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Risk-Sharing in the Design

of Environmental Policy

by

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I. Introduction

Many forms of pollution are stochastic in the sense that they result from accidental spills or releases rather than continuous (intentional) emissions. Examples include releases of hazardous substances from manufacturing plants and contamination of groundwater from unintended releases from landfills. At both the state and the federal levels, environmental policy to control these forms of stochastic pollution is made in two arenas. The first is the regulatory arena, where in response to statutory mandates administrative agencies impose constraints on potential polluters, generally in the form of restrictions on operations. These constraints are ex ante constraints in the sense that they are imposed independently of any specific pollution event. The second arena in which environmental policy is formed is the judicial arena. This approach is generally ex post. Through the common law systems of negligence, nuisance, strict liability, and trespass, the courts address environmental problems "after the fact," i.e., once damages have already occurred. Prior to the 1970's, this ex post judicial approach predominated. However, during the 1970's increased awareness and concern for environmental quality provided the impetus for the creation of an extensive regulatory system of pollution control.

Recent concerns about the burdens of "over-regulation" and the imperfections of the regulatory system have given rise to an increased interest in the comparison of these two approaches to environmental policy [e.g., Baram; Johnson, Kolstad and Ulen; Shavell (1984a, 1984b); White and Wittman]. These comparisons have focused on the incentive effects of the two approaches and have ignored the fact that the approaches imply different allocations of the risk created by stochastic pollution events. When either the victims of those events or the polluters responsible for them are risk averse, then the allocation of that risk may be an important determinant of the relative desirability of alternative policies. Although this is well recognized in other contexts [e.g., Stiglitz and Shavell (1979)], it has generally been ignored in discussions of the appropriate design of environmental policy. Ignoring it was perhaps reasonable in the context of localized problems of air or water pollution where the risks to victims (and thus the potential financial liability of polluters) was relatively small. However, the recent litigation over damages from asbestos exposure and the chemical leak in Bhopal, India suggests that the financial liability for some pollution events may be very large as a result of widespread damages. Furthermore, recent concerns over the near-collapse of the market for pollution liability insurance suggests that polluters may be risk averse with regard to these large potential liabilities. Thus, in the context of potentially catastrophic pollution problems such as those arising from hazardous waste disposal, chemical leaks or spills, and uncontrolled releases of other toxic substances, the importance of the allocation of risk implied by different policy approaches needs to be considered.

Of course, the allocation of risk is only one feature of a given policy that affects its desirability. As noted above, another well recognized feature of importance is its incentive effects, i.e., its ability to induce individual polluters to take actions to reduce either the probability or the magnitude of a pollution problem. Whether it is possible to design a policy that will both allocate risk optimally and induce an optimal level of prevention or precautionary action depends crucially on whether the actions of the polluter that influence the probability or magnitude of damages are observable (i.e., able to be monitored at a reasonable cost). Models of the regulatory approach to pollution control implicitly assume that all such actions are observable and thus can be regulated. On the other hand, typical models of incentive schemes assume that all actions are unobservable and thus that regulation is not possible. In most real world cases, the truth lies somewhere in between, i.e., both observable and unobservable actions affect environmental risks. For example, in the case of land disposal of hazardous waste, the design used for construction of a landfill is easily observable and can be subject to regulation, where failure to comply with the standards would be detectable. However, the care taken in the daily handling of waste is not easily observable by regulatory authorities and regulations relating to care would not generally be enforceable. Thus, whether actions are observable or not also influences the appropriate design of environmental policy.

This paper presents a conceptual framework for choosing an efficient policy for the control of stochastic pollution that incorporates both the risk sharing and the incentive effects of alternative policies. It assumes that polluters can affect the probability of a given magnitude of damages through both observable and unobservable actions.

Three alternative cases are presented and compared. The first is the policy choice when no incentive problems exist, i.e., when there is no need to induce polluters to undertake an efficient level of precaution. This is the "first-best" problem that reflects only optimal risk sharing. The second case assumes that there is no regulation of any actions and only the possibility of ex post liability for damages. In this case, both the risk-sharing and incentive effects of the liability rule are important, and the question of the efficient form of the rule is addressed. The third case assumes that observable actions are regulated, and addresses the efficiency of the joint use of regulation and liability.

