1$. Define $\tilde{t}$ as the largest $t$ such that $H_N = 1$. It can be shown that $\tilde{t} = k - (1-q)p$. If $t = \tilde{t}$, then $\frac{dL}{dt} < 0$ since $p > c + k$ and $k > \frac{(1-q)}{q}c$. This implies that, when $c + k < p \leq \frac{k}{(1-q)}$, the optimal reimbursement

must satisfy $0 < t < t^*$. Setting $\frac{dL}{dt} = 0$ and substituting $H_N = \frac{k-t}{(1-q)p}$ lead to the optimal reimbursement $t$ satisfying $H_N - \frac{1-G(H_N)}{g(H_N)}(1-q) = \frac{c+k}{p}$.

When $p > \frac{k}{(1-q)}$, $H_N < 1$. Therefore, the optimal reimbursement $t$ satisfies $H_N = \frac{k-t}{(1-q)p}$ and $H_N - \frac{1-G(H_N)}{g(H_N)}(1-q) = \frac{c+k}{p}$. Q.E.D.

*Proof of Proposition 3*: (1) Suppose that $k < \frac{(1-q)}{q}c$. According to Lemma 2, $t$=0. Then $H_N = \frac{k}{(1-q)p}$. The firm recalls the product if and only if $c(1-G(H_N)) < qp\int_{H_N}^{1} HdG(H)$. The left hand side of this condition is always smaller than $c$, while the right hand side is strictly increasing in $p$. Therefore, there exists $p_N^2$ such that the firm makes a recall when $p > p_N^2$. Furthermore, when $p \le \frac{k}{(1-q)}$, then $H_N = 1$ and the firm will not make a product recall. When $\frac{k}{(1-q)} < p \le c+k$, $H_N < 1$ but the firm still does not make a recall since

$$c(1-G(H_N)) > q(c+k)(1-G(H_N)) \ge qp(1-G(H_N)) > qp\int_{H_N}^{1} HdG(H)$$

where the first inequality follows from $k < \frac{(1-q)}{q}c$, and the second inequality is true given $p \le c + k$. In summary, there exists $p_N^1 > c + k$ such that the firm does not make a recall whenever $p < p_N^1$.

To maximize social welfare, consumers should return the recalled product if and only if $H \ge H^{**} = \frac{k+c}{p}$, which is higher than $H_N = \frac{k}{(1-q)p}$. That is, there are more returns than socially desired.

Suppose that *H* follows the uniform distribution on [0,1]. As shown earlier, the firm would not recall the product when $p \le \frac{k}{(1-q)}$. Consider the case with $p > \frac{k}{(1-q)}$. The firm will make a recall if and only if $c(1-H_N) < qp\int_{H_N}^{1} HdH$, which is equivalent to $\frac{c}{qp}(1-\frac{k}{(1-q)p}) < \frac{1}{2} - \frac{k^2}{2(1-q)^2 p^2}$. Define $x=1/p$ and, for $x \in [1, \frac{(1-q)}{k})$, define $T(x) = \frac{c}{q}x(1-\frac{k}{(1-q)}x) - \frac{1}{2} + \frac{k^2}{2(1-q)^2}x^2$. The firm will make a recall if and only if $T(x) < 0$.

$T(x)$ is quadratic and $T(x = \frac{(1-q)}{k}) = 0$. Since $k < \frac{(1-q)}{q}c$, $T(x)$ is inverse U-shaped and $x = \frac{(1-q)}{k}$ is the larger number which solves $T(x) = 0$. Let $x_N$ be the smaller number which solves $T(x) = 0$. Therefore, $T(x) < 0$ if and only if $x < x_N$. Let

$p_N^2 = p_N^1 = \frac{1}{x_N} = \frac{2c}{q} - \frac{k}{1-q} > c + k$ if $\frac{2c}{q} - \frac{k}{1-q} \le 1$. The firm would make a recall if and only if $p > p_N^1 = p_N^2$. Note that $p_N^2 = p_N^1 = 1$ if $\frac{2c}{q} - \frac{k}{1-q} > 1$.

(2) Suppose that $k > \frac{(1-q)}{q}c$. According to Lemma 2, if the firm offers $t>0$, then consumers with $H \ge H_N = \frac{k-t}{(1-q)p}$ would return the product, and $H_N - \frac{1-G(H_N)}{g(H_N)}(1-q) = \frac{c+k}{p}$. However, the socially optimal return should satisfy $H \ge H^{**} = \frac{c+k}{p}$. Hence, $H_N > H^{**}$. If the firm makes a recall but offers no reimbursement, then consumers with $H \ge \frac{k}{(1-q)p} > H^{**}$ would return the product. In summary, there are fewer returns than socially desired.

