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ENVIRONMENTAL ACCIDENTS: AN ECONOMIC FRAMEWORK FOR POLICY EVALUATION

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Environmental Accidents: An Economic Framework

for Policy Evaluation

I. INTRODUCTION

Environmental pollution problems can be divided into two categories. In the first category are problems that result from the intentional release of environmental pollutants as a by-product of production or consumption processes. Examples include emissions of conventional air and water pollutants (such as sulfur dioxide and nitrous oxides) from industrial plants. In the second category are problems that result from environmental "accidents", where the effect was not an anticipated result of a production or consumption process but rather arose unexpectedly.[1] This category includes both sudden releases (such as accidental spills and releases of oil, chemicals, or nuclear radiation), as well as gradual releases (such as unintentional leaching or leaking of materials from landfills and other waste disposal facilities and from the application of chemicals (pesticides and fertilizers) to the land).

In this paper, a framework is presented for evaluating policies designed to address the second category of environmental problems, namely, environmental accidents. Policy design in this context is particularly challenging because of the many obstacles that arise. For example, the likelihood of an accident is often not accurately anticipated and hence appropriate preventive measures are not taken. In addition, it is often difficult to prove causation and identify responsible parties. Even when the responsible parties can be identified, adequate resources may not be available (from either the responsible parties or elsewhere) to pay for cleanup and response and compensation for damages. This is particularly problematic for "low-probability/high-consequence" events, such as large toxic chemical releases. In such cases, the damages can be very large; yet the involved parties often do not provide adequate contingencies for such events. Finally, even if resources are available, compensation for damages is hampered by the difficulty in measuring those damages in economic terms.[2]

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[1] More precisely, in the first case of intentional releases, the probability of the release, conditional on the production or consumption taking place, is one. In contrast, with environmental accidents, the production or consumption process may or may not lead to a release, i.e., the conditional probability of the release is less than one. Depending on the magnitude of this probability, the release might or might not have been legitimately "unexpected". Nonetheless, we use this terminology to denote all situations where the probability of a release is significantly different from one.

[2] The difficulty of quantifying the value of damages also arises in cases of intentional releases of pollutants as a by-product of production or consumption. In both cases, the

An evalutation of policies designed to address environmental accidents requires that these many dimensions of the problem be considered. Specifically, it requires answers to the following questions:

(a) what can and should be done now to improve incentives for pollution prevention and safety so that environmental accidents are less likely to happen in the future?

(b) when an environmental accident does occur, how much should be cleaned up and how much (if any) compensation should victims of the accident receive?

(c) who should be held responsible (liable) for cleanup costs and compensation for various types of damages? and

(d) how can we ensure that adequate financial resources will be available at the time of the accident to pay for cleanup and compensation?

In order to provide specific answers to the above questions, some prior questions must be asked. Specifically, we first need to know the following:

(i) what tools or policy instruments are available for use in addressing the problem?

(ii) what are we trying to accomplish with these tools, i.e., what are our goals? and

(iii) how well do the tools work in accomplishing our objectives?

This paper provides a framework that can be used to answer these questions. It focuses on this second set of questions in an attempt to provide the background necessary to answer the first set of questions. The framework that is presented is based on economic principles regarding resource allocation. While alternative perspectives are possible, an economic approach seems particularly relevant in the context of transition economies where resources are scarce, since the premise of economic analysis is the efficient allocation of scarce resources.

II. CHARACTERISTICS OF ENVIRONMENTAL RISKS

The risks from environmental accidents can have a number of characteristics that make public policymaking in this context particularly challenging. The following is a list of some of

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quantification of damages in economic terms requires the valuation of non-market goods. For an overview of non-market valuation techniques, see, for example, Freeman (1993).

those characteristics.[3]

(1) Non-monetary nature of risks. Most environmental risks are non-monetary in that the risk involves loss of something other than money, such as health, life, or an ecological environment. In addition, in general there are no close substitutes for the "good" that could be lost. This has implications for the determination of the benefits from a reduction in the risk. For example, the non-monetary nature of the risks implies that putting a dollar value on risk reduction may be difficult.[4] In addition, the lack of close substitutes implies that individuals would not be able to replace goods that they might lose as a result of an environmental accident (such as their health or environment quality) with other goods that they view as being equally valuable. As a result, people may place a greater value on things that they currently have and would be giving up in the event of an accident than they would place on things that they do not currently have.[5] Thus, it may be difficult to come up with a single, meaningful measure of the value or benefit of a particular reduction in the risk of an environmental accident that can be compared to the cost of achieving that reduction.

(2) Sudden vs. Gradual releases. As noted above, some environmental accidents involve sudden releases (e.g., spills) while others involve more gradual releases over time (e.g., leaching from landfills). In addition, within the category of sudden releases, we can further distinguish between those releases for which most of the damages are realized immediately (e.g., the ecological impacts of an oil spill or deaths from exposure to a toxic substance) and those for which the damages are not realized immediately (e.g., a future cancer case caused by exposure to a toxic substance). We can thus identify at least three different types of accidents: (i) sudden releases with immediate damages, (ii) sudden releases with latent damages, and (iii) gradual releases with latent damages. As will be seen below, the policies that are appropriate for one type of accident may not be appropriate for the other types. Thus, it may not be possible to use a single policy approach to address all three types of accidents. Instead, a set of policies that are tailored to or have sufficient flexibility to deal with different types of accidents may be required.

(3) Long latency periods. For gradual releases and sudden releases with latent damages, there is a considerable lag between the time that the risk-generating activity is undertaken and the time that the environmental effect is realized. For example, exposure to a given toxic substance today may cause cancer in an individual 20 or 30 years later. Similarly, waste

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[3] For a more detailed discussion of some of these characteristics, see Segerson (1992).

[4] See Freeman (1993) for a discussion of economic methodologies that can be used to place monetary values on risk reduction.

[5] More formally, a large difference may exist between willingness-to-accept and willingness-to-pay measures of value. See Hanemann (1991).

disposal undertaken decades ago is now causing environmental problems in places where the substances have leached or migrated through the soil or water. The property might have been sold several times between the time of the initial disposal of the contaminating substance and the time the contamination is discovered.[6] These long time lags imply that it is often difficult to prove the exact cause of a given outcome (i.e., whether the cancer case was caused by exposure to the toxic substance or something else) or to identify the party who was responsible (i.e., which firms disposed of which substances in a given landfill). In addition, even if the responsible party can be identified and causation proven, that party may now be judgment-proof. For example, the firm may no longer be in operation and thus can no longer be held responsible for the damages resulting from its actions. Long time lags also imply that discounting of future damages may have important consequences for the evaluation of current policies, although the non-monetary nature of environmental risks suggests that discounting in this context is likely to be controversial.

(4) Composite nature of risks. Most environmental risks involve a sequence of events, each of which has its own conditional probability distribution (Crouch and Wilson, 1981). For example, the risk from consumption of groundwater contaminated by pesticides involves the probability that the pesticide applied to the surface will leach to the groundwater, the probability that the pesticide plume in the groundwater will migrate to the point of withdrawal, the probability that the contaminated water withdrawn will be consumed, and the probability that consumption of the water will lead to disease. The overall "risk" then is a combination of these individual "risks". This implies that any safety margin built into estimation of the individual risks will be compounded in the estimation of the overall risk. In addition, it implies that there are multiple points at which to intervene to reduce the overall risk. For example, steps can be taken to prevent leaching of a pesticide, prevent migration of a plume, or prevent consumption of contaminated water. Any one of these steps will reduce the overall risk of damages from consumption of contaminated water. Thus, while the composite nature of many environmental risks makes them difficult to measure, it also provide a broader range of opportunities for risk reduction.

(5) Definition of risk/damages. Related to the composite nature of environmental risks is the question of how to define the risk and how to determine when damages have occurred. This issue is most apparent in cases of either gradual releases or sudden releases with latent damages. For example, in the example above, one could define damages to have occurred at the time of ingestion when there is now a positive probability of contracting the disease (time of exposure) or at the time that the exposed individual actually gets the disease (time of contraction). This distinction has important implications for the design of compensation mechanisms. While traditionally compensation is based on contraction of the disease, some have argued that those who are exposed but never ultimately contract the disease have still suffered

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[6] In addition, there may have been multiple parties that used a landfill site for disposal. In such cases, it is often difficult to identify a single (or small number of) parties who are responsible for the contamination.

damages and should thus be compensated (Robinson, 1985).[7] Compensating on the basis of exposure rather than contraction would also alleviate some of the problems posed by long latency periods, such as the difficulty of proving causation and the possibility that the responsible party will be judgment-proof. It would not, however, alleviate the difficulty of quantifying the damages in economic terms. In fact, putting a monetary value on the damages from exposure may be more difficult than putting a monetary value on the damages from actually contracting the disease since the former requires a quantification of the increased probability of contracting the disease that results from the exposure.

