Chapter 26

THE ECONOMICS OF HEALTH, SAFETY, AND ENVIRONMENTAL REGULATION

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Contents

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1. Introduction

1.1. Economists' disinterest in externalities

Economists have long recognized the theoretical possibility of externalities and their role in disrupting the efficiency of competitive equilibrium. More recently, the incentive and appropriability features of information markets have raised questions regarding the efficiency of the private market as a mechanism for generating and disseminating information.

Environmental pollution clearly constitutes an externality. Moreover, in a setting where information is imperfect and held asymmetrically, the regulation of environmental externalities will inevitably become intertwined with problems of information. Health and safety decisions typically involve few direct externalities, although there can be important public good aspects. When public goods are important, basing private decisions regarding health and safety matters on an information set that reflects the shortcomings of private information markets may produce inefficient outcomes. Thus, externalities, public goods, and the shortcomings of private information markets which stem in large measure from the nonappropriability of information, provide a theoretical justification for health, safety, and environmental regulation (HSE).

In practice, however, economists have tended to emphasize the positive role of unfettered markets in attaining objectives such as efficient allocation and growth. By giving little attention to externalities and information, most economists implicitly assumed them to be unimportant, or at least of no more than second-order importance. After Pigou (1920), externalities were seen to pose no new theoretical issues; for example, Arrow (1983) characterizes externalities as simply a problem with incomplete markets. Few economists saw phenomena such as the devastating air pollution in Pittsburgh in 1948 and in London in 1952 as compelling attention. We assumed that the doctrine of caveat emptor would handle dangerous or defective products and polluted neighborhoods. Workers would select jobs and consumers would select housing with the preferred amount of risk, based on market generated wage and rent differentials that reflected safety and health risks (along with the other attributes of jobs and housing) [Oi (1974), Viscusi (1983b), Harrison and Rubinfeld (1978)].

The economic paradigm stresses making tradeoffs rather than meeting a lexicographic hierarchy of needs. An economic consumer would not strive for a totally pristine environment or products with no safety and health risks. As long as there are positive marginal costs in improving along these dimensions, utility

from other desirable goods and services would lead to choosing a somewhat polluted environment. Externalities and inefficiencies in private information markets may provide a theoretical basis for regulation, but there is no guarantee that a practical regulatory program will move society towards the Pareto frontier. We are acutely aware of the direct costs of government regulation as well as the potential evils of discretionary government actions that tend to reflect politics, individual wealth-seeking behavior, or merely arbitrary forces. This leads economists to demand large efficiency losses from externalities or information market failures before recommending government action.

In practice, the bias against intervention is reflected in such mundane matters as how GNP is measured [Nordhaus and Tobin (1972)]. A despoiled environment is not reflected in GNP and even occupational injury and disease is reflected only indirectly, if at all. The GNP measure is biased and glosses over issues such as the conditions under which economic growth is good. Since it fails to address the negative aspects of urban concentration and industrial growth, the economic paradigm directs the attention of policy-makers away from these issues, encouraging them to regard these concerns as largely illegitimate or irrelevant.

A series of public scandals led to the creation of the Food and Drug Administration in 1906 and the periodic amendments that have strengthened the law. Adulterated food and drugs were the initial target, although the FDA later was charged with ensuring that food and drugs were safe, and, in the modern era, that drugs were effective. The National Highway Transportation Safety Administration was created in 1966 to make highways safer; the Occupational Safety and Health Administration was created in 1969 to protect workers; the Environmental Protection Agency was initiated in 1970 to clean the environment; the Consumer Product Safety Commission was created to ensure the safety of all products [Lave (1980)].