It remains to show that the firm has incentives to recall the product whenever $p > c + k$. Note that $\frac{k}{1-q} > c + k$. First of all, when $c + k < p \le \frac{k}{1-q}$, if the firm recalls the product but offers no reimbursement, no consumer would return the product and the firm's expected liability is the same as without the product recall. However, according to Lemma 2 and its proof, when $c + k < p \le \frac{k}{1-q}$, it is optimal for the firm to offer $t > 0$. This implies that the firm would make a recall.

Secondly, when $p > \frac{k}{1-q}$, it is sufficient to show that the firm's total costs would be lower when making a recall and offering no reimbursement than its expected liability when not making a recall. If the firm recalls the product and offers $t = 0$, $H_N = \frac{k}{(1-q)p} < 1$. The firm's total costs are $c(1-G(\frac{k}{(1-q)p})) + qp\int_0^{\frac{k}{(1-q)p}} HdG(H)$; if the firm does not make a recall, its expected liability is $qp\int_0^1 HdG(H)$. Define $Z(p) = c(1-G(\frac{k}{(1-q)p})) - qp\int_{\frac{k}{(1-q)p}}^1 HdG(H)$. The firm recalls if and only if $Z(p) < 0$.

$$\frac{dZ(p)}{dp} = -\frac{k}{(1-q)p^2} g(\frac{k}{(1-q)p})(\frac{qk}{(1-q)} - c) - q\int_{\frac{k}{(1-q)p}}^1 HdG(H),$$

which is negative, given that $k > \frac{(1-q)}{q}c$. Since $Z(p)$ decreases in $p$ and $Z(p = \frac{k}{1-q}) = 0$, $Z(p) < 0$ for any $p > \frac{k}{1-q}$. That is, the firm would make a recall.

(3) Finally, suppose that $k = \frac{(1-q)}{q}c$.According to Lemma 2, if the firm makes a recall, it does not offer reimbursement. Consumers with $H \geq H_N = \frac{k}{(1-q)p} = \frac{c+k}{p}$ will return the product. Similar to part (2), the firm makes a recall whenever $p \geq c + k$. Therefore, the social optimum is achieved. Q.E.D.

*Proof of Proposition 4:* First, when $p < k$, consumers never return the product. Thus, under the "full duty to return" rule, the firm has no costs in the recall but can deny all future liabilities. Therefore, the firm recalls the product when $p < k$. Secondly, when

$p \geq k$, the firm recalls the product if and only if $c(1-G(\frac{k}{p})) < qp\int_0^1 HdG(H)$. When $p$ increases from $k$ to 1, the left hand side increases from 0 to $c(1-G(k))$ while the right hand side increases from $qk\int_0^1 HdG(H) > 0$ to $q\int_0^1 HdG(H)$. So there exists $p_D^2, p_D^1$ ( $p_D^2 \geq p_D^1 > k$ ) such that the firm recalls the product when $p > p_D^2$ and $H < p_D^1$.

Now assume that $g(H)$ is upper-bounded by a fixed number $M$. When $p \geq k$, the firm recalls the product if and only if $c(1-G(\frac{k}{p})) - qp\int_0^1 HdG(H) < 0$. Given $k$ and $p$ fixed, the left hand side of the condition decreases in $q$ and increases in $c$. Furthermore, the derivative of the left hand side with respect to $p$ is $g(\frac{k}{p})\frac{c}{p^2} - q\int_0^1 HdG(H)$, smaller than $M\frac{c}{k^2} - q\int_0^1 HdG(H)$. Therefore, if $k$ is large enough, $g(\frac{k}{p})\frac{c}{p^2} - q\int_0^1 HdG(H) < 0$ and correspondingly, $c(1-G(\frac{k}{p})) - qp\int_0^1 HdG(H) < 0$ whenever $p \geq k$. So there exists $\bar{k}$ such that, if $k \geq \bar{k}$, the firm would always make a recall.