II. The General Model

Assume that there are two individuals, a polluter and a victim, and n possible states of the world. There is assumed to be uncertainty about which state of the world will occur because of random factors such as weather or randomness associated with chemical or physical processes. Let d_i be the (exogenous) level of damages suffered by the victim in state i and let p_i be the probability that state i will occur with $p_1+p_2...+p_n = 1$. It is assumed that the polluter can take both observable and unobservable actions that affect p_i. Thus, $p_i = p_i(x, a)$ where x is the expenditure on observable precaution and a is the expenditure on unobservable precaution. Denote the payment made by the polluter to the victim in state i by f_i. If f_i is independent of i, i.e., $f_i = f_j$ for all i,j, then the polluter faces no ex post liability. He simply makes an ex ante (i.e., state-independent) payment to the victim. Alternatively, if f_i is not independent of i, then the firm is subject to some liability for actual damages. A scheme of the form $f_i = d_i + k$ for all i and some constant k would represent full liability, while a payment scheme with $\partial f_i/\partial d_i < 1$ implies a system of partial liability.

Both the polluter and the victim are assumed to have Von-Neumann-Morgenstern utility functions and the polluter is assumed where appropriate to make decisions to maximize his expected utility.[1] If the utility functions are represented by $U(\bullet)$ and $V(\bullet)$ respectively and u_o and v_o are the initial wealth positions, then the expected utility of the polluter is given by

$$EU = \sum_i p_i(a,x)\, U(u_o - f_i - a - x) \qquad (1)$$

while that of the victim is given by

$$EV = \sum_i p_i(a,x)\, V(v_o + f_i - d_i). \qquad (2)$$

III. First-Best Problem (Optimal Risk Sharing)

In the absence of incentive problems, i.e., if the level of both observable and unobservable precautions could be imposed on polluters, then the choice of a Pareto efficient policy would be the solution to:

$$\underset{\{a,x,f_1,\ldots,f_n\}}{\text{maximize}} \quad EV \qquad (3a)$$

$$\text{subject to} \quad EU = \bar{U} \qquad (3b)$$

where $\bar{U}$ is a reservation level of utility for the polluter. This problem is simply a problem of optimal risk-sharing.[2] The first order conditions that give the first-best policy (a^*, x^*, f_i^*) as defined by (3) require that

$$V'(v_0+f_i^*-d_i)/U'(u_0-f_i^*-a^*-x) = \lambda \quad \text{for } i=1,\ldots,n \tag{4}$$

where $\lambda \geq 0$ is the multiplier on (3b). This is the standard condition for Pareto efficient risk-sharing [e.g., Holmstrom]. From (4) we have the following result, which has been well-recognized in other contexts but generally not in discussions of the design of environmental policy.

Result 1: (a) If polluters are risk-neutral and victims are risk averse, then under a first best policy polluters should be subject to full ex post liability; (b) If polluters are risk averse and victims are risk neutral, then a first best policy implies no ex post liability for polluters, i.e., the amount of the transfer from polluters to victims should be state-independent; and (c) if both polluters and victims are risk averse, then neither full liability nor zero liability is optimal. Instead, a form of partial liability that divides risk between the two parties is preferred to either extreme.

Part (a) follows directly from the fact that, if U' is constant across states, then by (4) $f_i^*-d_i$ must be independent of i, i.e., $f_i^* = d_i+k$ for some constant k, which corresponds to a system of full liability. Polluters might be expected to be risk neutral if their potential financial liability is small relative to their overall operations. An analogous argument can be made for part (b). If V' is constant across states, then (4) implies that f_i^* must also be constant across states, i.e., the transfer should be made ex ante without any liability for actual damages. Victims might be expected to be risk neutral if the risks are spread over a large number of people through, for example, a government compensation scheme.

