

Should 'State of the Art' Safety Be a Defense Against Liability?

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Abstract

Liability for injury due to hazardous products often hinges on the safety of the defendant's product relative to the safety of similar products. For instance, firms that can show their product's safety was "state of the art" can in some cases have their liability removed. This paper explores the legal definition of what it means to be state of the art and considers whether or not the availability of the defense is likely to improve product safety. The state of the art defense's effect on safety is found to depend on whether courts rely on a "technological advancement" or a "customary practice" tests of state of the art. When consumers are under-informed regarding product risks, the technological advancement test improves safety, and welfare, in a broad set of situations.

Key Words: product safety, liability, state of the art, customary practice

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I. INTRODUCTION

Economic analyses of product liability make important simplifying assumptions about the conditions under which defendants are liable. Models of strict liability typically assume that defendants are always liable when use of their product results in harm to a consumer or third party. Models of negligence tend to assume that defendants are liable whenever their investments in safety fall below the level that equates social marginal costs and benefits. In practice, however, the determination of liability is not so straightforward under either rule, since a defendant has recourse to a set of defenses that complicate the test of liability. This paper analyzes one of these -- the state of the art defense -- and in so doing broadens the understanding of incentives and market outcomes that arise given the practical implementation of product liability law.

Versions of the state of the art defense are defined in state statutes,¹ have been upheld in recent appellate decisions,² and are advocated in proposals for liability

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¹ State statutes frequently disallow a finding of product defect, and liability may therefore be removed, if, for example, "the design, methods of manufacture, and testing conformed to the generally recognized and prevailing standards or state of the art in existence at the time the design was prepared and the product manufactured" Ky. Rev. Stat. Ann. [*7]@411.310(1) (1992).

² Even in states without an explicit statute authorizing state of the art as an affirmative defense, state of the art defenses are often upheld. For example, see *Billy Glen Harwell v. American Medical Systems, Inc.* 803 F. Supp. 1287 (1992) which features testimony finding the defendant's product "the best available on the market" and the court's conclusion that that evidence "represents an affirmative defense to any claim of strict liability or negligence." Currently, at least 26 states admit the defense in design defect cases. For more detailed state-by-

reform.³ With the defense, manufacturers can avoid liability if their product's safety at the time of manufacture and sale compared favorably to the safety of similar, competing products, or to the customary practices in the industry. In this sense, a state of the art defense creates a relative, rather than absolute, test of liability. As an example, in *Elliott v. Brunswick Corp.*, a case involving injury by a motorboat propeller, the court found that when the plaintiff

"failed to demonstrate the existence of a safer, practical propeller guard for use on planing pleasure boats ... she failed to establish a products liability or negligence claim."⁴

The opinion makes no reference to the marginal benefits and costs of propeller guards. Instead, the liability test relies almost exclusively on a comparison between the characteristics of the defendant's product and the characteristics of its competitors' products.

The definition of what it means to be "state of the art" is an ongoing source of controversy among courts and commentators. Section II describes two primary, but conflicting, legal definitions of state of the art. The first regards a state of the art product as one which conforms to the "customary practice" of the industry. The second definition equates state of the art with more exceptional safety: being at the "forefront of technical advancement" or capability. Under this "technological advancement" definition, simply conforming with industry custom may, in fact, directly invalidate a state of the art defense.⁵

state descriptions of the relevant law, see Robert Klein (1986). Also see W. Kip Viscusi (1991). Based on data from the insurance industry, Viscusi finds that states with statutory provisions for a state of the art defense exhibit significantly lower insurance loss to premium ratios than do states without such provisions.

³ See James Henderson and Amos Twerski (1992) and especially the authors' discussion of the relationship between their proposed Restatement and the state of the art provisions of state statutes (pp. 1529 ff).

⁴ 903 F.2d 1509 (11th Circuit 1990).

⁵ For further discussion of the confusion between these interpretations of the term "state of the art", see Louis

The alternative definitions lead to different tests of liability. In turn, the different tests lead to qualitatively distinct "contests" in which firms compete in product safety in order to have their liabilities removed. In Section III, the strategic consequences of the tests and their effect on firm incentives are described. For both tests we then make a welfare comparison of a liability rule with the defense (either strict liability or negligence) and a liability rule without the defense (absolute liability).⁶

The state of the art test is used in situations where the safety of relatively complex products is being judged and where consumers are relatively uninformed regarding product characteristics. Information asymmetries between producer and consumer are important to understanding when the state of the art defense is used in practice and to evaluation of the defense's normative desirability. For instance, use of the term "custom" in this context -- where consumers are informationally hampered -- must be differentiated from custom's alternative use as a form of implicit contract. As Epstein and others have argued, standards based on custom can economize on contracting costs between mutually informed parties.⁷ Our analysis is directed at a different set of legal issues. In particular, the state of the art defense

Frumer & Melvin Friedman (1991) @2.26, Klein *supra* note 1, William Warfel (1991), or Kevin Cox (1987).

⁶ The analysis deliberately obscures the distinction between negligence and strict liability when a state of the art defense is allowable. Both rules provide for the removal of producer liability if a relative safety test is satisfied. Under strict liability, the state of the art test is used to demonstrate "absence of defect." Under negligence the test is used to demonstrate "due care." In both cases, the relative safety test determines whether the relevant criteria for removing liability is met.

Previous legal scholarship has noted that the distinction between strict liability and negligence is blurred when a state of the art defense is allowed; see for instance comment on O'Brien v. Muskin Corp. 94 N.J. 169, 463 A.2d 298 (1983) in Frumer & Friedman §2.26, where opinion based on state of the art determination is criticized due to "injection of negligence principles into a strict liability case."

⁷ Richard Epstein (1992). Also see Stewart Macauley (1963). Macauley's is an early statement of the contract view of custom: "Those who write and read specifications are experienced professionals who will know the customs of their industry and those of the industries with which they deal. Consequently, these customs can fill gaps in the express agreements of the parties."

does not apply to cases involving "obvious" defects or danger. Put differently, a manufacturer is not liable for failing to incorporate a level of safety that a consumer *knowingly* rejects.⁸

Relative safety tests are therefore not applicable in situations where there is no information asymmetry between producers and consumers.