1.2. An increased public demand for regulation

By the end of the Second World War, business leaders in Pittsburgh saw that pollution was choking economic activity and set out to curtail it. Organizations such as the Ford Foundation and Resources for the Future supported economic inquiry into these externalities that made notable contributions [Kneese and Bower (1972)]. Public values began to shift in the mid-1960s with an increase in concern for air and water quality, the environmental effects of pesticides, and highway safety. HSE problems were not getting markedly worse in the 1960s; indeed, there are some indicators of improvements in indices such as air pollution. Why, then, was there such an abrupt shift in public concerns? One explanation revolves around the superiority (income elasticity greater than one) of HSE attributes [Lave (1980)].

By the 1960s sustained economic growth had produced high incomes and most people had attained a reasonable standard of material welfare. A more receptive public was presented with new data on DDT concentrations in human tissues and milk, data on the effect of DDT on the ability of hawks to lay eggs, and fragmentary data on the road handling of Corvairs. Carson (1962) and Nader (1965) raised public awareness and catalyzed dissatisfaction. "Environmentalists" and "consumerists" used the fragmentary data to broaden the inquiry from DDT to all pesticides, to air and water quality, and to health problems more generally.

Earth Day 1969 demonstrated the extent of public concern. The public demanded that the federal government take charge of what they perceived to be important neglected problems. Over the course of a decade, Congress created several new regulatory agencies and enacted legislation that gave these agencies a central role for the first time in highway safety, safety of consumer products, controlling air and water pollution, and occupational safety and health.

The conditions of the 1960s led to more general concern for health and safety. For example, in 1962 Congress significantly strengthened the powers and broadened the authority of the Food and Drug Administration. The FDA not only was to determine if drugs were safe, it was to decide if drugs were effective in combating disease.

1.3. Regulatory reform

By 1980, economists and business leaders had affirmed that HSE regulation was costly, both in terms of the direct budget and the indirect costs imposed on the economy [Ruff (1978), Weidenbaum and deFina (1978), Environmental Protection Agency (1979), Denison (1979), Lave (1980)]. Since regulations were not designed with cost effectiveness and efficiency in mind, it is hardly surprising that they failed to meet these criteria. Studies also showed that the goals of the legislation had not been achieved. There were not "zero discharges into the waterways", air quality was not good enough to "protect the most sensitive group in the population with an ample margin of safety", and working men and women had not been "assure[d] insofar as practicable that no employee will suffer diminished health, functional capacity, or life expectancy as a result of his work". The problems were much more difficult than either the public or Congress had appreciated. The rhetoric of zero risk and a pristine environment had little mirror in reality. Neither the economic models nor practical wisdom had much to say about how to bring regulation under control while satisfying public desires.

Economic deregulation of the airlines, trucks, railroads, banks, and financial markets generally met with public approval [Bailey et al. (1985), Derthick and Quirk (1985), Joskow and Noll (1981), Robyn (1987)]. Surveys revealed that

people continued to desire improvements in health, safety, and the environment and were prepared to pay for them. Discontent with the federal agencies stemmed from frustration with their heavy-handed and inefficient manner of operation rather than from opposition to their goals. What was needed was not euthanasia for the HSE agencies, but rather regulatory reform that addressed the major problems.

1.4. A zoology of concerns

The material in this chapter is organized by issues, with difficulties and examples given in each section. We now list the issues and refer the reader to the section where each is discussed.

We begin by considering the *efficiency of implementation mechanisms*, the most inherently "economic" of the issues. Section 2 reviews the extensive pure and applied theory work on efficient and cost-effective regulation. The primary motivation for environmental regulation is the recognition that environmental quality is itself a public good. Mechanisms for handling environmental externalities in a perfect information context have received some attention. However, most of the recent pure and applied theory on efficient or cost-effective regulation focuses on information issues that are pervasive in the real world, such as uncertainty surrounding cost and benefit functions and incentives to reveal private knowledge. While information issues are prominent in environmental regulation models, they complicate a problem that would exist even in a perfect information setting. In contrast, health and safety regulation is driven primarily by the perception of information problems in private markets. In Section 2 we consider environmental regulation first, and then move to the literature on health and safety regulations.

