The Use of Liability Rules in Controlling Hazardous Waste Accidents: Theory and Practice

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Economists since Pigou have advocated the use of economic incentives for controlling environmental degradation. In a similar vein, environmental economists have long lamented a near unanimous reliance of environmental policy on the use of direct regulation. However, several pieces of legislation, as well as common law doctrine, provide strict liability for damages from a variety of pollution incidents. The term strict liability means that a polluter is liable for the penalty imposed for a pollution incident irrespective of intent, fault, or even knowledge of the pollution incident.[1] Negligence need not be proved, thus strict liability allows for no defense of due care or conformance with common practice.

By making the polluter financially responsible for the damages from a pollution incident, strict liability for damages can potentially internalize pollution externalities, and thus can be viewed as a form of economic incentives for pollution control. However, despite the fact that financial liability is provided by several pieces of current legislation, their role as a practical policy tool for controlling pollution does not seem to be widely recognized within the environmental economics literature.

This is not to say that economists have totally ignored the potential role of liability rules. Going back to Coase (1960), for example, a quite rich literature has examined theoretical implications of liability rules.[2] However, with the exception of a relatively small number of articles specifically addressing the issue of oil spills, and largely within the legal literature, liability rules as a practical form of economic incentives for pollution control have not received wide discussion within the mainstream of environmental economics.[3] For example, several recent articles enumerate and examine market type institutions employed by current environmental regulation, but do not even mention strict liability.

This paper first reviews strict liability as provided by environmental legislation, with particular emphasis on its role in hazardous pollution events. The discussion will be somewhat broader than hazardous waste management, in that it will include pollution by hazardous substances which may be valuable commodities prior to the pollution incident. This may include, for example, spills of fuel oil or leakage from underground gasoline storage tanks. We will see that current legislation provides various forms of strict liability for hazardous pollution events. Liability for such events is shown to be consistent with common law doctrine on strict liability, and may be particularly useful given institutions provided by other legislation, notably the Resource Conservation and Recovery Act of 1976.

The paper then constructs a brief conceptual framework for liability for pollution incidents, and presents some simulation results concerning perceptions of the probability of a hazardous pollution incident.

Strict Liability in Environmental Regulation

Several pieces of legislation provide liability rules for a variety of costs from certain types

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[1] The various pieces of legislation contain some form of exemption for incidents caused solely by an act of war, by acts of a third party or by grave, unanticipated natural disasters which are exceptional, inevitable, and irresistible, the effects of which cannot be prevented or avoided. Third party exemptions will be briefly discussed below.

[2] Also see Brown, 1973; Diamond, 1974; Shavell, 1974; Polinsky, 1979; Greenwood and Ingene, 1978; and Just and Zilberman, 1979; among others.

[3] Bradley, 1974; Polinsky, 1979; Conrad, 1980; White and Wittman, 1981; Russell, 1981; Anderson, 1983; and Opaluch and Grigalunas, 1984, the only empirical piece.

of pollution incidents. Even more basic, however, is the foundation of strict liability within common law doctrine. While considerable leeway remains for individual decisions, strict liability appears to be accepted by the courts in cases of abnormally dangerous conditions or activities. Key factors in determining if an activity is "abnormally dangerous" include the degree of risk or harm which may result; whether society should expect complete protection from such risk; whether the activity is inappropriate or uncommon practice for the location in which it occurs.

Thus, for example, day to day emissions of sulfur dioxide from a power plant, although hazardous, would not fall under the common law doctrine of strict liability since they are a normal part of operations, unavoidable under common practices and are "appropriate" for their location in a properly located power plant. On the other hand, a spill of rare toxic materials into a water supply should be avoidable and is not commonplace (we hope), and thus would fall under the strict liability guidelines. There does, however, seem to be some movement by the courts towards imposing strict liability in all cases of particular danger, whether "normal" or otherwise, with the reasoning that a person engaged in a dangerous activity should bear the costs of that danger (Rodgers, 1976). Hence, under common law doctrine strict liability tends to be upheld for incidents such as spills of hazardous substances.

Given the philosophical underpinnings of strict liability within common law, it is not surprising that current environmental legislation provides strict liability for hazardous pollution accidents. The remainder of this section will briefly review liability rules provided by several pieces of environmental legislation.