The state of the art defense arises in cases marked by technological complexity where consumers and courts find it more difficult to judge whether a particular product characteristic is efficiently safe or not.⁹ When safety characteristics are not obvious to the consumer, the state of the art is relevant to the determination of whether or not a product is "unreasonably dangerous."¹⁰ A product may be unreasonably dangerous--and a finding of liability established--if

"alternative products were available to serve the same needs with less risk of harm."¹¹

Again, this legal test relies on estimations of relative safety, rather than on an "objective" calculation of efficient safety. Of course, the benefits of a contest in safety are likely to be

⁸ *Scallan v. Duriron Co.*, 11 F.3d 1249; 1994 U.S. App. LEXIS 700, *Linegar v. Armour of America, Inc.*, 909 F.2d 1150; 1990 U.S. App. Lexis 12510. For this reason, in most jurisdictions an automaker that offers a safety feature as optional equipment is not liable for injuries that would have been prevented by that option. That is, the relative dangers of cars not equipped with the safety option are "obvious" and "knowable" to the consumer.

⁹ State of the art cases arise almost exclusively in situations marked by technological complexity and change -- situations where product information and contracting costs are likely to be large. Judicial acceptance of a test based on relative safety often explicitly hinges on the complexity of the product in question. See *Hoppe v. Midwest Conveyor Co.* 485 F.2d 1196,1202 (8th Cir. 1973) in which comparison to a competing product's design was considered relevant on the grounds that the defendant's product was a "highly complicated piece of machinery."

Epstein (note 7 *supra*) makes a similar point, saying "the defense of custom is not that it is certain but that it is superior to any ex post reconstruction of the reasonable level of care that a judge or jury is likely to undertake." In his analysis, he does not directly speak to the issue of technological complexity. He does note, however, that customs are "more likely to be robust when there are thousands of repeat transactions ... They will perhaps be weaker where there are isolated large losses, as with employer liability, medical malpractice, and product liability cases arising out of a consensual arrangement."

¹⁰ *Delvaux v. Ford Motor Co.*, 764 F.2d 469, 474 (7th Cir. 1985), "A design is unreasonably dangerous only if it presents dangers not apparent to the ordinary consumer or user."

¹¹ *Halphen v. Johns-Manville Sales Corp.*, 484 So.2d 110 (La. 1986).

greatest when there are asymmetries in information between a producer and consumers or courts.¹²

An overview of our results is as follows. Under the technological advancement test, the market bifurcates into two sets of firms, differentiated by their distinct safety investments. Firms who successfully satisfy the technological advancement test win a prize: the removal of liability with some probability. This incentive leads some firms -- the "safety leaders" -- to spend more on safety than they would under absolute liability. Not all firms can gain by emulating the safety leaders, however. As more firms seek to emulate the leaders, their safety investments are less likely to be judged exceptional (all firms cannot expect to be "exceptionally" safe). As a consequence, and since safety is costly, a subset of firms chooses to not be state of the art. These firms are liable with probability one and thus make safety investments identical to those they would make under absolute liability.

Therefore, relative to absolute liability, average safety increases when a state of the art defense based on the technological advancement test is allowed. No firm invests in less safety than under absolute liability and a subset invest in strictly greater safety. If inadequate safety is motivated by absolute liability, this increased safety improves welfare. For instance, the technological advancement state of the art test can improve efficiency relative to absolute liability when (1) safety is the product of costly and imperfectly appropriable innovative

¹² The safety contests created by a state of the art defense are similar in flavor to the contests created by regulators in the theory of "yardstick competition." In both cases, the rationale for rewards based on performance relative to one's peers is due to informational constraints faced by the regulator or courts. See Andrei Shleifer (1985).

The incentives created by the technological advancement test are also reminiscent of issues in the economic literature on research and development, particularly the literature on technology adoption, where firms use R&D investments to compete for asymmetrically distributed benefits. As examples, see Drew Fudenberg and Jean Tirole (1985), or Jennifer Reinganum (1981).

activity, and/or (2) when, due to imperfect enforcement, firms do not expect to fully internalize the social costs of product-related harm under absolute liability.

In contrast, the benefits of a customary practice test are, at best, uncertain. The customary practice test is functionally equivalent to a negligence rule, but one with an endogenously determined standard of non-negligent safety (the industry custom). Clearly, the desirability of the customary practice test depends on the custom that emerges in equilibrium. Given consumers' and courts' lack of information in cases where the state of the art defense is used, however, an important discipline on the level of custom that emerges is removed. If courts are constrained in their ability to derive efficient standards *ex post*, and if consumers cannot condition on safety characteristics *ex ante*, the custom is likely to be below the level that would have emerged under absolute liability.¹³ Therefore, when technological or scientific complexity clouds the derivation of an efficient standard -- the situation in which the state of the art defense is most likely to be used -- the customary practice test does not lead to the efficiency improvements generated by the technological advancement test.

Our prescriptive conclusion: A state of the art defense can improve efficiency, subject to the important caveat that being adjudged state of the art requires a greater burden of proof than mere conformance to a common industry standard. Permitting liability to be removed by simple compliance with industry custom does not account for the possibility that information is costly or liabilities are externalized. In contrast, when absolute liability leads to suboptimal

¹³ The reason custom performs poorly in this situation is that consumers cannot observe the level of custom and evaluate its desirability at the time of purchase. The use of custom analyzed by Epstein is different, since he addresses the use of custom by mutually informed trading partners. Epstein's point is that the customary practice standard under negligence can be expected to converge to the jointly optimal level of care since it is possible to "contract out of" any unacceptable custom.

safety due to imperfectly appropriable intellectual property rights or incomplete internalization of product risks, the technological advancement test improves welfare.

II. RELATIVE LIABILITY

Neither courts nor legislatures have settled on a consistent definition of what it means to be state of the art. In some jurisdictions, evidence of common industry practice is used to define the state of the art. Other jurisdictions require evidence of more exceptional safety. These contrasting views define two distinct tests for determining liability: the "customary practice" and "technological advancement" tests. This section characterizes the legal distinctions between the tests and relates the tests to the analytical structure of the model.

Consider an industry with n firms, each making safety investments that translate into reduced product risks. In judging the validity of a defendant's state of the art defense, courts weigh the "technical context" at the time of manufacture, whether or not the product was the "safest on the market," or the existence of a "practical alternative" in their determination of manufacturer liability.¹⁴ This requires courts to observe, in effect, not only the safety of the defendant's product, but the safety of an entire line of similar, competing products. Having observed the distribution of safety choices made by a relevant set of competitors, the court determines liability by comparing the defendant's safety to this overall distribution.