In particular, assume that $H$ follows the uniform distribution on [0,1]. Consider the scenario with $p \geq k$. Since $H_D = k/p$, the firm recalls the product if and only if $c(1-\frac{k}{p}) < \frac{1}{2}qp$. Define $J(p) = -qp^2 + 2cp - 2ck$. When $J(p) < 0$ the firm will recall the product. Note that $J(p)$ is inverse U-shaped. In addition, $J(p \leq k) < 0$. Therefore, if $k \leq \frac{c}{2q}$, there exists two numbers larger than $k$ such that $J(p) = 0$. The solutions to

$J(p)=0$ are $\frac{c+\sqrt{c^2-2qck}}{q}$ and $\frac{c-\sqrt{c^2-2qck}}{q}$. If $\frac{c-\sqrt{c^2-2qck}}{q}<1$, define $p_D^1=\frac{c-\sqrt{c^2-2qck}}{q}$ and $p_D^2=\min(1,\frac{c+\sqrt{c^2-2qck}}{q})$. Then $J(p)<0$ if and only if $p<p_D^1$ or $p>p_D^2$. If $\frac{c-\sqrt{c^2-2qck}}{q}>1$, then $J(p)\le 0$ for all $p\in[k.1]$. If $k\ge\frac{c}{2q}$, $J(p)\le 0$ for all $p\in[k.1]$. Q.E.D.

*Proof of Corollary 1:* According to Lemma 1, to maximize social welfare, the firm should recall the product when $p\ge c+k$. Suppose that $p\ge k$. The firm recalls the product if and only if $c(1-G(\frac{k}{p}))<qp\int_0^1 HdG(H)$. When $k$ equals zero, the firm recalls the product if and only if $p>\frac{c}{q\int_0^1 HdG(H)}$; at the same time, $c+k$ diminishes to $c$. There are fewer recalls than socially desired, since $\frac{c}{q\int_0^1 HdG(H)}>c$. By continuity, there exists $\hat{k}>0$ such that, if $k\le\hat{k}$, there are fewer recalls than socially desired. The remaining results follow on from Proposition 4. Q.E.D.

*Proof of Proposition 6:* (1) Suppose that $q=1$. Under the "no duty to return" rule, the firm recalls the product if and only if $p\int_0^1 HdG(H)\ge c+k$. Under the "full duty to return" rule, the firm recalls the product if and only if $p\int_0^1 HdG(H)\ge c(1-G(\frac{k}{p}))$. Since $c+k\ge c(1-G(\frac{k}{p}))$, the "duty to return" rule leads to more recalls.

(2) According to Proposition 4, under the "full duty to return" rule, there exists $\bar{k}$ such that if $k \geq \bar{k}$, the firm always recalls the product and therefore there are more recalls than under the "no duty to return" rule.

Now suppose that both *H* and *p* follow the uniform distribution on [0,1] and $2c \leq q$. The assumption $2c \leq q$ is a sufficient condition for $p_N^1, p_N^2, p_D^1, p_D^2$ to be interior solutions within [0,1]. According to Proposition 4, for any *q*, if $k \geq \frac{c}{2q}$, the firm recalls the product under the "full duty to return" rule. In this scenario, the "full duty to return" rule leads to more recalls than the "no duty to return" rule.

If $k < \min(\frac{c}{2q}, \frac{(1-q)c}{q})$, according to the proofs of Propositions 3 and 4, under the "no duty to return" rule, the probability of not making a recall is $\frac{2c}{q} - \frac{k}{1-q}$; under the "full duty to return" rule, the probability of not making a recall is $\frac{2\sqrt{c^2 - 2qck}}{q}$. Note that $\frac{2c}{q} - \frac{k}{1-q} \geq \frac{2\sqrt{c^2 - 2qck}}{q}$ is equivalent to $8c - \frac{4c}{1-q} + \frac{qk}{(1-q)^2} \geq 0$ for any $k>0$. Define $X(k) = 8c - \frac{4c}{1-q} + \frac{qk}{(1-q)^2}$, which strictly increases in *k*.

Now suppose that $\frac{(1-q)c}{q} \leq k < \frac{c}{2q}$. According to Propositions 3 and 4, under the "no duty to return" rule, the firm does not make a recall if and only if $p < c + k$. The corresponding probability is $c + k$. In contrast, under the "full duty to return" rule, the

firm does not make a recall if and only if $\frac{c-\sqrt{c^2-2qck}}{q} < p < \frac{c+\sqrt{c^2-2qck}}{q}$. The corresponding probability is $\frac{2\sqrt{c^2-2qck}}{q}$. Define $Y(k)= c+k-\frac{2\sqrt{c^2-2qck}}{q}$, which is strictly increases in *k*.