(6) Irreversibility and learning. Environmental risks often involve effects that are irreversible, such as contraction of a disease, death of an individual, destruction of a unique habitat, or loss of a species. If the future benefits associated with environmental improvements are uncertain, there is the possibility of learning more about those benefits over time. However, the irreversibility of the current effect may foreclose the opportunity to respond to that new information when it becomes available. Thus, in designing policies to reduce environmental risks, care must be taken to avoid "mistakes" now that cannot be undone in the future if the benefits from environmental quality in the future are found to be larger than expected.

(7) Role of risk perceptions. Because of the complex nature of most environmental risks, the perceptions of those risks can play an important role in both individual choice and policy formation. In such cases, the standard expected utility theory may be an inappropriate model of how choices are and should be made.[8] For example, individuals can have subjective probabilities and use reference points in evaluating changes, implying possible framing effects.[9] Such factors suggest that some of the non-expected utility theories of decision making under uncertainty (such as prospect theory (Kahneman and Tversky, 1979) or regret theory (Loomes

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[7] Recipients of compensation based on exposure would then be free to use their awards to purchase insurance that would cover actual damages at the time of contraction if contraction occurs. Alternatively, the awards that would have been made for exposure could be set aside in a compensation fund that would be used to compensate victims that actually contract the disease. This would effectively force victims of exposure to use the awards that they would have received for exposure to purchase insurance.

[8] For overviews of some of the criticisms of the expected utility model, see Schoemaker (1982) and Machina (1987).

[9] Framing effects exist when individual choices are affected by changes in the way in which a decision context is posed when the change does not alter the essential nature of the choice. An example is the different response of consumers to identical cash vs. credit price differentials when those differentials are called "cash discounts" rather than "credit surcharges."

and Sugden, 1982)) may provide better predictions of actual choices than the expected utility model. However, the implications for normative analysis are unclear (Weinstein and Quinn, 1983).

III. POLICY APPROACHES

The damages that result from environmental accidents are affected by a number of different factors. Figure 1 illustrates how some of these factors combine to determine potential interim and residual damages from a firm's activities and the role that policies can play in affecting damages. The figure reflects the sequential nature of the process that links the activities of the polluter and other related parties to environmental damages. This process can be decomposed into four stages: (1) creation of the potential for an accident, (2) occurrence of an accident, (3) cleanup (if any), and (4) victim compensation. Figures 2 through 5 provide more detail regarding the policies that can affect each of these stages. The list of alternative policy approaches is not meant to be exhaustive but rather simply reflective of the types of alternatives that are available.

Production and Prevention Policies. Figure 2 depicts the role of policies that affect the potential for an accident to occur. These policies are generally of two types. The first are production-oriented policies. The firm's primary focus is on its production activities, since these are the main motivation for operation. Production decisions are made in response to existing and expected future prices (for both inputs and outputs) and market conditions, as well as current (and, in some cases, anticipated future) government policies, which can either encourage or discourage such activities. Production activities generate consumption and/or investment benefits that yield profits for the firm. However, they also generate potential environmental damages. More specifically, the production process creates the potential for environmental accidents. For example, oil extraction and transport create the potential for oil spills, while industrial production creates the potential for chemical releases and generates hazardous wastes that could eventually lead to unexpected contamination of soil and water resources.

As noted above, production activities respond to policies that either encourage or discourage production of certain goods and services. For example, government policies that promote a certain industry (such as the oil industry) indirectly contribute to the potential for environmental accidents. Such policies include favorable tax or depreciation treatment, investment incentives, and other forms of government subsidies aimed at output promotion. Clearly, eliminating policies that encourage production of potentially-polluting activities can reduce the likelihood of environmental accidents. Conversely, policies that are aimed at output reduction (such as excise and corporate income taxes as well as regulation or restriction of output levels) reduce the potential for accidents. However, in general, controlling environmental risks by discouraging production is not the most efficient way to reduce those risks. If production processes or equipment can be modified to reduce the potential for accidents without forfeiting output, this is generally preferred since it is not the output per se that is the problem but rather the way in which it is produced.

Firms can often reduce the potential for environmental accidents by investing in pollution prevention or safety. For example, oil transporters can invest in double-hulled vessels, while industrial firms can use production processes that reduce waste generation or use waste disposal procedures that are less likely to lead to future contamination. The extent to which firms invest in safety will depend on the nature of their production activities (e g., how easily production processes can be modified to reduce risks of accidents) and government policies.

Perhaps the most common approach to reducing the potential for environmental accidents is the use of direct government regulation. Most risky activities are subject to some sort of regulation. Those regulations generally take the form of safety or quality standards and environmental quality goals. Standards are designed to ensure "safe" production processes and products. They often include requirements for inspections, audits, and other forms of monitoring to detect potential problems prior to the occurrence of an accident. Environmental quality goals, on the other hand, are used to identify targets that must be met by some approach (unspecified in the goal). Again, the objective is to ensure the use of operating procedures that provide sufficient protection against accidents.

To be effective, regulations must be coupled with some form of sanction for failure to comply with the requirements of the regulation. These sanctions often take the form of monetary fines or penalties, which can be either civil or criminal. Targeting individual managers or firm owners with criminal liability (which in some cases includes imprisonment) can provide strong incentives for regulatory compliance.

An alternative approach to encouraging increases in safety is through the use of ex ante economic incentives such as taxes or deposits that induce firms to reduce risk-generating activities.[10] For example, taxes on pesticides encourage farmers to cut back on pesticide use and therefore reduce their associated risks. Likewise, taxes on waste generation or disposal can encourage firms to reduce the amount of hazardous waste that must be disposed of in landfills. Instituting waste disposal fees that vary with the design of the landfill would further encourage firms to choose landfills with better safety records.

Both tax-based policies and regulations are examples of ex ante policy approaches that are operative before any environmental damages occur. In contrast, legal liability is an ex post policy tool. It becomes operative only after damages have occurred, at which time the responsible party becomes liable for those damages. The two main approaches to legal liability are strict liability (under which a responsible party is held liable regardless of the amount of care he exercised in his activities) and negligence-based rules (under which the responsible party is liable only if he conducted his activities in a "negligent" way).

Finally, safety and prevention can be encouraged simply through education and increased awareness. Subsidized assistance to finance training and education of employees and the

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[10] See Stewart (1988) for a discussion of the use of economic incentives in this context.

development of environmental monitoring systems provide a "carrot" rather than a "stick" approach to encouraging accident prevention.

Mitigation Policies. Figure 3 depicts the factors that affect the occurrence of an accident. Given the potential for an accident to occur, whether an accident actually occurs or not will depend on at least two factors. The first is naturally occuring randomness, such as random weather conditions. The second factor is activities by other parties that may contribute to the accident. For example, in the context of oil spills, a poorly-constructed tanker may create the potential for an accident, but it is a collision with another vessel that actually triggers the accident.[11] These contributing activities are not random from the perspective of the party who engages in them, but they may not be fully anticipated by the firm. Like the production activities of the firm, they yield profits or net consumption or investment benefits for the contributing party, yet create the potential for an environmental accident when combined with the activities of the firm. In addition, decisions regarding contributing activities respond to government policies, which can either encourage or discourage such activities. These policies are analogous to the policies that affect the production and prevention activities of the polluter, depicted in Figure 2.

Once an accident occurs, the initial impact depends upon the nature of the activities that contributed to it (production, prevention, and contributing activities) as well as physical conditions at the site of an accident. For example, the inital impact of an oil spill depends on the location of the spill and the sensitivity of the surrounding ecosystems to environmental damage. Similarly, the initial impact of a chemical release can depend upon the prevailing winds or other physical factors that govern the movement of the released substances.

In some cases, it is possible to reduce the initial impact through mitigation. For example, the initial physical damages from an oil spill or a leaking landfill can be reduced through early detection and containment. Mitigation can be undertaken by either the firm whose production activities led to the accident or the victims, who can sometimes take steps to reduce the damages they bear as a result of an accident. For example, victims of groundwater contamination can reduce the damages from consumption of contaminated water by buying bottled water. Similarly, individuals who live in the vicinity of a spill or release of toxic substances may be able to reduce damages by leaving or avoiding the site.[12] The final physical

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[11] Situations in which the activities of more than one party combine to create damages that are then borne by a third party are termed "joint torts".

[12] Accidents for which victims can reduce damages through mitigation activities are termed "bilateral care" accidents, since the total damages depend not only the care taken by the firm but also the care taken by the victim to avoid or reduce the damages from the accident. In contrast, accidents where only the firm can affect the level of damages are referred to as "unilateral care"

impact of an accident will thus depend on its initial impact plus any mitigation activities that are undertaken.

Mitigation decisions by both firms and victims will respond to government policies designed to increase mitigation. Mitigation can be increased through mandatory response requirements. These could include mandatory procedures for responding to accidents and for reporting accidents to appropriate authorities (both within the firm and within the affected communities). Disclosure laws that impose stiff penalties for failure to report accidents could be used to encourage prompt reporting.