Assume courts behave *as if* the following process occurs when a defendant seeks to employ a state of the art defense.

¹⁴ See *Boatland v. Bailey*, 585 S.W.2d. 805 (Texas Civ. App., 1979). "Whether the product was defectively designed must be judged against the technical context existing at the time of manufacture," and "in relation to safer alternatives."

- First the court observes or estimates the safety investments of all n firms in the defendant's market.
- Second, liability is based on a determination of the defendant's *relative safety*, i.e., comparison of the defendant's safety investment (s_i) to the safety investments made by competitors (s_{-i}).

Let

$\rho_i = \rho_i(s_i, s_{-i})$ = the probability the defendant is found to be liable, based on its relative safety.

If the firm is liable, the court imposes compensatory damages for the full social costs of injuries due to the product's use. The same level of damages are imposed under *absolute liability*, the benchmark case where a state of the art defense is not allowed. Under absolute liability, the defendant is liable irrespective of the safety of its competitors' products ($\rho_i = 1$).

Throughout, we assume that consumers cannot condition their demands on the safety of a particular firm's product. As noted in the introduction, relative liability tests are most often observed in cases where courts find objective measures of efficient product safety to be too costly or impossible to determine. In the same situations, consumers *ex ante* are unlikely to be able to observe safety characteristics.¹⁵

A. The Customary Practice Test

In some jurisdictions, a defendant can avoid liability with a state of the art defense by demonstrating that its product conformed to "industry standards" existing at the time the

¹⁵ The net benefit to a consumer of measuring safety is typically much less than the benefit to either party in products litigation for two reasons. First, when consumers choose among alternative products, a product-related loss is probabilistic and usually unlikely. Second, a typical consumer will usually be less able than a court (informed by expert testimony and more extensive data) to measure product safety.

product was manufactured and sold. For example, in *Alevromagiros v. Hechinger Co.*, a case involving injury on a ladder, the plaintiff appealed on the basis that the original trial judge erred in not allowing the introduction of a competitor's ladder -- one with more safety features than the defendant's -- as evidence of the defendant's non-conformance with the state of the art.¹⁶ On appeal, the Circuit Court upheld the district judge's statement that "simply because certain manufacturers put certain features on ladders, that is not the test. . . . (B)ringing in one particular competitor's ladder . . . and making that an industry standard, that is terribly misleading." The Court of Appeals concluded that

"(A) plaintiff may not introduce a single example of a competing product and purport to make it a standard for the industry. He or she must establish the violation of industry or government standards. . . ." ¹⁷

Given this customary practice test, if courts compare the defendant's safety to an industry standard \bar{s} derived from the set of competing firms' safety choices, then a customary practice defense is admissible if the defendant's product met or exceeded the standard.

We now turn to the court's derivation of the industry standard, \bar{s} . Assume that at the time they make safety decisions, manufacturers view \bar{s} -- the court's determination of the "customary practice in the industry" -- as a random variable that depends on the set of safety choices made by itself and its competitors. To maintain generality, we place minimal structure

¹⁶ 993 F.2d 417 (1993).

¹⁷ Or, "generally speaking, state of the art refers to the customary practice in the industry" as in *Sturm, Roger, & Co. v. Day*, 594 P.2d 38 (Alaska 1979). See also, *Banks v. Iron Hustler Corp.*, 59 Md. App. 408, 475 A.2d 1243 (1984) and *Turner v. Manning, Maxwell & Moore, Inc.* 216 Va. 245, 251, 217 S.E.2d 863,868 (1975) wherein compliance with industry custom "may be conclusive when there is no evidence to show that it was not reasonably safe."

on the judicial process that determines \bar{s} . If all firms make identical safety expenditures ($s_i = s$, all i), then that safety expenditure is the industry standard \bar{s} with probability one. Otherwise, the industry standard never exceeds the highest safety expenditure made by any firm in the industry. Beyond that, we require only that, all else equal

- the higher is s_i in the distribution of safety expenditures (the larger the fraction of firms whose expenditures do not exceed s_i), the more likely that s_i will meet or exceed the court's determination of \bar{s} ; (CUS1)
- the probability that a given s is viewed as the standard increases as the fraction of firms making that s increases. (CUS2)

Given individual firms' safety investments, there is an implied probability distribution over the \bar{s} chosen by the court. Note that we do not assume that the customary practice defense is conclusive. That is, given the realization of an industry standard, a firm whose safety expenditures meet or exceed the standard can still be found liable.¹⁸ We do assume that whenever the defendant's safety is found to be in compliance with the court's determination of the industry custom, then (1) the defendant's probability of liability ρ_i is strictly less than one and (2) ρ_i falls as \bar{s} increases.

B. The Technological Advancement Test

A commonly applied alternative definition of state of the art holds the defendant to a more stringent test than conformance with industry custom. *Chown v. USM Corp.* is illustrative¹⁹:

¹⁸ The court may determine that the industry standard is itself unreasonably unsafe. As stated by Judge Hand in *The T.J. Hooper*: "Courts must in the end say what is required; there are precautions so imperative that even their universal disregard will not excuse their omission."

¹⁹ 297 N.W.2d.218, Iowa (1980). Also, see *Cantu v. John Deere Co.*, 603 P.2d 839 (1979): "plaintiff's brief refers to the 'state of the art,' which is sometimes confused with 'standards of the industry.' We believe the two phrases are

"(A) distinction exists between custom and state of the art, custom refers to what was being done in the industry, state of the art refers to what feasibly could have been done."

In this view, the distinguishing characteristic of a state of the art product is that no competing product is safer.

In recent support of this view, the court in *Montgomery Ward v. Gregg* argues that "plain and common" definitions of the term state of the art "suggest the concept of technological advancement; [none] contains an element of industry practice."²⁰ In this case, in apparent contradiction to the decision in *Alevromagiros*, the court upheld the introduction of a competing product as evidence that a tire supplied by Montgomery Ward was not state of the art. Indeed, in recognition of the controversy between the customary practice and technological advancement interpretations, the court stated that

"Were we to construe 'state of the art' as the custom and practice in the industry, a manufacturer would be excused from liability, regardless of a product's defective, unreasonably dangerous condition, simply because other manufacturers were producing similar products."