Rivers and Harbors Act of 1899 (Refuse Act)

The Refuse Act prohibits discharge into navigable waters of ". . . any refuse matter of any kind or description whatever other than that flowing from the streets and sewers and passing therefrom in a liquid state." Also forbidden is depositing ". . . any material of any kind in any place on the bank of any navigable water . . . where the same shall be liable to be washed into such navigable water. . . ."

The Rivers and Harbors Act is considered a strict liability statute in that the penalty is imposed without question of fault, intent, mistake, or even knowledge of the occurrence. While the Act has no specific statement concerning private parties receiving compensation for damages of an incident which violates the Act, ". . . the trend in cases favors implying Civil remedies . . . to the advantage of damaged parties" (Rodgers, 1976). Thus, even the first piece of the environmental legislation has been interpreted as providing a form of strict liability for damages.

The Clean Water Act

In its various amended versions, section 311 of the Clean Water Act establishes a form of strict liability for the discharge of oil or hazardous substances ". . . into or upon the navigable waters of the United States, or adjoining shorelines or waters of the contiguous zone." Up to established limits on liability, and with certain limited defenses, the polluter ". . . shall be liable . . . for a civil penalty per discharge . . . based on toxicity, degradability and dispersal characteristics of such substances." Thus, liability provided by the Clean Water Act is in fact closer to an emission charge, in that the damages from the actual incident need not be determined. This is even more clear in the 1977 version which imposes ". . . a penalty determined by the number of units discharged multiplied by the amount established for such unit . . . ," where this amount is ". . . based on the toxicity, degradability, and dispersal characteristics of the substance." Note that the unit charge is removed from the 1982 version, which requires that "(t)he Administrator shall . . . conduct a study and report to Congress on methods, mechanisms, and procedures to create incentives to achieve a higher standard of care in all aspects of the management and movement of hazardous substances." To be included in this study is liability for third party damages, penalties, fees, and whether the unit charge described in the 1977 version of the Clean Water Act should be imposed.

One difficulty with penalties under the Clean Water Act is that they are based only on the characteristics of the substance, and not on the social damage done. Since damages are likely to vary considerably depending upon location of the pollution incident, any financial incentive should most strongly discourage activities in particularly sensitive locations.

Since the penalty provided for hazardous pollution under the Clean Water Act to not vary according to the potential for damage, no incentive is provided for locating hazardous activities away from particularly sensitive areas. An optimal incentive scheme should encourage appropriate siting of such activities

The Outer Continental Shelf Lands Act of 1978 (OCS Lands Act)

Sections 303 and 304 of the OCS Lands Act provide strict liability for damages from OCS related spills, including

(1) Removal costs
(2) damages, including
  (A) injury to, or destruction of, real or personal property;
  (B) loss of use of real or personal property;
  (C) injury to, or destruction of, natural resources;
  (D) loss of use of natural resources;
  (E) loss of profits or impairment of earning capacity due to injury to, or destruction of, real or personal property or natural resources; and
  (F) loss of tax revenue for a period of one year due to injury to real or personal property.

This is perhaps the most comprehensive statement of strict liability, in that it explicitly includes non-commercial natural resources damaged, in addition to third party damages and indirect loss of profits. This would include lost profits to fishermen and to recreation-related business which result from damages to natural resources. Liability is subject to upper end limits and to usual limited defenses.

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)

CERCLA, the so-called Superfund Act, provides liability, compensation, cleanup, and emergency response for hazardous substances released into the environment and provides for the cleanup of inactive hazardous waste dump sites. Subject to limits on maximum liability and the usual defenses section 107 of CERCLA establishes liability for

(A) all costs of removal or remedial action incurred by the United States Government or a State not inconsistent with the national contingency plan;
(B) any other necessary costs of response incurred by any other person consistent with the national contingency plan; and
(C) damages for injury to, destruction of, or loss of natural resources, including reasonable costs of assessing such injury, destruction, or loss resulting from such a release.