First, let $q \le 1/2$. Then $\frac{(1-q)c}{q} \ge \frac{c}{2q}$. In this scenario, $X(k=0) \ge 0$ and $X(k=\frac{c}{2q}) \ge 0$. Therefore, $X(k) \ge 0$ for any $k < \frac{c}{2q}$. In summary, if $q \le 1/2$, the "full duty to return" rule always causes more recalls than the "no duty to return" rule.

Second, let $1/2 < q < 5/8$. If $k < \frac{(1-q)c}{q}$, $X(k=0) < 0$ and $X(k=\frac{(1-q)c}{q}) > 0$. If $\frac{(1-q)c}{q} \le k < \frac{c}{2q}$, $Y(k=\frac{(1-q)c}{q}) > 0$ and $Y(k=\frac{c}{2q}) = c+\frac{c}{2q} > 0$ so that $Y(k) > 0$ for any $\frac{(1-q)c}{q} \le k < \frac{c}{2q}$. Therefore, there exists $\tilde{k} > 0$ such that the "full duty to return" rule causes more recalls than the "no duty to return" rule if and only if $k > \tilde{k}$.

Finally, let $5/8 \le q < 1$. If $k < \frac{(1-q)c}{q}$, $X(k=0) < 0$ and $X(k=\frac{(1-q)c}{q}) < 0$, which implies that $X(k) < 0$ for any $k < \frac{(1-q)c}{q}$. If $\frac{(1-q)c}{q} \le k < \frac{c}{2q}$, $Y(k=\frac{(1-q)c}{q}) \le 0$ and $Y(k=\frac{c}{2q}) = c+\frac{c}{2q} > 0$. Therefore, there exists $\tilde{k} > 0$ such that the "full duty to return" rule causes more recalls if and only if $k > \tilde{k}$. Q.E.D.

*Proof of Proposition 7:*

(1) Under the "no duty to return" rule, according to Proposition 3, if $k > \frac{(1-q)c}{q}$, the firm's recall decision is socially efficient and consumers with $H \geq H_N$ will return the product, where $H_N - \frac{1-G(H_N)}{g(H_N)}(1-q) = \frac{c+k}{p}$. Note that when $q$ is arbitrarily close to 1, $H_N$ is arbitrarily close to $\frac{c+k}{p}$. Therefore, the social loss is arbitrarily close to zero. In contrast, under the "full duty to return" rule, if $k \geq \bar{k}$, the firm always recalls the product and consumers with $H > \frac{k}{p}$ return the product. So there would be excessive returns. The social loss is positive and does not depend on $q$. By continuity, there exists $\hat{q} < 1$ such that, if $\hat{q} < q < 1$ and $k > \max(\bar{k}, \frac{(1-q)c}{q})$, the "no duty to return" rule generates higher social welfare than the "duty to return" rule.

(2) When $k$ is equal to $1-c$, it is socially efficient not to make any recall. Given $q > c$, if $k$ is equal to $1-c$, then $k > \frac{(1-q)}{q}c$. According to Proposition 3, under the "no duty to return" rule, the firm does not recall the product. In this case, the social optimum is achieved. However, under the "full duty to return" rule, the firm recalls the product whenever $c(1-G(\frac{k}{p})) < qp\int_0^1 HdG(H)$, which holds strictly when $p$ is larger than but close to $k$. In this case, there are socially inefficient returns. Given continuity, there exists $k' < 1-c$ such that for any $k \geq k'$, the "no duty to return" rule generates higher social welfare than the "full duty to return" rule.

(3) Note the probability for $pH < c + k$ is zero. To maximize social welfare, the firm should always recall the product and all consumers should comply with the recall. Under the "full duty to return" rule, given $pH \geq c + k$, consumers always comply with the recall. Therefore, the firm makes a recall if and only if $c < qp\int_0^1 HdG(H)$, which holds when $q$=1. By continuity, there exists $\tilde{q} < 1$ such that if $\tilde{q} < q \leq 1$, then $c < qp\int_0^1 HdG(H)$, that is, the firm would always make a recall. In contrast, under the "no duty to return" rule, if $q$<1, according to Lemma 2, the firm does not offer sufficient reimbursement and there are socially insufficient returns. Therefore, the "full duty to return" rule generates higher social welfare. Q.E.D.