Beginning in Section 3 we consider a host of economic issues surrounding actual regulation that arise outside of the context of the stylized regulatory models examined in Section 2. *Goal-setting*, the determination of how safe is safe enough, and how clean is clean enough, is a primary issue. Congress and the agencies have not given clear answers to these questions because there is no public consensus about answers. Having failed to answer the questions directly, Congress has retreated to seeking answers through defining the *process of deciding issues* (Subsection 3.3). For example, Congress requires agencies to publish information about what areas they are thinking of regulating, to publish preliminary regulations and then to hold hearings on them, and to publish final rules. Congress has given standing to virtually anyone to challenge the rules during the hearings process or in federal courts after they are finalized. The courts have reacted by examining not only whether agency actions followed due process and statutory authority, but also whether the actions seem reasonable

[Stewart (1975)]. The President (through executive order) requires agencies to do benefit–cost analyses of important rules and to explain why the most cost-effective solution was not proposed. The resulting process is extremely cumbersome, requiring large amounts of professional work and a great deal of time to issue a final rule. In virtually every case the rule is challenged in federal court, so that judges often become the final arbiters of what is in the public interest.

Goal-setting often involves the striking of a balance between *paternalism* (Subsection 3.2) and reliance on responsible individual judgment. Much of health and safety regulation is concerned with overriding private decisions in order to protect individuals from themselves. Paternalism poses difficulties both for goal-setting and for implementation. For goal-setting, it implies that we know better than an individual what is in his best interest [Lave (1987a)]. For implementation, as Prohibition demonstrated, it is hard in a generally free society to force large numbers of people to comply with a rule to which they object.

Another issue is *equity*: the allocation of risk and the cost of regulation (Subsection 3.1). Economists give short shrift to equity since it is subjective, controversial, and economic theory provides no unique insights. However, equity is the focus of politicians and of political decisions [Wilson (1980)]. The neglect of equity has left economists able to say little in normative or descriptive terms about regulations in practice. Political economists have begun to remedy this oversight by investigating voting behavior and the role of narrowly defined self-interest in political decisions [Downs (1957), Buchanan and Tullock (1975), Romer and Rosenthal (1984), Crandall (1983), Peltzman (1983), Pashigian (1985)].

The remainder of the chapter focuses on issues that arise in implementing regulatory programs. Section 4 deals with the quantification and valuation of benefits. Section 5 examines the discipline of the market and its feedbacks. In shaping proposals for efficient regulation, academic economists usually neglect *administrative simplicity* and *transparency*. Economists design policies to appeal to a philosopher-king (or rather an economist-king) rather than to a diverse constituency of voters, interest groups, and politicians. Yet, almost all people, except economists and some "Chicago" lawyers who believe in the free market more than most economists themselves, fail to see how economic incentives will call forth desired behavior as quickly and comprehensively as command-style regulation. Given the difficulty of overcoming public mistrust of economic approaches to regulation, a push for regulatory reform is attractive only if significant improvement over the status quo is possible (Subsection 5.1).

Regulation, in either present or improved form, also raises several issues beyond the scope of the inherently static models considered in Section 2. Among these are the impact of regulation on the investment and technology choices of firms in the regulated sector (Subsection 5.2) and its effect on the behavior of those whom it is designed to protect (Subsection 5.3). Since one industry or activity may be regulated under multiple programs, the problem of contradictory

regulation may also arise (Subsection 5.3). The distributional impact of regulation and its effect on the overall economy, considered in Subsections 5.5 and 5.6, are also central implementation issues.

Finally, there are also a host of *noneconomic issues*, or issues that are less explicitly economic (Section 6). For example, environmental impact statements, the development of the field of risk analysis, the gains and losses associated with regulatory due process, and judicial and administrative review have had profound effects on the economics of HSE regulation.