Mitigation activities will also be affected by policies that assign liability for damages. Parties who will be responsible for damages or bear those damages themselves will have an incentive to increase mitigation to reduce the magnitude of the loss. The allocation of costs/damages depends on the liability rule that is used. For example, under a strict liability rule where the firm is liable for all damages, it has an incentive to undertake mitigation to reduce its liability. However, under a negligence rule, the firm may not face proper mitigation incentives. If negligence is determined solely on the basis of prevention, the firm will not be penalized for insufficient mitigation. Alternatively, if the determination of negligence is based not only on prevention activities but also on mitigation, then the firm will be induced to undertake appropriate mitigation. Similarly, a victim's incentive to take steps to mitigate damages depends on the extent to which s/he will bear those damages. If the firm is held strictly liable for all damages, the victim does not face a proper incentive to reduce those damages since s/he will be compensated for any amount of damages that are realized. In contrast, under a negligence rule where the firm is found non-negligent, the victim would bear any damages that result and would thus have an incentive to reduce those damages through mitigation. Likewise, under a negligence rule with a defense of contributory negligence, a victim would face proper mitigation incentives provided his negligence was determined on the basis of his mitigation activities.

Cleanup and Financing Policies. The final impact of the accident (after any mitigation or response has occurred) determines the initial damages from the accident. Sometimes it is possible to reduce those damages through cleanup activities.[13] For example, it is often possible to cleanup some of the oil that is released in an oil spill. Similarly, it is sometimes possible to clean contaminated soil or groundwater. The timing and extent of the cleanup will determine the magnitude of the interim damages (i.e., those that occur prior to cleanup) and the residual damages (i.e., those that remain even after cleanup).

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accidents.

[13] In other cases, however, "cleanup" is not possible. For example, the damages from releases of toxic substances into the air that are then inhaled by neighboring residents (as in the case of the Bhopal accident) cannot be reduces through cleanup.

Clearly, both the timing and the extent of cleanup will be affected by government policies, as depicted in Figure 4. The extent of required cleanup can be subject to government regulations or laws that either directly specify a required amount of cleanup or specify a process for determining that amount (e.g. use of certain equipment or technologies). Alternatively, if firms are strictly liable for all damages, they will face incentives to cleanup to a point where any additional investment in cleanup costs is more than the reduction in their liability that would result from the cleanup. Thus, liability can provide incentives for firms to invest in an efficient amount of cleanup, while government regulations specifying a required amount of cleanup may be based on other, non-efficiency criteria.

Of course, in order for cleanup to occur, funds must be available to finance the cleanup. The two basic approaches to financing cleanup are the use of private funds (financed by responsible parties) and the use of public funds (financed more broadly by the society as a whole). The availability of private funds will depend upon the profits of the firm, as well as government policies designed to ensure the availability of financial resources for cleanup. The likelihood that private funds will be available for cleanup can be increased in two ways. The first is to require firms to "pay up-front" as a condition for production through, for example, purchasing mandatory insurance, posting of an environmental bond, or payment of firm or industry-specific taxes to a fund to be used for cleanup. A second approach is to extend the liability "net", i.e., the definition of potentially responsible parties, sufficiently far to ensure inclusion of parties with "deep pockets", such as parent companies and lending institutions.

To ensure the availability of public funds for cleanup, revenue sources can be earmarked specifically for cleanup funds. The revenue can come from a tax designed primarily to raise revenue for cleanup. Alternatively, it can come from a tax that is designed primarily to discourage certain types of activities (such as pollution taxes or sin taxes), but with the revenue from the tax earmarked for cleanup. Reliance on general purpose revenues is likely to be less effective in ensuring the availability of public funds for cleanup.

Victim Compensation Policies. When either interim or residual damages occur, government policies will affect the amount of victim compensation that is required (see Figure 5). Compensation can be sought either under statutorily-imposed liability or under tort law. In either case, the prevailing liability rule will determine the extent to which victim compensation is required. For example, under a negligence-based rule, firms would not be required to compensate victims for damages if the firm complied with the specified due standard of care. In contrast, under a strict liability rule, compensation would be required regardless of the firm's efforts to avoid or reduce damages.

Of course, the actual payment of required compensation will depend upon the availability of funds. As with cleanup, the availability of private funds to pay for victim compensation will depend upon the profits of the firm, as well as government policies designed to ensure the availability of adequate resources for compensation (see discussion above). In addition, a requirement of compensation must be accompanied by a well-defined institutional procedure by which victims can actually secure compensation when it is due. Without such a procedure and

the associated institutional structure, the mere requirement of compensation will never be effectively implemented.

If liability is not imposed on the firm, then victims would not be compensated by the private parties whose actions led to the damages. In such cases, the government can establish publicly-funded victim compensation funds or otherwise help in the provision of insurance as a risk management approach.[14] Victim compensation funds can be either narrowly or broadly-based. For example, a fund can be designed to provide compensation for victims of a specific type of environmental risk, such as Black Lung disease. This requires that a victim be able to establish the connection between his illness and an environmental exposure. While this is relatively easy in some cases (such as Black Lung disease), it can be difficult to establish causation for more broadly-based diseases such as cancer. While the causation problem can be solved by using a broad-based compensation fund (such as Workers' Compensation) that does not require proof of causation, such funds effectively become public insurance mechanisms. In either case, as with publicly-financed cleanup, a mechanism must be established for ensuring that these victim compensation funds have adequate resources to pay the required compensation (see discussion above).

IV. GOALS OF RISK MANAGEMENT POLICIES

The above overview of alternative policy approaches suggests that there are a wide range of policies that can be used to manage environmental risks. However, in order to evaluate these policies and choose among them, it is essential to identify explicitly the goals that we are seeking to accomplish, i.e., what we want the policy to achieve. Some policy approaches are effective in achieving one goal but not another, and tradeoffs among goals are often necessary. In this section, three possible goals for risk management policies are discussed: risk reduction, cost allocation, and risk allocation. While other goals are certainly possible, these three goals capture the primary economic dimensions of risk management policies.

Risk Reduction. Risk reduction can be achieved either through a reduction in the probability of a given event (e.g. a chemical spill) occurring or a reduction in the magnitude of the damages given the event has occurred (e.g., a reduction in exposure given a spill). A reduction in the probability is achieved through increased prevention, while the magnitude of the damages can be reduced through either mitigation or cleanup. Policies can be designed to provide parties with incentives to engage in these activities or to control them directly. Of course, risks can also be reduced by reducing production activities, where in the extreme case closing down a given industry can eliminate the associated risks.

What criterion should be used in determining the amounts of production, prevention, mitigation, and cleanup that are desired? An economic approach to determining the extent to which risk-reducing activities should be undertaken recognizes that these activities involve both

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[14] See Trauberman (1981) for a discussion of the use of victim compensation funds.

potential benefits (in the form of a reduction in expected environmental damages) and potential costs. The resources (capital, labor, materials, etc.) that are used to produce additional safety (through increased prevention or mitigation) could have been used for the production of other goods and services that society values. Thus, devoting these resources to the production of safety involves a cost. This cost is "justified" if the potential benefits are sufficiently high. As long as the benefits outweigh the costs, it is economically efficient to invest resources in safety production.[15] Similarly, efficiency requires that a firm increase its output up to the point where the benefit from additional output equals the additional cost of producing that output, including any associated environmental costs. Beyond that point, any additional output costs more (in terms of combined production and environmental costs) than it is worth.[16] Firms will be induced to choose an efficient level of output if they bear the full costs of their production activities, including the environmental costs.

An alternative approach might be to claim that individuals have a right to a clean environment and thus a right to complete cleanup of any contamination that exists. However, even with a right to 100% cleanup, it is not clear that this is the level that should or even would be chosen by victims. To see this, consider the following experiment. Assume that full cleanup would cost $10 million while partial (say 75%) cleanup would cost $7.5 million. Suppose that the victim[17] were given the $10 million that would be required for full cleanup and told that she could spend the money in any way that she chose, including (but not necessarily limited to) cleanup. It is not clear that the victim would necessarily choose to spend all of the money on cleanup. She might, for example, choose to spend some on cleanup and some on other things that she values. As with any private spending decision, she would presumably look to the additional benefit that she would receive from spending additional dollars on cleanup and compare it to the cost (in the form of foregone other goods and services that could have been purchased with the money). While she might still choose to spend it all on cleanup (if every last dollar of money spent on cleanup was "worth it"), she might instead choose to use some of the money in other ways, depending on the benefits she gets from additional cleanup relative to the

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[15] More specifically, resources should be devoted to safety production up to the point where the benefit from devoting any additional resources is just equal to the cost of devoting those resources to the production of safety. The resulting level of safety production will be "efficient" since it ensures that the net benefits that society as a whole receives from the use of these resources is maximized.

[16] For a general discussion of efficiency in the context of pollution control, see Baumol and Oates (1988). Efficiency in the context of risks and accidents is discussed in detail in Shavell (1987).

[17] We consider the simple case of a single victim. The argument would be essentially the same with multiple victims, although additional complications relating to differences across victims would have to be discussed.

cost.

The above discussion suggests that the question of victim rights often can and should be separated from decisions regarding the amount of decisions about risk reduction and cleanup. Risk reduction and cleanup decisions should be based on economic efficiency, i.e., on a comparison of benefits and costs. Questions regarding victims' rights instead relate to a different goal of environmental policy, namely, cost allocation.