Note that liability for damages to third parties is not explicitly provided by CERCLA, except for damages to natural resources, where it is specified that ". . . liability shall be to the United States Government and to any State for natural resources within the State or belonging to, managed by, controlled by, or appertaining to such State." However, it is repeatedly emphasized that "(n)othing in this paragraph shall affect or modify in any way the obligations or liability of any person under any provision of State or Federal law, including common law, for damages, injury, or loss resulting from a release of any hazardous substance. . . ." Hence, CERCLA appears to take a weaker path of relying on common law doctrine for third party damages, other than cleanup, remedial actions, and damages to government owned natural resources. Compare this to the OCS Lands Act which explicitly provides strict liability for damages to real or personal property and lost profits or impairment of earning capacity. Since uncertainty concerning court decisions under the vague common law doctrine may lead to incomplete internalization, there appears to be a need for a more comprehensive definition of damages for which a firm is held liable under CERCLA.

Several additional provisions of CERCLA deserve mention. CERCLA holds as liable for damages from the release of a hazardous substance

(1) the owner of a vessel (otherwise subject to the jurisdiction of the United States) or a facility;
(2) any person who at the time of disposal of any hazardous substance owned or operated any facility at which such hazardous substances were disposed of;
(3) any person who by contract, agreement, or otherwise arranged for disposal or treatment, or arranged with a transporter for transport to disposal or treatment of hazardous substances owned or possessed by such person, by any other party or entity, at any facility owned or operated by another party or entity and contained such hazardous substances; and

> (4) any person who accepts or accepted hazardous substances for transport to disposal or treatment facilities or sites selected by such person, from which there is a release or a threatened release which causes the incurrence of response costs of a hazardous substance. . . .

Under CERCLA, liability is maintained when the substance is controlled by ". . . one whose act or omission occurs in connection with a contractual relationship, existing directly or indirectly with the defendant. . . ." The individual is relieved of liability when the substance is controlled by a contracted third party only if

> . . . the defendant establishes by a preponderance of the evidence that (a) he exercised due care with respect to the hazardous substance concerned, taking into consideration the characteristics of such hazardous substance, in light of all relevant facts and circumstances and (b) he took precautions against foreseeable acts or omissions of such third party and the consequences that could foreseeably result from such acts and omissions.

Compare this with the OCS Lands Act which exempts liability ". . . if the incident is caused by the negligence or intentional act of the damaged party, or any third party . . . ," or with the Clean Water Act which exempts the individual from liability in the case of ". . . an act or omission of another party without regard to whether such act or omission was or was not negligent. . . ."

Thus, unlike other pieces of environmental legislation, liability under CERCLA extends beyond the individual responsible for the operation in which the spill occurs, but includes all those involved in the process. Each individual is held jointly and severally liable, which means that any single party can be held responsible for the entire cost when other parties cannot be found or are insolvent, defunct, or bankrupt.

While inclusion in liability under CERCLA, despite the fault of a third party, may at first appear excessive, the intent is to ensure that all those involved in the process, from the time of generation to disposal, are responsible actors and that each will take care to involve only other reputable individuals. The fear is that generators could avoid liability by hiring a low-cost transporter who maintains a "fly-by-night" operation. Since proper disposal of hazardous wastes can cost 10 to 50 times as much as improper disposal (Council on Environmental Quality, 1982), there is a need to provide incentives for all actors to utilize reputable transport, disposal, and treatment services. Thus, by extending liability beyond physical custody of the hazardous substance, CERCLA provides economic incentives for ensuring proper final disposal.

For cases where the liable party cannot be located, CERCLA creates the Hazardous Substance Response Trust Fund, which is financed 86% through taxes which range from 22¢ to $4.87 per ton on various hazardous substances. The remainder of the fund is appropriated from general revenues by Congress.

An additional important provision of CERCLA is its approach to dealing with inactive dump sites. At the time of closure of the dump site, operations which have complied with regulation of the Solid Waste Disposal Act are issued a permit under the Act. Ninety days after closure, liability is transferred to the Post-closure Liability Fund, which is established by section 232 of CERCLA. The Liability Fund is financed by a tax of $2.13 per dry weight ton of hazardous wastes when received by a qualified hazardous waste disposal facility. Hence, at the time of closure of a hazardous waste facility, the philosophy of regulation shifts from strict liability to a technology forcing strategy under the Solid Waste Disposal Act.