2. A gallery of externalities and information management approaches

2.1. Externalities

From an economist's perspective, consideration of the sufficient conditions for the optimality of competitive equilibria is a natural starting point for an examination of HSE issues. One of the great accomplishments of modern economics is specification of sufficient conditions under which a competitive equilibrium is Pareto optimal [see Arrow (1983), Stiglitz (1983)]. These sufficient conditions are not a good description of the U.S. economy. Monopoly power, information asymmetries, and externalities can each negate the optimality of competitive equilibrium. Both economic regulation (considered by Joskow and Noll in Chapter 27 in this Handbook) and HSE regulation may be viewed as attempts to correct market failures.

The importance of these deviations was recognized long before the sufficient conditions were demonstrated. Although monopoly has been an important part of economic theory from the beginning, fruitful models of externalities are of recent origin. In particular, Pigou (1920) described externalities and argued that they could be treated via taxes and subsidies. In contrast to Pigou, Coase (1960) gave prominent attention to the role of private negotiation as a means of achieving efficiency in situations involving externalities. In his view the essential role of government in externality problems is limited to providing a clear allocation of property rights to provide a basis for subsequent private negotiations. Negotiation has its place when there are few parties involved and complete information. The need for mechanisms with lower transactions costs for situations combining large numbers with imperfect and asymmetric information is readily apparent (e.g. a situation where the externality is a public good for a sizable group).

Consider a regime in which firms hold the right to generate sulfur dioxide pollution, a major cause of acid rain. An individual damaged by the impact of acid rain on his favorite mountain fishing lake might be unable to identify a

negotiating partner from the numerous and distantly located sources of the problem. Even where a negotiating partner could be identified, the free rider problem (among those who would benefit from a reduction in the externality level) sharply reduces the likelihood that potential Pareto improving deals between externality sources and victims will actually be consummated. Note that similar problems arise when victims hold the right not to be damaged, so that externality sources are liable.

Either direct negotiation or enforcement of victims' rights through the courts engender high transactions costs. When the courts hold firms liable for damages, firms can be expected to cut their externality output. However, because a liability scheme tries to compensate victims for actual damage sustained, it makes victims less anxious to forestall damages by undertaking efficient avoidance behavior.

Given the limited applicability of direct negotiation in all but a few externality problems and the informational economy of competitive market systems, it is natural to consider how other approaches, such as government intervention through the market mechanism, might be used to reach efficient outcomes.

2.2. Optimal regulation of environmental pollution

2.2.1. Full information regulation

Baumol and Oates (1975) present a Pigouvian taxes–subsidies approach to indicate how government might handle environmental externalities. They characterize the market equilibrium of a system that includes potential compensation payments to those impacted by externalities and a charge on the externality itself. They show that the first-order conditions characterizing the market solution can be made to coincide with those for Pareto optimality by pricing the externality at a rate equal to the sum of marginal damages across all victims while providing no damage-related compensation to those victims. The charges deter firms from generating externalities that can be eliminated at a marginal cost below the marginal damage imposed, while the absence of compensation ensures efficient damage avoidance by the victims.

Knowledge of both the victims' damage functions and the externality producers' cost functions is required to set the optimal Pigouvian tax. With this information in hand, the regulatory authority could directly limit each firm to the externality level it would choose under an optimal tax rather than impose the tax itself. Indeed, from the polluter's perspective, such command and control regulation would result in a more favorable income distribution than that achieved under optimal externality taxes.

2.2.2. Regulation with incomplete information

In a full information world, there is no efficiency basis for choosing among price-oriented, quantity-oriented or mixed regulation. However, regulators rarely have perfect knowledge. There are significant uncertainties in estimates of the dose–response functions that form the basis of the damage function. Firms generally have imperfect information about their abatement cost functions and may also have an incentive to misrepresent the information they do have in dealings with the regulator. A major strand in the literature has examined how imperfect or asymmetric information affects the choice of regulatory instruments.