Cost allocation. A second goal of environmental policy is to allocate the costs associated with contamination, including both the costs of cleanup and any interim and residual damages, in a manner that is deemed appropriate. Clearly, different policies imply different allocations of these costs. Policies that make firms responsible for damages resulting from their production activities are consistent with the "polluter-pays-principle". Alternatively, those that absolve polluters of responsibility for payment provided they "play by the rules" transfer the costs of contamination to other parties, such as victims or the government.

Unlike risk reduction, however, cost allocation is generally not evaluated in terms of economic efficiency.[18] Since it concerns the distribution of costs across different groups, it is instead evaluated on the basis of fairness.[19] Many have argued that the polluter-pays-principle is justified on the basis of fairness, since those firms who benefited from the activity that led to contamination should be made to pay for it. On the other hand, some have argued that, as long as the firm complied with all existing environmental regulations at the time of its production, it is unfair to make it pay for unexpected contamination. This argument has been made most forcefully in cases where the production activity that led to contamination occured many years ago, at a time when no one anticipated the possibility of future liability for contamination.[20] In such cases, increasing costs now by imposing liability will make current consumers or stockholders bear the associated costs, even though they were not the beneficiaries of the artificially low prices that existed at the time of the contamination.

Risk allocation. A third goal of environmental policy relates to the allocation of the risk associated with production activities. While the two are often lumped together, risk allocation is in fact a different issue than cost allocation. Consider, for example, a policy under which firms pay a waste generation tax but are not liable for actual cleanup costs, which would be paid

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[18] To the extent that ensuring an efficient output choice requires that firms bear the full social costs of their activities, then the cost allocation can be judged on the basis of its efficiency implications. Here, however, we focus on the distributional implications only.

[19] For a discussion of the allocation of property rights implicit in any cost allocation, see Bromley (1993) and the references cited therein.

[20] See, for example, Pace (1993).

by the government using revenues from the tax. Under such a policy, firms would still bear the costs of cleanup through payment of the tax. However, the costs that the firm will bear are certain given its level of waste generation. The tax-based approach to financing cleanup essentially provides a form of insurance for firms, where the "premium" takes the form of tax payments. Thus, such a policy imposes costs without imposing risks. In contrast, if firms are held liable for cleanup costs, then they bear both the costs of cleanup and the risk associated with the uncertainty of those costs.[21] If they can purchase environmental liability insurance in the market, they can transfer the risk to the insurer and be left simply with the cost. However, when liability insurance is not available, a liability-based approach can leave the polluter bearing both the costs and the risks associated with cleanup.

If firms are averse to bearing risk, then the risk per se imposes an additional cost on the firm (Arrow 1971). In other words, for a risk averse firm, the firm would prefer to make sure payments of a certain amount rather than face uncertain payments with the same expected value since those uncertain payments involve risk. Thus, a risk-averse firm would always want to purchase actuarily fair insurance[22] against losses, since that insurance allows it to make a sure payment (the insurance premium) in lieu of facing the prospect of uncertain losses. Similarly, a risk-averse firm would rather pay $10,000 in sure tax payments than face a 5% chance of having to pay $200,000 in liability (where .05*200,000=10,000). Firms are likely to be risk averse with regard to liability payments if they are not able to purchase insurance to cover environmental liability or to diversify risks in other ways. In addition, small firms are more likely to be risk averse than large firms, since they have a smaller asset base to cushion against large, unexpected costs.

When firms are risk averse, the allocation of risk implied by a given policy becomes an important element in evaluating the desirability of that policy. As with risk-reduction incentives, risk allocation can be evaluated in terms of economic efficiency. Economic efficiency requires that risks be allocated to those parties who are best able to bear them.[23] In other words, if some parties are able to diversify risks (making them "risk neutral") and others are not, then transferring risk from the latter to the former (in exchange for a sure payment) can make both parties better off, since the amount the risk-averse party would be willing to pay to eliminate his risk would be more than what the risk-neutral party would require as compensation for accepting

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[21] The allocation of risk under a liability rule depends on the specific rule that is used. See further discussion below.

[22] Insurance is said to be "actuarily fair" if the premiums reflect the average or expected payout by the insurance company, i.e., the average loss that is covered.

[23] When all parties are risk averse, then efficiency requires that risks be spread across the parties rather than concentrated on any individual party. For a discussion of optimal risk sharing, see K. Borch (1962), Shavell (1979), Segerson (1986), and Segerson (1989).

the risk. The risk-neutral party would effectively be providing insurance against losses for the risk-averse party in exchange for an insurance premium. Through such an exchange, both parties (i.e., both the insurer and the insured) can be made better off.

In evaluating alternative policies, we can look to see how well they achieve the goal of efficient risk allocation or risk spreading. In doing so, however, it is important to keep in mind the distinction between risk allocation and cost allocation. For example, the question of who should pay for hazardous waste cleanup is separate from the question of who should bear the risks associated with the uncertainty of the cleanup costs. In principle, those who bear the costs need not be the same as those who bear the risks.

V. EVALUATION OF POLICIES

As noted above, policies can be evaluated on the basis of how well they achieve the above policy goals, although tradeoffs among goals are likely to be necessary. Table 1 summarizes some of the main policy approaches in terms of their ability to achieve (at least in principle) the different policy goals.

V.A Liability Policies

Within the class of liability rules, a choice must be made between a strict liability rule, under which a party responsible for damages is held liable regardless of the amount of care taken in conducting the activity that led to those damages, and a negligence rule, under which the party is held liable only if it was negligent in conducting the activity, where negligence is defined as failure to conform to some "due standard of care".[24] These two rules differ somewhat in terms of both their incentive effects and the associated allocation of costs and risk.

Economic theory suggests that in principle either a strict liability approach or a negligence approach can be used to induce firms to undertake an efficient amount of care or prevention to reduce damages.[25] [26] Since under strict liability firms will have to pay for the

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[24] These rules can be further delineated according to whether or not they allow a defense of contributory negligence by the harmed party or "victim". However, in the case of hazardous waste, victim incentives are not usually an issue, except, for example, when a party knowingly purchases property near a waste disposal site with the intention of "up-grading" the use of the land (which might increase the amount of required cleanup).

[25] See, for example, Shavell (1980).

[26] As discussed above, the answer to the question of what should be done to improve incentives for safety can, at least in principle, be answered on the basis of economic efficiency -- policies should be designed to ensure that an efficient amount of

damages or cleanup associated with contamination, they will have an incentive to engage in activities to reduce their costs. Likewise, since under a negligence rule firms will have to pay if they are negligent, they have an incentive to engage in efficient care in an effort to avoid liability. Thus, either approach can induce firms to take precautions to reduce risks.[27]

However, engaging in an efficient amount of care (i.e., an amount at which the benefits from additional care equal the corresponding costs) does not eliminate the possibility of an accident. Thus, there is still the possibility that mitigation and/or cleanup will be necessary and that damages will have to be paid. Strict liability and negligence also differ in terms of their implications regarding the allocation of the associated costs and risks. Assuming a firm engages in efficient care under either approach, that firm would still pay for any resulting costs under the strict liability approach, while it would not be liable for those costs under a negligence rule. In other words, under a strict liability approach a firm pays for both the costs of its pollution prevention activities as well as the costs of any contamination that still results. In contrast, under a negligence rule, if the firm complies with the due standard, it pays only for the cost of complying with that standard and not for any damages that might occur despite its compliance.

This difference in the allocation of costs has implications for risk reduction incentives. In addition to inducing efficient prevention, strict liability will provide incentives for firms to engage in mitigation and cleanup, since these activities will reduce damages and hence the amount of liability that the firm faces. In contrast, under a negligence rule, firms will have an incentive to undertake mitigation and cleanup only if negligent behavior includes failure to respond appropriately when an accident occurs

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prevention and mitigation are undertaken, where the efficient amounts are defined in terms of the marginal benefits and marginal costs of these activities. In practice, of course, determining this amount can be quite difficult because of the difficulty in measuring both the benefits and the costs of risk reduction. While a discussion of the methodologies for estimating benefits and costs is beyond the scope of this paper, we simply note here that efficiency can serve as a guiding principle in choosing a target level of safety or risk reduction.

[27] However, the efficiency of the negligence rule requires that the court set the due standard of care at the efficient level and that the standard be known to the injurer at the time of the care decision. If they are not, the negligence rule will no longer be efficient. (For a detailed discussion of negligence rules, see Cooter (1984).) Likewise, efficiency of strict liability requires that the firm would be liable for an efficient amount of cleanup. If the required cleanup is excessive, then under strict liability the firm would be excessively careful. A similar conclusion holds under a negligence rule if both the amount of potential liability and the due standard of care reflect the excessive cleanup.

In cases of bilateral care where victims can take steps to reduce damages, victim compensation can have incentive effects. Specifically, any compensation that reduces damages reduces the victim's incentive to invest in efficient mitigation. For this reason, policies that provide victim compensation can distort incentives for efficient mitigation by victims. Because victims are (in theory) fully compensated for damages under strict liability but not under negligence when the polluter meets the due standard of care, victims will face greater incentives to take steps to mitigate those damages under the negligence approach.