Clearly, this is not the same as the customary practice test.²¹ Specifically, given the technological advancement test, a firm *i*'s state of the art claim is admissible only if

- no other competitor's product is safer ($s_i \geq s_j$, all $j \neq i$). (TA1)

not synonymous." For a similar, but statutory, distinction see Colo. Rev. Stat. §13-21-403(1)(a) (1984 Cum. Supp.).

²⁰ 554 N.E.2d 1145 (Ind. App. 1st Dist. 1990).

²¹ For another explicit recognition of the controversy over the meaning of state of the art, see *Phillips vs. Cameron Tool Corporation*, 950 F. 2d 488; (7th Circuit Court of App. 1991).

If this condition is violated, the defendant's state of the art claim is inadmissible and $\rho_i = 1$. Note, though, that while existence of a safer product is fatal to the defense, multiple firms can simultaneously satisfy the admissibility criteria (TA1). That is, (TA1) does not require the defendant to have the *safest* product, only that there be *no safer* firm.²² As with the customary practice test, liability is not conclusively removed when all firms make the same safety expenditure. Instead, when all firms are identically safe, there is a probability that a plaintiff can successfully argue that this "customary practice" in the industry is, in fact, unreasonably unsafe.²³

More generally, given an admissible claim, assume that the probability of making a successful defense ($1-\rho_i$) increases as the defendant firm's safety s_i becomes more exceptional, relative to competitors' safety choices (s_{-i}). While our central results do not depend on a particular parameterization of this last assumption, it is most plausible to think of "exceptional" as summarizing two dimensions of relative safety: first, the difference between the safety of the defendant firm and the court's determination of the industry standard, and second, how unusual the defendant's expenditures were, i.e., the proportion of the firms in the market whose safety

²² Frumer & Friedman §2.26 [8](c), 2-1672: a successful state of the art defense requires "proof that no other manufacturers in the relevant industry were using a more advanced type of technology." See also *Maxted v. Pacific Car and Foundry Co.*, 527 P.2d 832 (Wyo., 1974), where the court ruled in favor of the defendant based on the finding that "there was no safer design available at the time the unit was manufactured."

Also, in the case of pharmaceuticals the existence of a safer alternative is in some jurisdictions fatal to the "unavoidably unsafe" defense. See, e.g., *Toner v. Lederle Laboratories* (1987) 112 Idaho 328, *Graham v. Wyeth Laboratories* (1987, DC Kan) 666 F Supp 1483, or *Kociemba v G.D. Searle & Co.* (1988 DC Minn) 680 F Supp 1293. For the description of what constitutes an unavoidably unsafe product see 70 A.L.R. 4th 16 ("Products Liability: What is an 'Unavoidably Unsafe' Product?") @3,@4,@7.

²³ Compare ρ when all firms make the same expenditure to ρ when i is the unambiguous safety leader. Note that we do not place restrictions on the relative values of ρ in these two situations. For example, if all firms make the same expenditure on safety, but at an objectively high level of expenditure, each firm could have a lower value of ρ than if one firm is the unquestioned safety leader, but all firms have objectively small expenditures.

expenditures matched the defendant's. For example, suppose there are two groups of firms with each firm in group 1 spending s_1 and each firm in group 2 spending s_2 on safety (where $s_2 > s_1$). Under the assumptions made, (i) since group 2 firms are strictly safer, firms in group 1 are always liable, whether the court determines the industry standard to be s_1 or s_2 ; (ii) as group 2 becomes larger relative to group 1, expenditures s_2 become less exceptional, and therefore, whether s_1 or s_2 is the standard, the firms in group 2 are more likely to be held liable; and (iii) when s_1 is the court's choice of industry standard, a group 2 defendant is held liable with a probability that decreases in $s_2 - s_1$.²⁴

Summary: The Probability of Being Liable

The two state of the art tests described above place different conditions on the removal of a defendant manufacturer's liability. The crucial difference is that the technological advancement test requires evidence that there is "no safer" product in the defendant's market. The customary practice test makes no such requirement. As long as the defendant's safety exceeds the standard, the customary practice test admits the defense.

Test	Relative Safety		
	$s_i = s_j, \text{ all } j$	$s_i > s_j, \text{ all } j$	$s_j > s_i, \text{ some } j$
technological advancement	$0 < \rho_i \leq 1$	$0 \leq \rho_i < 1$	$\rho_i = 1$
customary practice	$0 \leq \rho_i < 1$	$0 \leq \rho_i < 1$	$0 \leq \rho_i < 1$

The differences between the technological advancement and customary practice tests are summarized in the following table. The table shows the probability that defendant i will be

²⁴ That is, $\rho_i(s_i - \bar{s})$ is continuous in s_i when $s_i \geq \bar{s}$. And, if $s_i \geq \bar{s}$, then $\rho_i(s_i - \bar{s}) \leq 1$, $\rho_s(\cdot) = \partial \rho / \partial (s_i - \bar{s}) < 0$ and $\rho_{ss}(\cdot) \geq 0$.

held liable (ρ_i) as a function of its product's safety s_i and the safety of competing products s_j .

Because the two tests create different necessary conditions for the removal of liability, they lead to different incentives to provide product safety. We now turn to the equilibrium safety investments that result from the relative safety contest implied by the alternative definitions of what it means to be state of the art.

III. THE EFFECTS OF THE DEFENSE

In this section we characterize the effects of a state of the art defense on firm safety. The results in this section require only that every firm's safety (strategy) is a best response, given the decisions of other firms and the liability rule. As such, the results apply to a wide variety of market structures and are consistent with standard equilibrium refinements. As a benchmark, let \hat{s} denote the safety investment made by a profit-maximizing firm under absolute liability. For simplicity, assume a perfectly competitive industry characterized by free entry.²⁵

A. Safety Choices When 'Technological Advancement' Defines the State of the Art

The technological advancement test creates a contest in which exceptional safety is rewarded by reduced expected liability costs. This contest increases average market safety in equilibrium.

PROPOSITION 1: In equilibrium, if the TA test is used to determine the admissibility and validity of the state of the art defense, then all firms spend at least as much on safety as they would when liability is absolute and no defense is allowed.