A Conceptual Framework

This section will present a conceptual framework for the firm's choice of accident avoidance technology. The framework described in this section is similar to that contained in Conrad (1980), who discusses the policy implications in some detail. Thus, this section will briefly sketch the conceptual framework, and will discuss the perceptions issue to be examined with the simulation model. The reader interested in further details concerning the conceptual framework and its policy implications is referred to the Conrad paper.

The firm is assumed to be risk neutral, in that its objective is to maximize expected profits. For the purpose of this section, the only random variables are the occurrence of pollution incidents, X, and the amount of the substance released, S. The occurrence of incidents is assumed to follow a discrete probability density function

$$f(X = x) = P(x|T,Q) \text{ for } x = 0, 1, 2, \ldots$$

where T is an index of spill control technology which is linear in costs, and Q is the total quantity of hazardous substances processed. Given that a pollution incident occurs, the amount released in the incident is assumed to be independent and identically distributed according to the continuous probability density function g(S), for $S > 0$.

Expected profits can be expressed as

$$(1) \qquad E(\pi) = \sum_{x=0}^{\infty} \int (R(Q) - l(S) - cQT) g(S) dS \; P(X|Q,T)$$

where R(·) represents net revenues, ignoring costs of spills and spill avoidance technology, l(S) represents the loss in profits due to the spill, c represents the unit cost of increasing the spill control technology index, and T represents the level of technology employed. The lost profits due to a spill, l(S), is made up of three components: the value of the hazardous substance released, if any, the liability for social damages, and cleanup or control costs. This lost profits can, thus, be expressed as

$$(2) \qquad l(S) = pS + d(S) + cc(S)$$

where p is the value of the spilled substance, d(S) is the social damages from the spill, and cc(S) is the cleanup and control costs.

Equation (1) can be rewritten as

$$E(\pi) = R(Q) - cQT - \sum_{x=0}^{\infty} \int l(S) g(S) dS \; P(X|Q,T)$$

$$= R(Q) - cQT - \sum_{x=0}^{\infty} L \; P(X|Q,T)$$

where L is the expected loss in profits per spill. The optimal solutions for production and spill avoidance technology can be characterized by the first order conditions

$$\frac{\partial E(\pi)}{\partial Q} = \frac{\partial R(Q)}{\partial Q} - \sum_{x=0}^{\infty} L \frac{\partial P(X|Q,T)}{\partial Q} - cT = 0$$

$$(3) \qquad \frac{\partial E(\pi)}{\partial T} = cQ - \sum_{x=0}^{\infty} L \frac{\partial P(X|Q,T)}{\partial T} = 0.$$

These equations show that if firms maximize expected profits and to the extent that L reflects all social costs of spills, and the firm has the proper perceptions of the derivatives $\partial P(\cdot)/\partial Q$ and $\partial P(\cdot)/\partial T$, strict liability will properly internalize social costs of potential spills and will lead to optimal decisions concerning production and spill avoidance technology. However, these are very strong assumptions. Equation (2) states

$$l(S) = pS + d(S) + cc(S)$$

and, hence,

$$L = pE(S) + D + CC$$

where D is the expected social damage from a spill and CC is the expected control and cleanup costs. In the absence of insurance, the firm will face the value of the lost hazardous substance. Under ideal conditions, strict liability would lead to internalization of expected social damages and cleanup costs. However, as discussed above and by Conrad, current legislation does not achieve full internalization. Further than that, even given perfect institutions, we do not have sufficient understanding to accurately estimate the social damages of spills. More research in damage estimation is extremely important in improving the accuracy of estimates of social damages, hence providing more appropriate levels of incentives for spill avoidance.