Finally, part (c) follows since it can easily be shown that if neither V' nor U' is constant, then either full liability or zero liability would contradict (4). This raises the question of whether, in the case where both parties are risk averse, the risk would be optimally split through proportional liability, i.e., through a transfer scheme of the form $f_i = cd_i + k$ for some constants c and k. Although proportional liability would be optimal in the special case where both U and V are quadratic, under more general utility functions it would not be. However, proportional liability may be a reasonable form of the transfer rule to use in practice, since an empirical determination of the efficient nonlinear form of the rule would be difficult due to lack of information about the exact shape of individual utility functions.

IV. Liability Without Regulation

Attainment of the first-best solution described in the previous section assumes that firms will undertake the level of precaution determined to be socially efficient. In reality, however, firms must somehow be induced to do so. In this section we assume that the incentive for preventive action is provided only through the transfer scheme represented by the f_i, i.e., firms choose a and x to maximize EU given $\{f_1,....,f_n\}$.

When firms are free to choose a and x, then the pareto efficient policy (f_i) is given by the solution to

$$\underset{\{a,x,f_1,\ldots,f_n\}}{\text{maximize}} \quad EV \tag{5a}$$

$$\text{subject to} \quad EU = \bar{U} \tag{5b}$$

$$EU_a = 0 \tag{5c}$$

$$EU_x = 0 \tag{5d}$$

where $EU_a = \partial EU/\partial a$ and $EU_x = \partial EU/\partial x$. The first order condition for the choice of f_i implies that

$$V'/U' = \mu + (\tau\, p_{ia} + \psi\, p_{ix})/p_i - (\tau + \psi)\, U''/U' \tag{6}$$

where $p_{ia} = \partial p_i/\partial a$, $p_{ix} = \partial p_i/\partial x$, and μ, τ and ψ are the multipliers on (5b), (5c) and (5d) respectively. Comparing (6) to (4) shows the effect on the optimal policy of the need to provide incentives. In (6), the right hand side is not constant (as it was in (4)), and thus in general the optimal liability rule will differ when incentives are necessary. The exception to this is when polluters are risk neutral. In this case it can be shown that, at the optimum, $\tau = \psi = 0$ so that (6) reduces to (4). The problem is then simply one of optimal risk sharing and, since polluters are risk neutral, the solution is to place all of the risk on them through the use of full ex post liability. However, if polluters are risk averse, then (6) implies the following result.

<u>Result 2</u>: If polluters are risk averse and their actions affect the probabilities of alternative states of nature, then neither full ex post liability nor zero ex post liability is an efficient policy.

This follows from the fact that, using the first order conditions from (5), it can be shown that $\partial f_i/\partial d_i \neq 0$ and $\partial f_i \partial d_i \neq 1$, implies that $f_i \neq k$ for some constant k independent of i (i.e., zero liability is not optimal) and $f_i \neq d_i + k$ (i.e., full liability is not optimal).

Instead, some form of partial liability that divides the risk between the polluter and the victim is preferred. Note that this is true even if victims are risk neutral because the need to provide incentives for precaution implies that polluters should bear some risk.

V. Joint Use of Regulation and Liability

If the observable actions are subject to regulations, then polluters can no longer freely choose the level of x although they can still choose the level of expenditure on unobservable actions. In this case, the optimal policy (f_i, x) solves

$$\underset{\{a,x,f_1,\ldots,f_n\}}{\text{maximize}} \quad EV \tag{7a}$$

$$\text{subject to} \quad EU = \bar{U} \tag{7b}$$

$$EU_a = 0 \tag{7c}$$

A comparison of the problems in (5) and (7) gives the following result.

Result 3: If regulation of observable actions is possible, then the sole use of liability (i.e., relying on liability without imposing any regulatory standards) is never preferred to the joint use of regulation and liability.

This follows from the fact that the problems in (5) and (7) are identical except that (5) includes an additional constraint. Since the addition of a constraint can never increase the maximum value of an objective function, the maximum value of (7a) will never be less than the maximum value of (5a), i.e., liability alone can never be preferred. Note, however, that, in the special case where polluters are risk neutral, full ex post liability without any regulation will yield the same level of welfare as could be achieved by the joint use of regulation and liability.