Finally, since under strict liability firms are forced to bear all of the costs associated with their production activities,[28] both the prices of their products and the corresponding output levels will reflect all costs associated with production and will thus be economically efficient. However, under the negligence rule the firm's costs will actually be less than the true social cost of production (by the amount of the cleanup or damages that the firm does not bear). This results in a price that is "too low" (i.e., below the social opportunity cost of production) and a corresponding output level that is too high. Thus, in terms of economic efficiency, the allocation under strict liability is preferred.

Whether the allocation of costs under strict liability is "better" or "worse" than the allocation under a negligence rule when judged on the basis of fairness is a subject of considerable debate. Here, however, economic theory offers little guidance on the evaluation of the two approaches. The two represent a different allocation of property rights, with producers having more of a "right" to engage in potentially polluting activities under the negligence rule than under strict liability. Whether this is desirable or not depends on the notion of fairness applied. As noted above, the allocation under strict liability is consistent with the polluter-pays-principle, which states that those parties who benefit from a given production activity should pay the full costs associated with it. On the other hand, the allocation under the negligence rule is more consistent with the notion that if a party "plays by the rules" that party should not be penalized.

Who bears the damages from an accident under the regulatory approach depends upon whether or not the regulatory policy is coupled with explicit mechanism by which those costs would be transferred to the public (e.g., a publicly-financed victim compensation fund). Although victim compensation dilutes the victim's mitigation incentives, it might be desirable on the basis of cost and risk allocation. Since victims are not directly responsible for the activities that led to the accident, it can be argued that on the basis of fairness they should not bear the resulting damages. Even if one takes the view that the production activities that led to the accident are socially desirable and thus society should bear the costs, in most cases the associated benefits will be widely distributed while the costs will be concentrated on a small number of victims.[29]

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[28] See Polinsky (1980).

[29] Some might argue that, in cases where a victim voluntarily moved next to a potentially hazardous facility, they

Through its imposition of the uncertain cleanup costs on responsible parties, a strict liability rule is also imposing considerable risk on those parties. In contrast, the negligence approach does not impose risks, since compliance with the due standard absolves the party from responsibility for the uncertain costs.[30] As with costs, the risks are borne by whatever entity must ultimately pay for cleanup (e.g., the federal government) or bear the costs if no cleanup is conducted (e.g., the neighboring residents or other "victims"). Whether the allocation of risks is better under strict liability or negligence depends upon whether victims or the government will bear the risks when firms do not (i.e., whether the cleanup will be financed by the government) and on the ability of each of the parties to spread their risks through, for example, the purchase of insurance or increases in prices or taxes.[31] In general, in the absence of first-party insurance victims have little opportunity to spread the risks associated with exposure to contamination or payment of cleanup costs. This is particularly true for large, non-monetary risks such as risks from environmental accidents. In contrast, the federal government can spread cleanup costs across taxpayers. Similarly, while large firms may be able to spread the risks associated with uncertain cleanup costs through increased prices or self-insurance, small firms may not be able to do so unless environmental liability insurance is readily available. Thus, a negligence rule will place considerable risk on risk-averse victims if cleanup of contamination from non-negligent behavior is not paid for through government funds, while strict liability will place considerable risk on small, risk-averse firms if environmental liability insurance is not available.

In summary, while both strict liability and a negligence rule provide incentives for parties to take care, under the strict liability approach firms would be liable for the full social costs of their activities. This provides incentives for efficient output and pricing decisions that do not exist under the negligence rule. An evaluation on the basis of fairness depends on the criterion used, while their desirability in terms of risk allocation depends on the ability of parties to bear risks. Neither provides a mechanism for ensuring that funds will be available for cleanup and compensation if necessary.

V.B Regulation

An alternative to the use of liability is reliance on a regulatory approach to managing environmental accidents. Such an approach relies on regulations to control activities such as prevention, mitigation, and cleanup, that affect the likelihood and magnitude of accidents. In principle, a regulatory approach coupled with fines or other penalties for noncompliance is very similar to a negligence rule -- in both cases, a party faces additional costs when it fails to meet

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have voluntarily assumed the associated risk (perhaps in exchange for lower-priced housing).

[30] This assumes that the due standard is known in advance. Any uncertainty about the standard that will be applied would expose the firm to risk.

[31] See Shavell (1979) for related discussion.

some standard.[32] Thus, the entries in Table 1 are the same for regulation as they are for a negligence rule. In practice, however, the choice between regulation and liability will depend on a number of factors not reflected in Table 1. For example, a negligence rule might work better for sudden spills and releases than for gradual releases (for example, from waste disposal sites) that do not manifest themselves until some time in the future. Gradual releases might be controlled more effectively through regulation. We briefly discuss some of the factors that might affect the relative desirability of relying on liability vs. regulation to ensure efficient risk reduction.[33]

(1) Are the actions influencing the risk observable or unobservable by regulators? If it is difficult or costly for regulators to monitor the level of care taken by firms, then it will be difficult to regulate these activities since it will be difficult to monitor and detect non-compliance. In general, when actions are unobservable, it is preferable to provide incentives for the firm to make efficient decisions, so that it is in the firm's interest to do so even without government oversight. Liability can provide such an incentive.

(2) What is the probability that a responsible party would actually be sued and held liable under a liability rule? When damages are widely dispersed or it is difficult to prove causation, victims may be reluctant to incur the costs of filing suit against a responsible party. In addition, if the responsible party has insufficient assets or, in the extreme case, is bankrupt, it may not pay the full amount for which it is responsible. Causation and bankruptcy or asset problems are likely to be particularly problematic in cases involving long lag times, where damages appear only after a long period of time (i.e., sudden releases with latent damages or gradual releases). When responsible parties anticipate that they may not be held liable for the full amount of damages, either because victims will not bring suit or because the firm will have insufficient assets to pay, the incentive effects of liability are diminished and a regulatory approach is likely to be more effective in controlling risks.

(3) Does the private sector have more or less information than regulators about risky activities? The less information regulators have, the more difficult it will be to design regulations that ensure efficient risk reduction. The quality of the information available to regulators will depend on both the degree of heterogeneity (for example, the extent to which abatement costs differ across firms) and the existence of economies of scale in the collection of information.

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[32] There are, however, some differences in the application of this basic principle in the two cases. For example, under a regulatory approach, noncompliance alone can trigger imposition of the penalty. In contrast, under a negligence rule, the negligent behavior must actually lead to an accident before liability can be imposed.

[33] For a related discussion, see Shavell (1984).

(4) What are the administrative or transaction costs of liability vs. regulation? Administrative costs occur under a liability rule every time a suit or action is filed. The litigation costs associated with a suit can be very high. If accidents (and thus suits) are frequent, then the total administrative costs from a liability rule will also be high.[34] Administrative costs under regulation, on the other hand, depend upon the costs of monitoring and detecting non-compliance and the costs of responding to a detected violation. These costs include both the costs incurred by the firm (e.g., reports used to determine compliance) as well as the costs of inspections by regulators.

V.C Taxes on Outputs or Inputs

Neither a liability approach nor a regulatory approach to managing environmental accidents ensures that funds will be available to finance any needed cleanup or victim compensation. As noted above, there are alternative mechanisms available for ensuring that sufficient resources are available to finance cleanup and any compensation for damages. One approach is reliance on tax revenues to finance cleanup and compensation. Tax revenues can be generated by specific taxes targeted at the industry whose activities lead to a specific type of environmental accident (e.g., industries that generate significant quantities of hazardous waste). Alternatively, they can be generated by broadly-based taxes that apply to a wide sector of the economy without regard to their likely contribution to the accident potential.

Specific taxes that are targeted toward the polluting industry can induce prevention if the amount of the tax paid is linked to the extent to which a firm undertakes prevention activities. For example, taxes on waste generation or disposal provide an incentive for firms to find ways to reduce the amount of waste they generate and/or find alternatives to disposal (e.g., reuse and recycling). If the tax is on the firm's output, then it will induce a reduction in output, which will in turn generally reduce the potential for accidents.[35] In addition, if set properly, targeted taxes can ensure that firms pay the full social costs of their activities (both production and environmental costs) and thus induce efficient output decisions.

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[34] Transactions costs can differ under a strict liability rule and a negligence rule. Because a negligence rule requires a showing of negligence to establish liability, it can be argued that it will involve higher transaction costs per case. However, these higher transaction costs will also serve to deter potential lawsuits. Thus, the number of lawsuits filed could be lower under a negligence rule than under strict liability where no such finding is required. A reduction in the number of suits would tend to decrease total transaction costs (even though costs per lawsuit would be higher).

[35] However, as noted above, it is often more efficient to target the inputs that contribute directly to the accident potential.

However, because the tax is paid at the time of the activity that creates the potential for an accident (e.g., production or waste generation) rather than in response to the occurrence of an accident, it will not by itself create incentives for firms to undertake mitigation and cleanup to reduce damages. Likewise
if the tax revenue is used for victim compensation, a targeted tax will not provide victims with sufficient incentives to take whatever steps are available to them to reduce damages.