²⁵ The qualitatively identical case of oligopoly is addressed explicitly in a previous working paper, "The State of the Art Defense: Is 'Relative Safety' a Desirable Test of Liability?" Working paper, John M. Olin School of Business, 1994.

To demonstrate this result we first describe the possible Nash equilibria safety choices that can be made under the TA test. These equilibria are of only two possible forms: (i) *point equilibria*, in which all firms make the same safety choices ($s_i = \bar{s}$, all i), and (ii) *bifurcated equilibria*, in which some firms choose the same safety as under absolute liability, \hat{s} , and other firms choose strictly greater safety, $s^+ > \hat{s}$. We then argue that only bifurcated equilibria should be expected, given the most plausible refinement to the Nash equilibrium. Moreover, this same refinement implies that even if point equilibria exist, safety will be greater than under absolute liability.

To see that all equilibria are either point or bifurcated equilibria, assume otherwise. Suppose there are three firms making safety investments s_1 , s_2 , and s_3 , where $s_1 < s_2 < s_3$. Because firms 1 and 2 do not satisfy (TA1), both expect to be absolutely liable ($\rho_1(\cdot) = \rho_2(\cdot) = 1$) as long as they spend strictly less than firm 3. But firms facing absolute liability optimally spend \hat{s} on safety. Thus, any firm not spending at least as much as firm 3 will spend \hat{s} . That is, whenever firms make distinct safety expenditures, any firm that is not at the top of the distribution of safety will optimally spend \hat{s} . Therefore, there can be at most two distinct safety expenditures in equilibrium.

Bifurcated equilibria therefore imply a special kind of distribution of safety expenditures: A subset of firms spend \hat{s} , while the "safety leaders" spend strictly more than \hat{s} . A lemma in the appendix demonstrates that bifurcated equilibria exist. The lemma also shows that the safety leaders earn positive (expected) profits. This must be true since, in order to support a bifurcated equilibrium, if another firm emulated the safety leaders, then that emulating firm earns

non-positive profits. While free entry ensures that non-state of the art firms earn zero expected profit the TA test gives the safety leaders sustainable, positive expected profits.

By contrast, in a point equilibrium all firms earn zero expected profits due to free entry. Thus, because the safety leaders in a bifurcated equilibrium earn positive profits, bifurcated equilibria are more plausible, since they Pareto dominate point equilibria. To understand the intuition behind the "Pareto refinement," imagine that there is a point distribution at some \bar{s} . First suppose that $\bar{s} < \hat{s}$. In this case, any firm that understands the incentives of the TA test will want to increase its safety expenditure to some $s^+ > \hat{s}$. By increasing safety from \bar{s} to $s^+ > \hat{s}$, this firm breaks the point equilibrium and causes all other firms to become absolutely liable. If the first firm has chosen an appropriate value of $s^+ > \hat{s}$, though, not all firms will gain from emulation. The result is a bifurcated equilibrium in which the leader will make positive expected profits.

Obviously this same argument need not hold true if, for some reason, safety expenditures are irreversible and past history has led to a high $\bar{s} > \hat{s}$. If so, then a single firm may not be able to profit by increasing safety expenditures. As a result, any point equilibrium that can survive the Pareto refinement must imply safety expenditures that strictly exceed the safety that would emerge under absolute liability. Therefore, whether or not the TA test leads to a point or bifurcated distribution of safety, no firm spends less on safety than they would under absolute liability, and at least some firms spend strictly more. This completes the proof of Proposition 1.

Although we do not prove the existence of equilibrium for every possible market structure, the appendix proves that pure-strategy Nash equilibria exist under perfect competition.²⁶ We emphasize that since the above proposition, and those that follow below, rely only on the assumption that firms make best responses, the qualitative properties of the equilibria are robust to a broad range of market structures.

We now turn to the defense's effect on welfare. When will the extra safety stimulated by the defense improve welfare relative to absolute liability? Clearly, the defense can lead to welfare improvements only when absolute liability fails to induce efficient safety; otherwise, the technological advancement test induces some firms to overinvest in safety. To explore the welfare effects of the technological advancement test consider two causes of sub-optimal safety under absolute liability: a liability system that fails to fully internalize costs, and markets in which safety investments are a public good.

Sub-optimal safety due to incomplete cost internalization. Proposition 1 showed that the technological advancement test creates a bifurcated equilibrium with non-state of the art firms producing safety \hat{s} , the profit-maximizing level of safety under absolute liability. Safety \hat{s} may be less than the first best, s^* , when firms can externalize liability due to imperfect enforcement or potential bankruptcy.²⁷ If so, then the technological advancement test can

²⁶ Even when a pure strategy Nash equilibrium does not exist, the bifurcation result can still be guaranteed with minor refinements to the equilibrium concept. For example, the equilibrium in mixed strategies is bifurcated since no firm would want to place positive probability on making an investment s between \hat{s} and the largest s_i . Moreover, a pure strategy Nash equilibrium can be guaranteed in any example by assuming that safety investments are sunk.

²⁷ For analyses that feature the effect of potential defendant bankruptcy see, among others, Alan Schwartz (1985); Steven Shavell (1986); William M. Landes and Richard A. Posner (1987); and Lewis A. Kornhauser and Richard L. Revesz (1990). For analysis of the effect of imperfect enforcement on deterrence see Gary Becker (1968).

improve welfare by leading some firms to increase safety beyond \hat{s} .

Safety as the product of imperfectly appropriable innovation. Particularly in the case of technologically complex products, increased product safety may result from interactions between the innovative activities of multiple firms. When individual firms' safety innovations provide spillover benefits to competing manufacturers, inefficiencies in the provision of safety are created even when absolute liability fully internalizes costs, due simply to the public good nature of individual firms' safety investments.

In a previous working paper,²⁸ we showed that the technological advancement test -- by rewarding an innovator -- can reduce or eliminate the inefficiency that arises when safety innovation creates positive spillovers. By rewarding innovators with the removal of liability, the TA test can overcome the inefficiencies implied when property rights in innovations are incomplete or difficult to enforce. It is essential, however, that courts reward innovative activity, and not simply the adoption of innovations or product characteristics. Should courts fail to distinguish between firms that innovate in safety and those who simply appropriate others' innovations, then the incentive to innovate can be removed. If an innovator is copied by a rival and if the court views the rival's safety as equivalent to the innovator's, then, because all rivals will copy, the innovator will not be viewed as state of the art.