The second important factor in the effectiveness of strict liability is the accuracy of firms' perceptions of the probability of accidents and the effects of avoidance technology and the level of production on this probability. In the case of low probability occurrences, it is often argued that perceptions of probabilities are inaccurate, at least in part because experience with incidents is so rare. In such cases observing the frequency of incidents may not be a practical or desirable method of calculating probabilities. Faced with low probability events to be considered, decision makers are often argued to employ heuristic decision making processes, rather than "rational" maximization of expected profits (Simon, 1955; Tversky and Kahnemann, 1974; Schoemaker, 1982; Conrad, 1980). Expectations may be derived from frequent or representative cases, viewing low frequency occurrences as one of a kind, not to recur. This may be a particular concern in the present case where accident avoidance technology may be improved, so that industry may believe that past problems have been solved and, hence, past experience may be felt to be irrelevant in calculations of future probabilities. Under such conditions subjective probabilities may suffer the so-called "anchoring" problem (Tversky and Kahnemann, 1981) whereby they are biased towards zero and actual experience is not sufficiently weighted in updating the probabilities.

Hence, a special difficulty may arise when implementing liability rules in the case of low probability incidents, although at least some evidence suggests that this may not be a particular difficulty (Opaluch and Grigalunas, 1984).

The Monte Carlo Model

This section will describe a simulation model used to examine the anchoring problem, and will present the simulation results. Clearly such a model is quite data intensive, and the accuracy and availability of data is a primary difficulty to be dealt with. Due to this difficulty, the model will examine the issue of offshore oil production, because this area has been subject to the greatest degree of study and because regulations require reporting of considerable information. Hence, a substantial body of data is readily available for offshore oil production, technology, and safety.

For the purpose of this section, the production decision is taken as given. Hence the key equation of concern is equation (3).

$$cQ = \sum_{x=1}^{\infty} (pES - D - CC) \frac{\partial P(x|Q,T)}{\partial T} .$$

All data employed are obtained from various documents examining offshore oil production in the Gulf of Mexico. The model considers spills in excess of 1,000 barrels, whose probability is assumed to follow the Poisson distribution, as is commonly employed (see, for example, Smith et al., 1982). Hence, the density function for spills is assumed to be of the form

$$p(X = x) = (\lambda)^x \exp(-\lambda) \cdot \frac{1}{x!} \qquad \text{for } x = 0, 1, \ldots$$

The Poisson is a one parameter distribution, where the parameter, λ, is equal to the expected number of spills. This parameter is assumed to vary over time, depending upon the level of production and the technology employed. More specifically, the value of λ at some point in time is assumed to be

$$\lambda_t = \frac{\alpha Q_t}{T_t}$$

where α is an unknown parameter, constant over time, Q_t is the level of production at time t and T_t is the level of spill control technology employed at time t, which is constructed so as to be linear in costs. Employing usual Bayesian methods (see DeGroot, 1970, for example), α is assumed to follow the gamma distribution with parameters p_1 and p_2, whose mean is $p_1/p_2 = a$, the prior estimate of α. The parameters p_1 and p_2 are updated according to the equations

$$p_1(t+1) = p_1(t) + x$$
$$p_2(t+1) = p_2(t) + 1$$

hence the prior estimate of α is updated according to

$$a(t+1) = \frac{p_1(t) + x}{p_2(t) + 1}.$$

Thus, the firm is assumed to have a prior estimate of the probability of spills and chooses spill control technology so as to maximize expected profits under the assumptions of complete liability for any damages from spills and no further regulation on spill control technology. The firm observes the number of spills (x) which occur with that technology and uses that information to update its prior probability, which is then used to choose the optimal level of technology in the following period.

The parameter p_2 is known as the spread parameter of the gamma distribution, and reflects the degree of certainty with which the firm believes in its prior estimate of α, and hence the degree to which new information leads to changes in the prior. Hence, by varying p_1 and p_2 proportionately, the issue of insufficient weighting of new information can be examined. Under the anchoring assumption, the prior estimate of the expected number of spills, at given levels of production and technology, is less than the true expected value, and p_1 and p_2 are sufficiently large that updating does not allow appropriate adjustment to new information.