Finally, while a targeted tax ensures that the cost associated with cleanup and compensation are borne by the industry that generates the accident potential, the risk associated with the uncertainty of those costs is not borne by individual firms. If any surpluses or deficits from the tax fund goes into or comes out of general revenues, then the risk associated with the uncertainty of these costs is borne by the government (i.e., society as a whole). Alternatively, if surpluses or deficits lead to adjustments in the magnitude of the tax, then the risk is spread across the targeted industry.

In contrast to targeted taxes, taxes that are broadly-based do not create any incentives for risk reduction since there is no link between the amount of the tax paid and any risk reduction activities (prevention, mitigation, or cleanup) that the firm undertakes. In addition, the costs and the risks associated with cleanup and compensation are spread across the entire society rather than being borne by the firms whose activities generate the accident potential. As a result, firms do not face the full social costs of their production and hence tend to overproduce relative to the efficient level.

V.D Bonds and Insurance

The availability of funds to pay for cleanup and compensation can also be assured by requiring firms to post environmental bonds as a precondition for undertaking activities that create an accident potential. If an accident occurs, the bond would finance the required cleanup and compensation. Otherwise, it would be refundable upon a determination that the possibility of damages had been eliminated. Such a determination is relatively easy in the context of sudden accidents, such as oil spills, where safe completion of transport would ensure an elimination of potential damages. In cases of gradual releases with potential long term effects, the point at which the potential hazard has been eliminated is more difficult to determine.

The use of environmental bonds is conceptually similar to the use of a strict liability rule under which firms are responsible for all damages that result from their activities. Thus, the entries in Table 1 are the same for environmental bonds as they were for strict liability, except with regard to availability of funds. Requiring that firms post an environmental bond can create an incentive for firms to invest in prevention, mitigation, and cleanup, since they reap the benefits of any reductions in damages that would result. In addition, it imposes the cost on the firms whose activities are responsible for the damages. This ensures efficient output decisions and is consistent with the polluter-pays-principle. Firms also bear the risk associated with the uncertainty of damages under this approach.

However, when potential damages are large, the use of environmental bonds requires firms to set aside a large amount of money, especially if the amount of the required bond is set at the maximum possible damages (even if those damages are highly unlikely). For firms with cash flow constraints, such a requirement may be prohibitive. Thus, the requirement may prevent some socially beneficial production activities from being undertaken.

An alternative to environmental bonds is to require mandatory insurance that would cover the costs of cleanup or compensation. From the perspective of the firm, mandatory insurance is essentially the same as a targeted tax (and hence the entries in Table 1 are comparable). In either case, the firm makes a certain payment (the insurance premium or the tax) in exchange for an assurance that another party (the insurance company or the government) will cover cleanup costs. Under such a policy, the firm still bears the cost of cleanup (through payment of the insurance premium or tax) but it does not bear any risk (since, in the absence of any deductible, its payments are certain). The risks are instead borne by the insurance industry, which then pools risks to diversify them. Insurance thus provides a mechanism for protecting small firms who might not otherwise be able to bear the risk of large financial obligations. However, the firm will face efficient risk-reduction incentives only if the amount of the premium is dependent on the risk-reduction activities of the firm. Specifically, if the firm's payments are independent of actual damages or cleanup costs, it would incur the costs of risk-reduction without receiving any of the associated benefits (in the form of reduced payments). This creates a "moral hazard" problem, under which too little investment in risk reduction would occur.

Another means of increasing the availability of funds for cleanup is to expand the pool of potentially responsible parties to include parties with large asset bases, such as lenders and parent companies. If there is a contractual relationship between the firm and these other included parties, then the effect of this policy is similar to mandatory insurance or taxes in that, through adjustments in the terms of the contract, the liability can be transfered in exchange for a fixed payment. However, if the other included parties have a close working relationship with the firm, monitoring to ensure efficient investment in risk reduction may be easier. Thus, the moral hazard problem might be reduced through such "internal" monitoring. In contrast, if there is no contractual relationship between the parties, [36] then expanding the pool of potentially responsible parties dilutes the firm's risk reduction incentives and shifts both costs and risk to other parties.

VI. CONCLUSION

Many pollution problems take the form of environmental accidents. Examples include accidental releases or spills of toxic or hazardous substances as well as unintended leaching of substances from waste disposal sites. Such problems often have a number of characteristics that make policymaking in this context particularly challenging. In addition, the resulting interim

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[36] An example of potentially responsible parties who have no contractual relationship is two firms who dispose of their waste at the same commercial waste disposal site.

and residual damages are affected by a number of different activities (including production, prevention, mitigation, and cleanup). Each of these activities in turn responds to government policies. There are a number of different policy approaches that can affect environmental accidents. The main approaches are liability, regulation, taxes, environmental bonds and mandatory insurance.

An evaluation of alternative policies hinges on the policy goal. There are at least three possible goals in the design of policies to control environmental accidents: (i) risk reduction, (ii) cost allocation, and (iii) risk allocation. While risk reduction and risk allocation can be evaluated on the basis of economic efficiency, cost allocation can only be evaluated on the basis of some definition of "fairness".

Given these goals, one can then evaluate alternative policies to determine the extent to which they accomplish these goals in the context of a specific issue. For example, alternative policies to encourage prevention (safety) and mitigation can be evaluated on the basis of the efficiency of the incentives they create, as well as on the resulting allocation of the costs and risks associated with undertaking those measures and the costs and risks of the resulting interim and residual damages. The three goals often conflict. For example, a policy that is effective at reducing risk may yield an allocation of costs that is deemed "unfair". None of the proposed policy approaches achieves all of the goals in theory or in practice. Thus, the choice among alternative policy approaches is likely to involve some tradeoff in achieving the identified goals.

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Figure 1

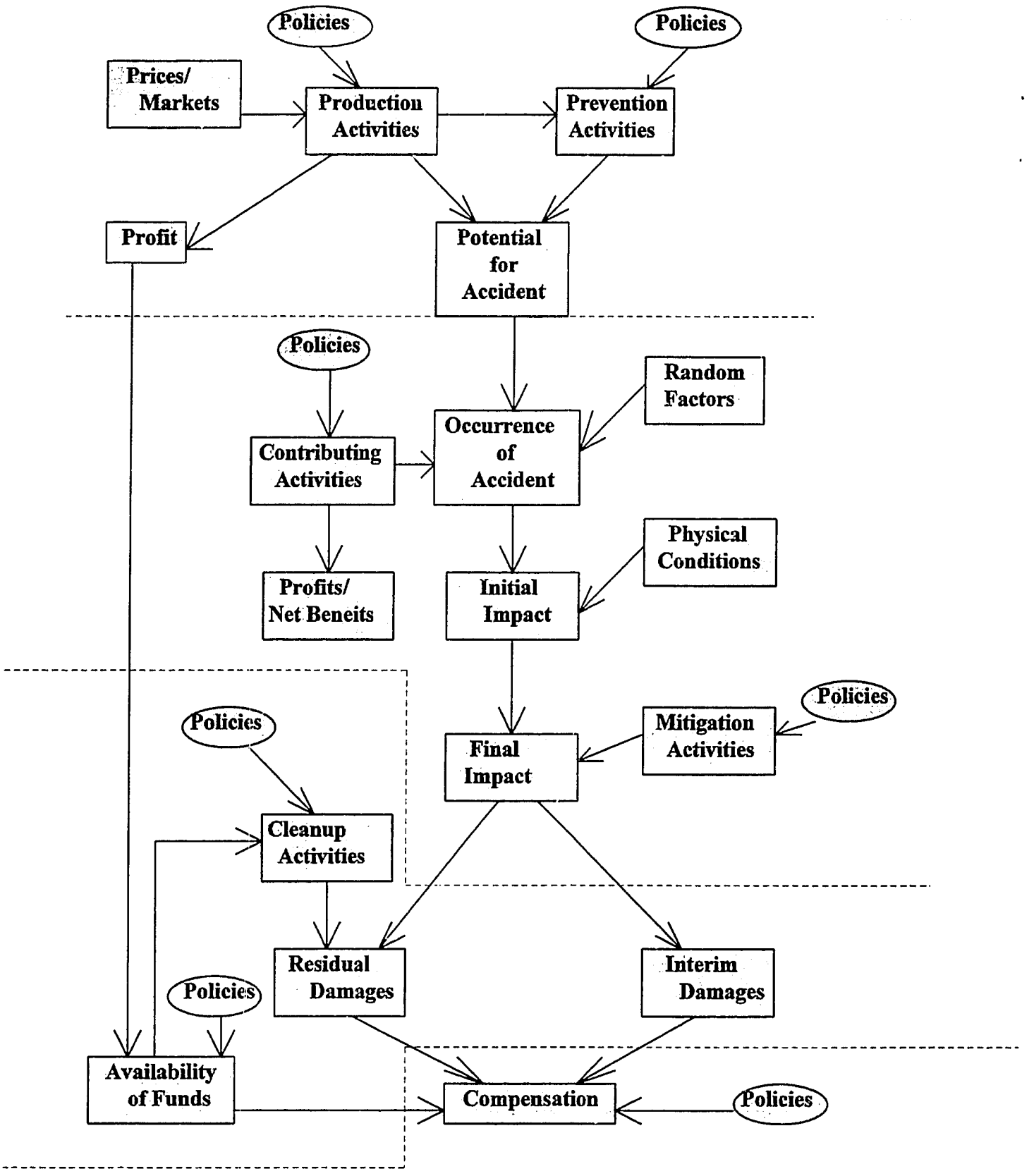
Policies
Policies
Prices/ Markets
Production Activities
Prevention Activities
Profit
Potential for Accident
Policies
Random Factors
Contributing Activities
Occurrence of Accident
Physical Conditions
Profits/ Net Beneits
Initial Impact
Policies
Policies
Mitigation Activities
Final Impact
Cleanup Activities
Residual Damages
Interim Damages
Policies
Availability of Funds
Compensation
Policies