The number of communication rounds and the complexity of the regulatory messages play an important role in the design of regulation when there is imperfect or asymmetric information. With an unlimited number of rounds, regulators might rely on a tatonnement process using either simple price or quantity regulation. Reactions to the policy settings at each stage might reveal information that could be used to adjust the settings. This would allow for eventual convergence to optimal regulation, assuming full adjustment of firms to the announced price. Alternatively, the regulator could issue contingency messages whose instructions would depend on the state of the world (say, the control costs for various pollution sources) actually realized.

Neither multiple iterations nor contingent messages are observed features of extant regulatory programs. The absence of continual fine tuning may be due to the fact that firms often incur large and irreversible fixed costs in responding to a particular level of regulation. An electric utility may build either a dry or wet sulfur dioxide scrubber depending on the tax or standard adopted, but cannot convert one type into the other as regulation changes. Also, because fixed investment is involved, a considerable interval of time must often pass before the impact of the initial regulatory settings is revealed.

Fixed costs that must be incurred before the state of the world is fully realized are also a problem for state-contingent regulatory schemes. Also, the states on which regulation must be conditioned represent the control cost functions for the externality producing firms, which may never be revealed to the regulatory authority. Finally, in a multifirm setting, state-contingent regulation would directly tie the regulation of each firm to the entire set of cost realizations.

Following regulatory practice, most attention has focused on the practice of having regulators request information from regulatees before they set standards (or fees). Some models envision more than one round of such information requests, and all need to ask whether regulatees are motivated to gather and provide complete, accurate information. The focus has been on models where communication is restricted to one or two rounds and the regulator can issue a rule with only a simple message specifying a price (externality tax), a quantity (a

standard), or some mixture. Weitzman (1974, 1978) and Roberts and Spence (1976) treat the one-round case in which the center transmits a single message or set of messages to the regulated population. Kwerel (1977) considers the two-round case in which the firms send information to the center which uses it as an input in formulating its own regulatory message. Dasgupta, Hammond and Maskin (1980) consider both one- and two-round communication. The results obtained in this literature are outlined below.

2.2.3. *Prices versus quantities*

With one-round communication and noncontingent messages the regulator is generally incapable of attaining a Pareto efficient outcome. Instead, he seeks to minimize the expected deviation from efficiency. In Weitzman (1974) the marginal control cost function of the single firm producing an externality is not known to the regulator, who is limited to the choice between a pure tax or a pure standards approach. Figure 26.1 illustrates the case where the regulators' uncertainty relates to the location of a linear marginal cost function. Assuming that the marginal cost uncertainty is symmetric around MC_E, p_E is the best tax, and q_E is the best standard. However, neither p_E nor q_E is efficient when realized marginal costs differs from MC_E. If marginal costs are high (MC_H), a tax of p_E provides less than the efficient level of externality abatement (q_H vs. q_H^*) while a standard of q_E provides too much. However, if costs are low (MC_L) a tax of p_E results in excessive externality removal (q_L vs. q_L^*), while a standard of q_E provides too little removal. From Figure 26.1, it is apparent that standards will yield smaller expected deviations from efficiency than taxes when marginal benefits have a steeper slope than marginal costs and that taxes minimize expected deviations from efficiency when the reverse is true. Intuitively, when the marginal benefits function is steep, the socially optimal level of externalities is relatively insensitive to cost conditions and the welfare losses associated with departures from the optimal level are large, favoring a standards approach over a tax approach which, with a relatively flat marginal cost function, could result in large deviations from the optimal externality level if either high or low marginal costs are realized.