We could also ask the opposite question, i.e., would the sole use of regulation (without any ex post liability) ever be preferred to the joint use of regulation and liability?

Result 4: (a) As long as the polluter has unobservable actions that affect the probabilities of different states of nature occurring, then an efficient policy includes some ex post liability, i.e., zero ex post liability (sole reliance on regulation) is not optimal, and (b) If in addition polluters are risk averse, then the joint use of regulation and full liability is not optimal either. A system of regulation plus partial ex post liability is preferred.

Note that part (a) implies that it is not efficient to impose zero ex post liability and then instead use a stricter regulatory standard for x to offset the inability to regulate a. Thus, recent proposals to absolve firms of ex post liability if they are in compliance with existing regulations would not lead to an efficient policy if unobservable actions are important determinants of risk. However, part (b) suggests that there may be some justification for limits on liability. Again, the intuition behind the result is the trade-off between risk-sharing and incentives. As long as there are incentive problems due to unobservable actions, polluters should face some risk so that at the margin they are induced to undertake some unobservable precaution. However, if they are risk averse, they should not bear the full risk.

VI. Limitations/Other Considerations

The model used in the above analysis focuses on the potential tradeoff between risk-sharing and incentives in the design of environmental policy. It ignores a number of other factors that are important in determining the relative desirability of alternative policy approaches, some of which are noted here.

First, the analysis ignores imperfections in the implementation of the liability or regulatory approaches that have been the focus of previous work (e.g., Johnson, Kolstad and Ulen, Shavell (1984a, 1984b)). These include imperfect information, evidentiary uncertainty the possibility of firm bankruptcy, and transactions costs associated with the difficulty of proving causation, long latency periods, and widely dispersed damages. When system imperfections do exist, the nature of these imperfections and their seriousness affect which policy approach is preferred.

The second factor that has not been discussed is the role of insurance markets (both for first party and liability coverage). Although insurance can be an effective way to reallocate risk, when the polluters actions can affect those risks in an unobservable way a moral hazard problem arises in the provision of liability insurance. The implications of the availability of insurance for the choice of policy is discussed in more detail by Shavell (1982) and Segerson (1986).

A third limitation is the short run nature of the analysis. To the extent that the alternative policies impose differing expected total costs on polluters or victims, in the long run non-marginal behavioral changes would be expected. For example, firms might enter or leave the polluting industry in response to differing expected total costs (and thus profitability). Alternatively, when victims face higher expected uncompensated damages under one policy than another, they might respond by choosing to relocate to areas where risks are lower. These long run responses are not captured in the model used above.

Finally, the analysis has not addressed the issue of fault. The liability system discussed here is the system of strict liability. No attempt has been made to compare this to the alternative negligence standard, which may be preferred under certain circumstances.[3]

VII. Conclusions and Implications

The results in the previous sections suggest that the allocation of risk associated with stochastic pollution events should be a factor in the design of environmental policy. For example, when polluters are risk averse (as might be expected when potential damages are large), a system of full liability is not efficient because it places an excessive amount of risk on polluters. However, even if victims are risk neutral (due, for example, to government compensation programs to spread risk), polluters should not be absolved of all ex post liability as long as some of their actions that affect the likelihood of damages are unobservable. In this case, a policy that couples regulation of observable actions with a system of partial liability seems to be a preferable way to balance the need for risk-sharing and incentives.

The above conclusions are of interest in light of recent attempts to limit the potential liability faced by polluters who are found to be in compliance with the relevant environmental regulations. These attempts include both legislative proposals and the interpretation of court decisions. The analysis above suggests reasons why a reduction in liability might improve efficiency but an elimination of liability would not. In addition, it suggests that current policies that explicitly couple regulation with statutorily-imposed liability (e.g., those relating to water pollution, hazardous waste and nuclear power) may make sense although the use of partial rather than full liability may be preferred.

ENDNOTES

[1]For a discussion of the validity of this assumption, see Schoemaker.

[2]Note that this differs from the first-best problem considered by Shavell (1982).

[3]See, for example, Shavell (1980, 1982), and Rizzo.

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