Figure 2: Potential for an Accident

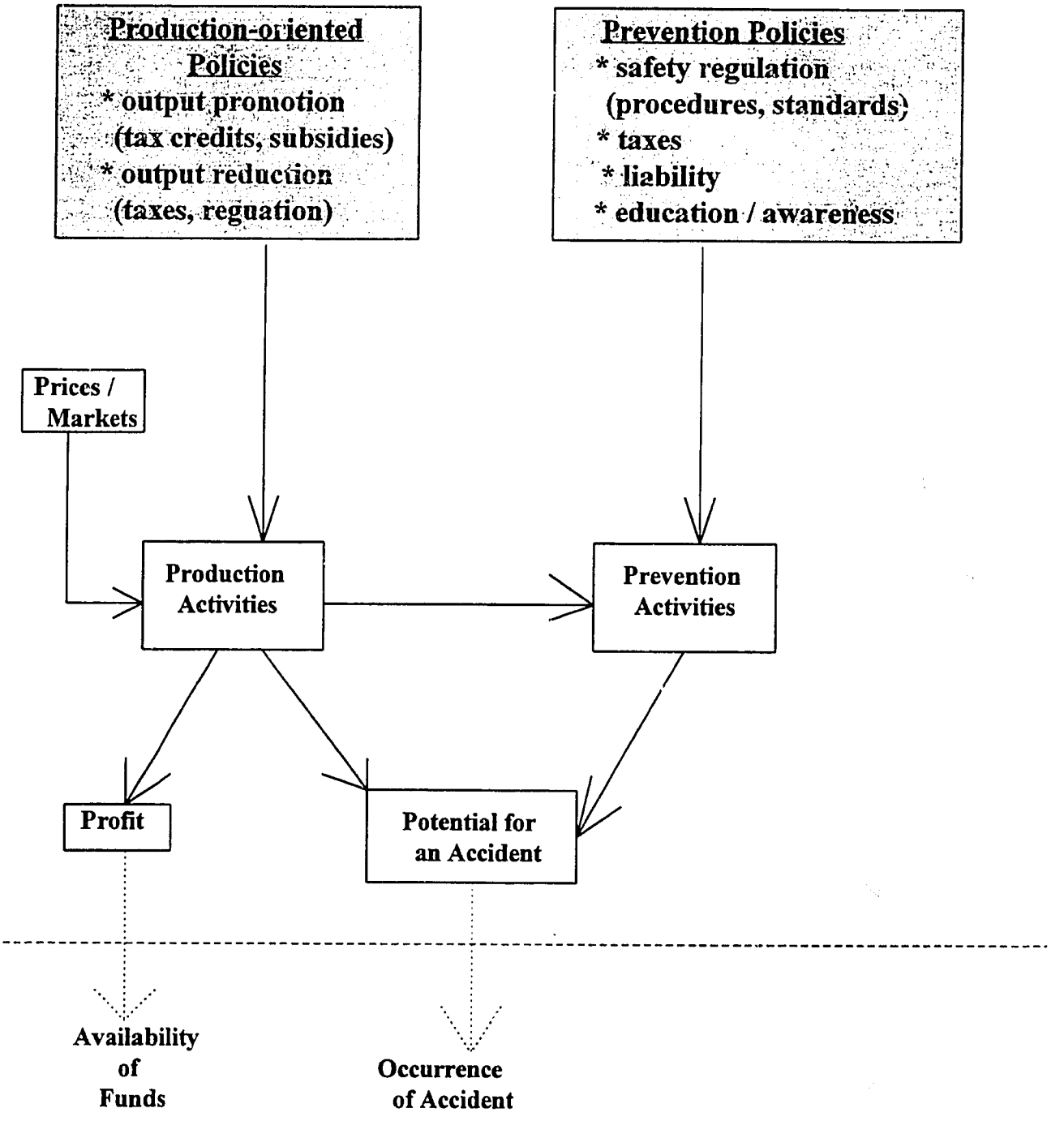

Figure 3: Occurrence of an Accident

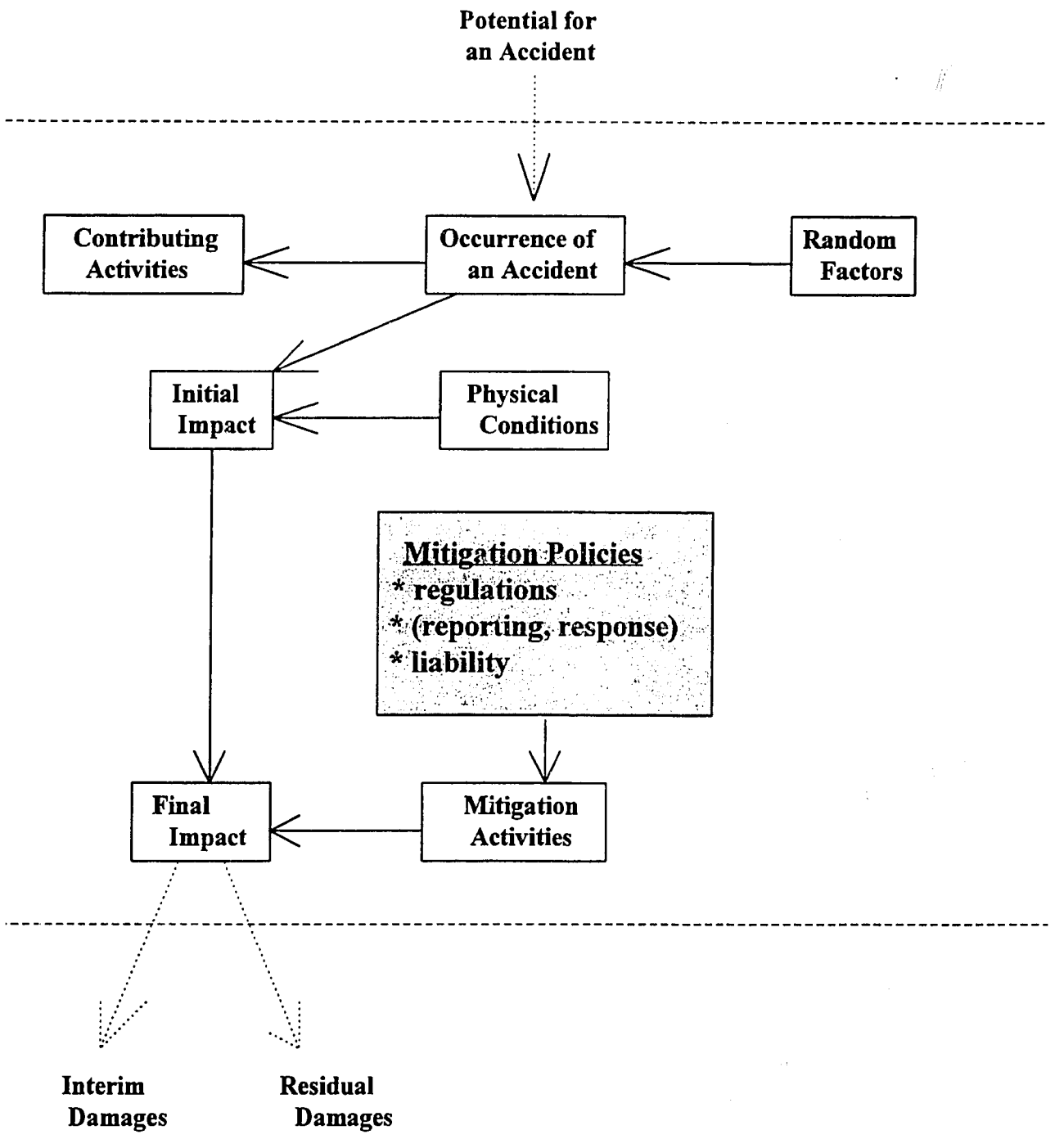

Figure 4: Cleanup

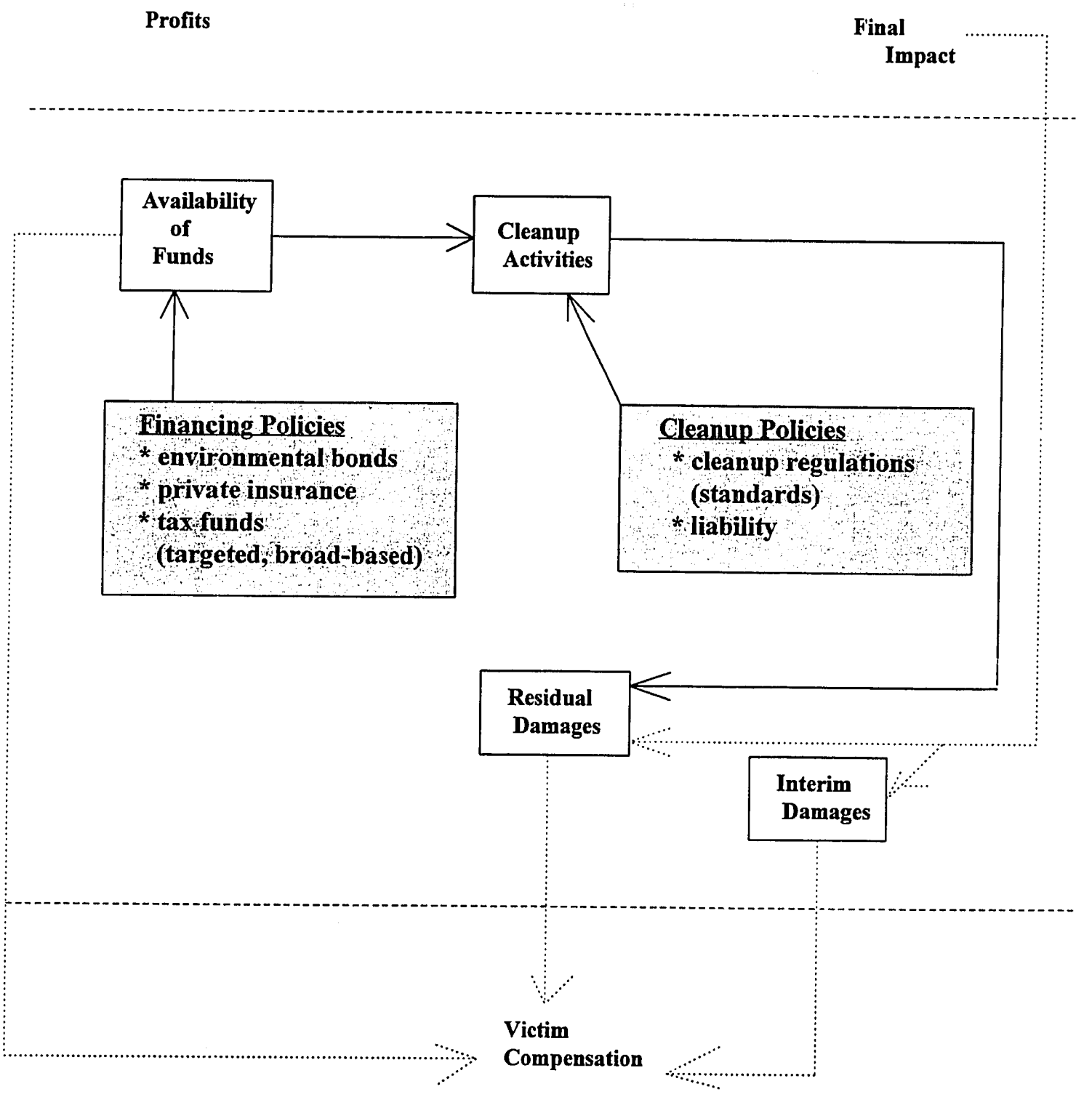

Figure 5: Victim Compensation

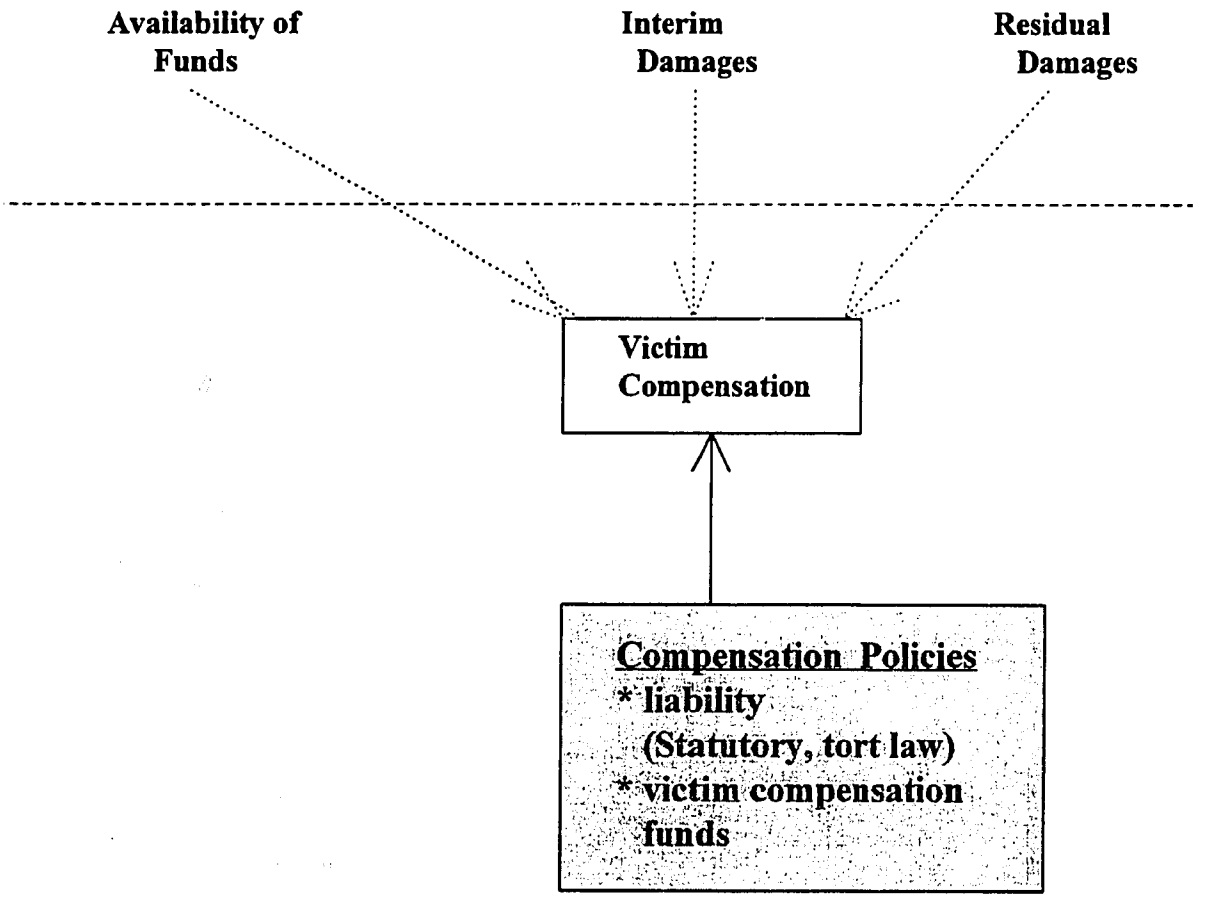

Table 1: Summary of Policy Evaluations

	Risk Reduction Incentives				Cost Allocation				Risk Allocation		
						Cost borne by			Risk borne by		
Policy	Prevention	Mitigation/ Cleanup by Polluter	Mitigation/ Cleanup by Victim	Output Level	Avail. of Funds	Firm(ppp)	Public	Victim	Firm**	Public	Victim
Liability											
Strict Liab.	x	x		x		x			x		
Negligence	x	(a)	x			(b)		(c)			(c)
Regulation	x	(a)	x			(b)		(c)			(c)
Taxes:*											
Targeted	(d)			x	x	x				(e)	
Broadly-based					x		x			x	
Environmental Bonds*	x	x		x	x	x			x		
Mandatory Private Insurance	(f)			x	x	x			(g)		

Notes for Table 1:

* Tax revenues, bonds and insurance payouts are assumed to be used for cleanup and victim compensation.

** Entries assume that the "rules" are known with certainty Unexpected changes in policies, regulations, or standards would impose risks not reflected here.

(a) Incentives for mitigation/cleanup by polluter would exist if negligence is defined to include failure to undertake appropriate mitigation and cleanup activities. Similarly, regulations must extend to mitigation and cleanup by polluters.

(b) Polluter bear the cost of complying with the due standard or regulation but do not bear the cost of any interim or residual damages that occur.

(c) Victims would bear costs and risks unless the policy is coupled with some specific mechanism by which those costs/risks would be transferred to the public (e.g., a publicly-financed victim compensation fund).

(d) Targeted taxes can induce prevention if the amount of the tax paid is linked to the extent to which a firm undertakes prevention activities (e.g., amount of waste generated).

(e) The risk is borne by the government is any surpluses or deficits from the tax fund goes into or comes out of general revenues. Alternatively, if surpluses or deficits lead to adjustments in the magnitude of the tax, then the risk is spread across the targeted industry.

(f) Prevention incentives depend upon whether the magnitude of the insurance premium is based on the prevention activities of the firm.

(g) Risk is transferred from the polluter to the insurance industry, which then pools risks to diversify them.

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