It is also possible that the TA test can lead to over-investment in safety, particularly when the safety choices made under absolute liability are relatively efficient. The removal of liability under a state of the art defense can imply a benefit to the firm that is greater than the social benefits of its increased safety. In effect, there can be excessive competition to secure

²⁸ See note 25 *supra*.

the prize offered by the state of the art defense. So while the TA test can never lead to less safety than absolute liability, the test can reduce welfare by stimulating excessive investments in safety.²⁹

B. Safety Choices When Customary Practice Defines the State of the Art

Unlike the technological advancement test, the customary practice test does not require a state of the art product to be the safest product in the market. We now show that, in contrast to the safety-promoting effect of the technological advancement test, the customary practice test is likely to reduce safety relative to absolute liability.

PROPOSITION 2: Under the customary practice test, the customary level of safety that emerges in equilibrium is likely to be lower than the safety induced by absolute liability.

To demonstrate the proposition we first show that the customary practice test leads firms to make identical safety choices in equilibrium. Then we argue that, while a broad range of Nash equilibria are possible, the most plausible equilibria are those in which the custom is inefficiently low.

The proof that equilibrium safety choices lead all firms to make identical safety investments is made by contradiction. Assume that an equilibrium exists in which there are two types of firms, 1 and 2, where firms of type 2 are safer, $s_1 < s_2$. With the market in

²⁹ When suboptimal safety arises under absolute liability due to potential insolvency, the defense can be shown to have a more certain, positive impact on welfare. More specifically, in markets that perform particularly poorly under absolute liability, the technological advancement test will lead no firms to spend more than the first-best safety expenditure. Low-wealth firms (those with little legally recoverable capital, e.g., firms using very labor-intensive production processes) will tend to make the lowest safety investments under absolute liability. So consider the set of markets comprised of firms whose legally recoverable wealth w is strictly less than s^* , the efficient safety choice. Clearly, no firm can be led to make safety expenditures that exceed its wealth. Therefore, when applied to such low-wealth markets, the technological advancement test will cause a subset of firms to increase their safety expenditures, but no firm will spend more than s^* .

equilibrium, all firms earn zero expected profits. Given this ordering of safety investments, firms of type 2 are less likely to be held liable ($\rho_1(\cdot) \geq \rho_2(\cdot)$). Expected profits can still equal zero for both types of firms, though, since safety is costly. Now suppose, however, that one or more of the type 2 firms reduce their safety expenditures from s_2 to s_1 , emulating the safety expenditures of the type 1 firms. This reduces the probability that a firm making expenditures s_1 is liable. The reason is that (i) under the customary practice test, liability is removed by meeting or exceeding a standard (that is not unreasonably unsafe), and (ii) by (CUS2), the probability that s_1 is the standard increases as more firms choose s_1 . Therefore, $\rho(s_1)$ falls as a greater fraction of firms choose s_1 . Since expected profits were originally equal to zero for both types of firms, once a firm changes from s_2 to s_1 , it becomes relatively more profitable to choose s_1 than s_2 , and therefore other type 2 firms will follow suit.³⁰ Therefore, the customary practice test precludes the existence of an equilibrium with two distinct safety choices. An analogous argument holds when more than two safety choices are postulated.

Why is a bifurcated equilibrium not possible under the customary practice test? In contrast to the TA test, which requires exceptional safety, the customary practice test rewards only "average" safety. Under the custom test a defendant's liability is removed simply by meeting the standard. Also, the probability that a defendant meets or exceeds the standard increases -- or at least stays the same -- as other firms match the defendant's safety. As a

³⁰ Observe that the test creates more of an incentive for the type 2 firms to reduce their safety than it does for the type 1 firms to increase their safety. The reason is that if the type 1 firms increase their safety to s_2 , the probability that type 2 firms are not liable need not fall. That is, the probability that type 2 firms are found to meet or exceed the industry custom equals one, independent of how many firms are of that type. Thus, unless the court is less likely to find s_2 unreasonably dangerous as a larger fraction of firms choose s_2 , firms of type 1 do not have an incentive to increase their safety to s_2 .

result, firms cannot profit from above average safety. Any firm that could profit, would be uniformly emulated -- thus removing any advantage to being at the higher level of safety. This is not the case under the TA test. Under the TA test a safety leader's probability of being found liable *increases* as more firms emulate its safety. This places a limit on emulation that implies positive profits for the safety leaders.

Although the contest created by a customary practice test leads to symmetric manufacturer safety choices, a range of equilibrium customs is possible.³¹ But what standard is most likely to emerge? Absent refinements to the equilibrium concept the customary practice test can yield either quite low or very high levels of custom. However, low levels are more likely in the informational environment where the state of the art defense is most likely to be admissible. As argued earlier, consumer sophistication and the ability to contract around an undesirable custom are inconsistent with the conditions that give rise to the state of the art defense. Thus, absent other legal tests, *no* safety may be the equilibrium value of \bar{s} . This can be seen from the earlier demonstration that firms can be led to adopt the lower safety expenditures out of any distribution of safety.

This "race to the bottom" may be avoided to the extent that courts can impose a "reasonableness" test on the industry custom.³² While this places a floor on the set of

³¹ When all firms make identical safety investments, all meet the industry standard \bar{s} and all expect to have their liability removed. This is true for any \bar{s} . Consider a situation, therefore, where all firms but firm 1 make the same expenditure. Also suppose that if firm 1 spends less than the other firms, then firm 1's safety expenditures will be found below \bar{s} with probability one. Under this specification of $\rho(\cdot)$, customary practice can support as an equilibrium any s in the interval $[0, s^{\max}]$, where s^{\max} is the largest safety expenditure that makes a firm indifferent between spending s^{\max} and having no liability ($\rho(\cdot) = 0$), and spending \hat{s} but being liable with probability one. If all firms make identical safety expenditures at any s in the interval $[0, s^{\max}]$, then no firm has a unilateral incentive to change its safety choice.

³² As in note 18 *supra*.

acceptable customs, we again emphasize that even customary practice augmented with a reasonableness test need bear no necessary relationship to the efficient custom. Even when the customary practice test is augmented with some form of a reasonableness test, when consumers cannot condition their demand on the industry custom, there is a strong tendency to minimize the standard in equilibrium. Therefore, we conclude that absolute liability will motivate more safety investment than will a state of the art defense based on the customary practice test. An absolutely liable manufacturer at least balances the costs and private (liability) benefits of increased safety. A manufacturer held to an industry custom need make no such calculation, since meeting the custom can be sufficient to remove liability.