*Proof of Proposition 8:* When the firm recalls the product without paying reimbursement, consumers return the product if and only if $(1-\alpha q)pH \geq k$, which is equivalent to $pH \geq \frac{k}{(1-\alpha q)} = c + k$. That is, consumers' returns decisions are socially efficient. If $q = \frac{c}{c+k}$, as shown in Proposition 3, the firm makes recall decisions as socially desired. If $q > \frac{c}{c+k}$, the firm has more incentives to recall the product but this does not cause inefficient returns. The social optimum is achieved. If $q < \frac{c}{c+k}$, there are excessive returns under the "partial duty to return" rule. Therefore, the social optimum cannot be achieved. Q.E.D.

**FOOTNOTES**

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[2] For example, the return rates of many product recalls were between 10% and 30% (New York Times, April 12, 2002). Even for automobiles, the return rates were estimated to be between 20% and 70% (The Philadelphia Inquirer, September 10, 2000).

[3] The Philadelphia Inquirer, September 10, 2000.

[4] This paper ignores the possibility that consumers may not get aware of the recall. The results in the paper hold even if some consumers do not receive the recall announcement.

[5] For some legal discussions on product recalls and negligence, see O'Reilly (2003) and Stilwell (2007).

[6] Mobley (2002) discusses the difficulty in determining plaintiffs' negligence in car safety and recall cases. For more general issues in determining negligence (such as consumers' costs of care and courts' mistakes), see Shavell (1987, pp. 86-97) and the Handbook of Law and Economics (2007, pp. 158-161).

[7] This paper does not consider fixed costs of making recall announcements. Spier (2008) shows that a firm may not buyback its product as often as socially desired, if there are significant fixed costs of recalls.

[8] The empirical work on product recalls tests stock market reactions and the divergence between firms' and governments' incentives to make recalls. See Jarrell and Peltzman (1985), Hartman (1987), Hoffer, Rruitt, and Reilly (1988), and Rupp and Taylor (2002).

[9] In the literature on return policies specified ex-ante when consumers purchase products. (See Moorthy and Srinivasan, 1995; Che, 1996; Anderson, Hansen, and Simester, 2009), product returns happen after consumers learn information about the product.

[10] There may be uncertainties of the damage level for a consumer. In such scenarios, $H$ is the expected damage for the consumer when she is harmed. All results would still hold.

[11] This normalization simplifies the notation use in the analysis and does not affect the results in the paper.

[12] In this alternative scenario where consumers face heterogeneous likelihoods to be harmed, it may be due to consumers taking different care or using the product in different ways. Such differences may affect the determination of consumers' negligence in lawsuits. I would like to thank one referee for pointing this out. The results would be changed quantitatively but not qualitatively.

[13] Typically, firms cannot distort this information given that most recalls are monitored by government agencies such as the Consumer Product Safety Commission and the Food and Drug Administration (FDA).

[14] Having linear costs does not affect the results qualitatively. If the cost function is concave, there are economies of scale and the firm is more likely to recall the product and offer reimbursement. If the cost function is convex, the firm is less likely to do so.

[15] For simplicity, litigation costs are ignored.

[16] See Shavell (1987, pp. 86-97) and the Handbook of Law and Economics (2007, pp. 158-161), North Holland.

[17] If government agencies could share firms' costs or provide insurance on firms' liabilities, firms would have more incentives to make recalls. However, such cost sharing or insurance could not affect consumers' return decisions.

[18] For examples, in Frank P. Hammes and Jean Feehan v. Yamaha Motor Corporation, District Court for Minnesota, No.03-6456 (2006), the court did not admit the evidence relating to Yamaha's recall at trial, though it allowed the use of tests and reports created by Yamaha employees during the recall, to conclude that the product at issue was unsafe.

[19] As discussed in the introduction, this result differs from the literature since the firm's costs of recalls depend on consumers' returns and the firm cannot observe heterogeneous consumers' damage levels.

[20] There is discontinuity in the firm's incentives to recall the product when $q$ becomes 1. If $q$=1, the firm has to offer full reimbursement in order to make a recall. In contrast, even when $q$ is arbitrarily close to 1, the firm has some flexibility to adjust reimbursement.

[21] $\bar{k}$ is defined in Proposition 4.

[22] Note that there is discontinuity in the firm's recall decision when $q$ becomes 1, as shown in Section 3. Therefore, the result may not hold with perfect strict liability.

[23] In such scenarios, if feasible, courts may introduce punitive damage compensation and then reduce the punitive damage compensation if the firm recalls the product. However, such punitive damage compensation may be hard to be determined or enforced.

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