With information on the probability of spills as a function of expenditures on spill control technology, one could construct estimates of α, a technology index, and the unit cost of technology, c. Unfortunately, although widely recognized as important and achievable with current knowledge (Conrad, 1980; Russell, 1981), this information does not appear to be currently available. Instead, the parameters were determined as follows: the unit cost of spill control technology, c, was arbitrarily set equal to 1, so that the technology index is equal to expenditures on spill control technology per unit production. The parameter was then determined from information on expenditures on meeting federal regulations (Shirley, 1981) and an estimate of the expected number of spills per billion barrels of oil produced (Lanfear and Amstutz, 1983). Information on production and total revenues from OCS operations in the Gulf of Mexico from 1964 through 1982 (U.S. Department of Interior, 1983a) were used for time paths for production and price. While oil spill fate and effects modelling is available (U.S. Department of Interior, 1983b), no estimates of expected social costs of spills are given. Hence, the costs of spills, including damages and cleanup costs, were constructed from case studies of the costs of previous spills and an estimated distribution on the size of spills in the Gulf of Mexico (Lanfear and Amstutz, 1983).

Simulation Results

The model was used to simulate the technology choice and spill occurrence in the Gulf of Mexico over the period 1964 to 1982. In order to evaluate the anchoring problem, firms perceptions of the expected number of spills was assumed to be one-fifth the true expected number of spills. Three combinations of the parameters p_1 and p_2 were chosen so as to compare three levels of anchoring with initial perceptions of the probability of spills held fixed. The lowest values for p_1 and p_2 lead to relatively low anchoring, so that after a relatively short period of experience with spills, considerable updating occurs, while the highest lead to very little updating. For the lowest level of anchoring, a value of $p_2 = 4$ is used. This implies that the firm has the same level of confidence in its prior estimate as it has in four years of actual experience, so that the two would be equally weighted in updating the expected number of spills, given production and the level of technology. The two higher levels of anchoring are constructed with p_2 equal to 16 and 64 respectively. In all cases, p_1 is chosen so that the prior estimate, $a = p_1/p_2$, is equal to 7.4, or one-fifth of the "true" value, α. By comparing social costs, including social damages from spills, cleanup costs, and costs of spill control technology, under these differing levels of updating, these results are suggestive of the social losses from anchoring of prior estimates.

Table I contains the results of the simulation model. The first three columns contain the prior estimates of α, averaged over 100 repetitions, as they evolve over the time horizon. The bottom row contains the average social cost of spills and spill avoidance for each level of the parameters, again averaged over 100 repetitions. As can be seen, considerable damages result in each case. In addition, significant differences in costs occur as the parameters increase by a factor of 16, with their ratio held fixed. At the highest levels of the parameters, costs are \$247 million or about \$50 million greater than costs at the lowest level. Spill damage and control costs at optimal management are \$97 million. Hence incorrect information at the lowest level of anchoring increases costs by a factor of 2.

Table I. Updated Prior Estimates (a_t) For Three Levels of Anchoring

	$\alpha = 37$ Anchoring Level (p_2)			
Year	4	16	64	
1964	7.40	7.40	7.40	
1965	13.11	9.34	8.01	
1966	17.51	9.69	7.27	
1967	16.39	9.33	6.27	
1968	15.62	9.39	5.80	
1969	16.25	9.11	5.23	
1970	16.58	9.24	5.05	
1971	17.03	9.57	5.00	
1972	16.53	9.51	4.75	
1973	17.71	10.55	5.15	
1974	19.60	11.95	5.75	
1975	22.64	13.76	6.70	
1976	25.16	15.93	7.71	
1977	26.74	17.33	8.31	
1978	28.93	18.76	9.03	
1979	30.69	19.91	9.77	
1980	31.44	20.68	10.32	
1981	33.00	21.76	10.90	
Expected No. of Spills	22.3	27.6	36.7	(optimal = 15)
Social Costs (million \$ 1981)	186	206	242	(optimal = 103)

Conclusions

This paper examined the use of liability rules in controlling hazardous substance accidents. Liability rules can be viewed as a form of economic incentive for pollution control and are widely used in current environmental regulation. The success or failure of liability rules in providing incentives for accident avoidance should be subject to greater study, given economists' emphasis on the superiority of economic incentives for pollution control.

Several difficulties with current regulation lead to less than complete financial responsibility for damages from pollution accidents. In addition, inappropriate expectations concerning the probability of accidents may lead to imperfect internalization, particularly in the case of low probability events. Simulation results show that excessive confidence in current technology can lead to large environmental costs, both through underestimated probabilities of spills and through insufficient updating of these probabilities as new information accumulates. In such case, some form of direct regulation may be required in place of, or in addition to, liability for pollution damages.

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