As a result, we believe that when industry custom is used as a test of state of the art, it is therefore unlikely that the industry custom \bar{s} will converge over time to the efficient level of care. In other words, while we agree with Epstein (1992) that the customary practice test may lead to efficiency when risks are known and internalized by consumers, we do not believe that customary practice is an appropriate test of state of the art.

There is an additional reason to favor the technological advancement test. It is well known that conditioning the removal of liability on compliance with a negligence standard can create excessive consumption, since compliant firms will not internalize liability costs.³³ Thus -- since a customary practice state of the art test is equivalent to a negligence rule with an endogenously determined standard of compliance -- the customary practice test produces the same potential consumption inefficiency as a Learned Hand negligence rule. And, as argued

³³ Prices under absolute liability include expected social costs (due to the manufacturer's expected liability) while prices under negligence do not, since liability is removed conditional on compliance. See A. Mitchell Polinsky (1980).

above, the customary practice test is likely to reduce, not improve, firm safety incentives relative to absolute liability.³⁴

Unlike a negligence rule, however, the technological advancement test does not reduce prices relative to absolute liability. Instead, both state of the art and non-state of the art firms sell at the same price, the minimum average cost of a firm that faces absolute liability and invests \hat{s} in safety. The reason is as follows. First, because buyers cannot observe product safety *ex ante*, no firm can sell at a higher price and remain in the market. Second, no state of the art firm sells at a lower price, even though they have (weakly) lower marginal costs due to the expected removal of liability. Because the market is competitive, firms can sell as much as they want at the going market price. Rather than selling at a lower price, then, state of the art firms simply produce the output that equates marginal cost and price, and therefore produce a larger quantity of output than non-state of the art firms. Since an average unit of industry output is safer under the technological advancement test than under absolute liability, but market prices are unchanged, the technological advancement test can increase the efficiency of aggregate consumption.

IV. SUMMARY AND CONCLUSIONS

Both common and statutory law allow manufacturers to defend themselves against product liability by showing that their product's safety was "state of the art." The principal characteristic of the defense is that it removes liability based on a comparison of the

³⁴ A conventional negligence rule can be preferable to absolute liability when manufacturers are judgment-proof due to its ability to induce greater safety investment, Shavell (1986), Landes and Posner (1987). However, the negligence-type rule that emerges with a customary practice state of the art test does not share this beneficial property since the implied standard (custom) will tend to be inefficiently low.

defendant's safety to the safety of competitors. Although the defense is routinely admissible, jurisdictions and commentators differ over the definition and legitimate scope of the defense. The analysis evaluates the benefits and drawbacks of alternative definitions and applications of the defense that are observed in law. We show that the particular test used to determine whether a defendant's product is state of the art -- "customary practice" or "technological advancement" -- is crucial to the impact of a state of the art defense on welfare.

We find that a state of the art defense based on a customary practice test is unlikely to improve firms' safety incentives relative to absolute liability. An absolutely liable manufacturer at least balances the costs and private liability benefits of increased safety. A manufacturer facing a customary practice test need make no such calculation, since meeting the custom is sufficient to remove liability. And absent "reasonableness" requirements or other more objective tests, the lowest possible safety investment tends to emerge as the industry custom. By contrast, the technological advancement test never reduces any firm's safety incentives relative to absolute liability. Therefore, when absolute liability fails to generate efficient safety investments -- for instance, when individual firms' safety investments provide spillover benefits to competitors, or when firms are judgment-proof -- the technological advancement test can improve welfare by increasing the average safety of products. However, when individual firms' safety innovations provide spillovers to competitors, technological advancement should be judged on the defendant's investments in innovation (contributions to the public good), rather than on product safety characteristics (the product of that public good). Otherwise, the technological advancement test will not overcome the inefficiencies introduced by imperfect property rights in innovation.

V. APPENDIX

This appendix demonstrates the existence of bifurcated Nash equilibria under the technological advancement test. In order to formally represent "exceptional" investment, the safety of a firm satisfying TA1 is compared to an endogenous standard \bar{s} that is a function of the investments made by all other firms in the market. Given satisfaction of TA1, the probability that a state of the art defense succeeds for some firm i is an increasing function of $s_i - \bar{s}$. Specifically, we make the following definitions and assumptions.

$f(s)$ = fraction of firms j with $s_j \geq s$.

$\Phi(f(s))$ = cumulative probability that the court considers the standard \bar{s} to be less than or equal to s , as a function of f ; Φ is continuous and decreasing in f . If $s_i > s_j$ for all $j \neq i$, then $\Pr(s_i = \bar{s}) = 0$.

$\rho(s_i - \bar{s})$ = probability that a firm i will be liable, given its safety investment s_i , and the realized industry custom \bar{s} . If there exists any $s_j > s_i$, then $\rho(s_i - \bar{s}) = 1$. Otherwise, $\rho(s_i - \bar{s})$ is continuous in s_i , for all $s_i - \bar{s} > 0$. Also, $\rho_s(\cdot) = \partial \rho / \partial (s_i - \bar{s}) < 0$ and $\rho_{ss}(\cdot) > 0$.

LEMMA: Bifurcated equilibria exist.

Proof of Lemma: The proof is by construction. As proved in the discussion of Proposition 1, there are at most two distinct safety expenditures that can occur under the technological advancement test. Suppose therefore that the industry consists of a number of firms \hat{n} producing safety \hat{s} , and n^+ firms all making identical safety expenditures $s^+ > \hat{s}$.

The \hat{n} firms are liable with probability one. Since there is free entry and exit and all firms are identical *ex ante*, each of the \hat{n} firms' safety and output decisions $\{\hat{s}, \hat{q}\}$ minimize average costs, and the market price, \hat{p} , equals the minimized value of average costs given $\{\hat{s}, \hat{q}\}$. Average costs, including all direct production and expected liability costs are assumed to have a well-defined minimum.

Since we are able to focus on equilibria with at most two levels of safety expenditure, we can suppress $f(\cdot)$. Let $\phi(\hat{n}, \hat{s})$ represent the probability that the court views \hat{s} as the standard, and $\phi(n^+, s) = 1 - \phi(\hat{n}, \hat{s})$ as the probability that some $s > \hat{s}$, chosen identically by all n^+ firms, is considered the standard. $L^f(q, s)$ and $C(q, s)$ denote, respectively, a firm's expected damages when liability is assigned with probability one, and direct production costs, given its output q and safety expenditures s . Since average costs have a well-defined minimum, we can assume that $C_q, C_{qq}, C_s > 0$.

The key to the proof is the relationship between (i) the safety expenditures that maximize profits for the n^+ firms, (ii) the safety expenditures that set profits equal to zero for each of the n^+ firms, and (iii) \hat{s} . To this end, define

$s^+(n^+) =$ the safety expenditure that provides maximum profit to each of the n^+ firms spending $s^+ > \hat{s}$, given that \hat{n} firms spend \hat{s} ;

$s^{++}(n^+) =$ the safety expenditure that sets profits equal to zero for each of the n^+ firms spending $s^{++} > s^+(n^+) > \hat{s}$, given that \hat{n} firms spend \hat{s} .

More formally, let $G(q, s, n^+) = L^f(q, s)[\phi(\hat{n}, \hat{s})\rho(s - \hat{s}) + \phi(n^+, s)\rho(0)]$. Given any $n^+ \geq 1$, define $s^+(n^+)$ and $q^+(n^+)$ as the solutions to

$$\max_{s, q} \hat{p}q - C(q, s) - G(q, s, n^+). \quad (1)$$

Also, for any n^+ such that $s^+(n^+) > \hat{s}$, by continuity of $G(q, s, n^+)$ in s and q , there exists $s^{++}(n^+) > s^+(n^+)$ sets profits equal to zero for each of the n^+ firms. That is, $s^{++}(n^+)$ solves

$$0 = \hat{p}q^{++} - C(q^{++}, s^{++}) - G(q^{++}, s^{++}, n^+) \quad (2)$$

where q^{++} is the firm's optimal choice of q , given that $s = s^{++}$. Now, s^+ is defined implicitly by

$C_s = -G_s$. Also, $G_\phi < 0$, and $\phi(\hat{n}, \hat{s})$ is decreasing in n^+ , so $G(q, s, n^+)$ is increasing in n^+ .

Therefore, whenever $s^+(n^+) > \hat{s}$, $s^+(n^+)$ is decreasing in n^+ . Similarly, $s^{++}(n^+)$ is decreasing in n^+ .

Assume that $s^+(n^+) > \hat{s}$ for some $n^+ > 1$. There are two cases.

(CASE 1) If $s^+(n^+) > s^{++}(n^++1)$, then n^+ firms producing s^+ and \hat{n} firms producing \hat{s} is a Nash equilibrium. To see this, first consider the decisions of the n^+ firms. Observe that the n^+ firms earn positive expected profits. Also note that $\phi(\hat{n}, \hat{s})$ is invariant to any $s > s^+$ chosen by one of the n^+ firms (since the probability that any $s = \bar{s}$ depends on the fraction of firms with $s_j \geq s$, and s_i is never the standard when $s_i > s_j$, all $j \neq i$). Therefore, since any $s < s^+$ implies $\rho(\cdot) = 1$ and by construction of s^+ , any $s \neq s^+$ reduces profit for any of the n^+ firms currently spending s^+ .

Now consider the decisions of the \hat{n} firms. Observe that all the \hat{n} firms each earn zero profit. Since $s^+(n^+) > s^{++}(n^++1)$ and s^{++} decreases in n^+ , no other firm can produce $s > \hat{s}$ and earn non-negative profits. In particular, given n^+ firms spending $s^+(n^+) > s^{++}(n^++1)$, the $(n^+ + 1)^{\text{th}}$ firm earns negative profits from any $s \geq s^+(n^+)$; this follows since the $(n^+ + 1)^{\text{th}}$ firm would earn negative profits from any $s \geq s^+(n^+)$, given n^+ firms spending $s^{++}(n^++1)$.

(CASE 2) If $s^+(n^+) < s^{++}(n^++1)$, then n^+ firms producing $s^{++}(n^++1) + \epsilon$ is an equilibrium. First consider the n^+ firms. As in case 1, the n^+ firms each earn positive expected

profits. For any of the n^+ firms, any $s < s^{++}(n^+1) + \varepsilon$ implies $\rho(\cdot) = 1$ and non-positive profits. Again, since ϕ is invariant to any of the individual n^+ firms' choice of safety choice s that is such that $s \geq s^{++}(n^+1) + \varepsilon$, and $s^{++}(n^+1) > s^+(n^+)$, any safety choice $s > s^{++}(n^+1) + \varepsilon$ by any of the n^+ firms must also reduce the firm's expected profit.

Now consider the \hat{n} firms. By construction of $s^{++}(n^+1)$, no other firms have an incentive to produce an $s \neq \hat{s}$. For example, if any of the \hat{n} firms chooses a safety s that is such that $\hat{s} < s < s^{++}(n^+1) + \varepsilon$, the firm faces absolute liability, but earns negative expected profits since \hat{s} is the only safety choice that yields non-negative profits under absolute liability with free entry. And by definition of $s^{++}(n^+1)$, given the decisions of the n^+ firms, any of the \hat{n} firms that choose $s \geq s^{++}(n^+1) + \varepsilon$ will earn negative expected profits.

We have shown that for any $n^+ > 1$ such that $s^+(n^+) > \hat{s}$, an equilibrium exists in which n^+ firms are state of the art, and the rest are liable with probability one. So suppose $s^+(n^+) = \hat{s}$ for all $n^+ > 1$. By assumption, however, $\rho_s(\cdot) = \partial\rho/\partial(s_i - \bar{s}) < 0$. Thus, when all other firms spend $\hat{s} = \bar{s}$, a single firm would maximize profits by choosing $s^+ > \hat{s}$. Therefore, $s^+(1) > \hat{s}$. By assumption, $s^+(n^+) = \hat{s}$ for all $n^+ > 1$. Therefore, we have $s^+(1) > s^{++}(2) = \hat{s}$. The argument used in case 1 above then implies that one firm spending $s^+(1) > \hat{s}$, and all other firms spending \hat{s} , is an equilibrium, which completes the proof. ■

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