Laffont (1977) emphasizes the distinction between information gaps between the regulated firm and the regulator and genuine uncertainty, with only the former having relevance to the choice of regulatory instruments. In addition to the cost-side information gap considered by Weitzman, Laffont allows for those affected by externalities as well as those who generate them to have information unavailable to the regulator. In this context, a third regulatory option of setting a price for consumers and subsequently transmitting their quantity choice to the producers is considered along with Weitzman's taxes and direct quantity standards. In a structure with information gaps on both sides, he finds that direct

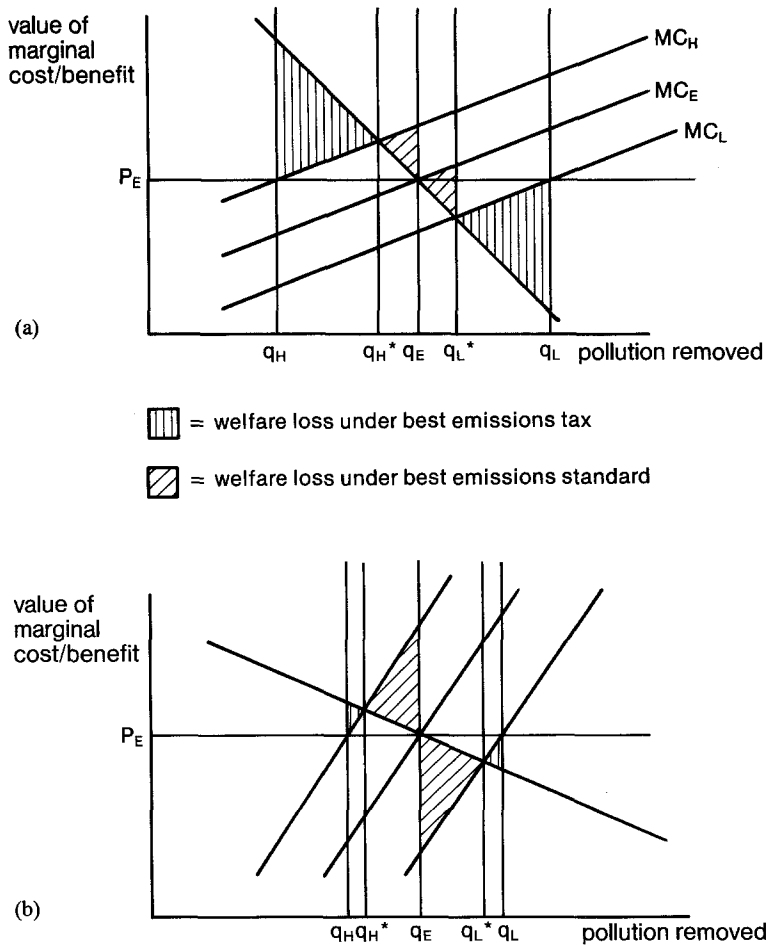

Figure 26.1. Prices versus quantities, (a) standard preferred to tax; (b) tax preferred to standard.

specification of quantities is always dominated by one of the two pricing modes. However, he also shows that in a more general framework where the slopes as well as locations of the marginal cost and benefit functions are subject to information gaps, direct quantity regulation can dominate both pricing alternatives.

In a pollution externality context, there are likely to be a large number of firms simultaneously subject to regulation. With many firms, a tax system, even if it results in a socially inefficient aggregate externality level, has the desirable property that marginal costs of abatement are equalized across firms. A quantity

scheme that sets individual standards for each firm does not have this desirable property. However, the issuance of transferable property rights provides an alternative specification for a quantity scheme that does retain this feature, relying on a competitive market to allocate the permits in a manner that minimizes the cost of reaching the specified aggregate target. The choice between a tax scheme and marketable permits would still depend on the factors identified in Weitzman's single-firm analysis. Since marketable permits are at the implementation frontier we will consider them in some detail below.

Weitzman (1978) derives the best one-round policy in a multi-firm setting with quadratic cost and benefit functions. This policy incorporates both price and quantity components whose relative weight depend on the relative slopes of the marginal cost and benefit functions, the interdependence of the cost uncertainties across the regulated firms, and the degree of substitutability between the externality outputs of the different regulated firms in the social benefit function.

The relationship between the weight on the quantity term and the slopes of the marginal cost and benefit functions follows his 1974 article. Ceteris paribus, high positive correlation among the cost realization across firms favors an increased weight on the quantity component, since all firms are likely to err in the same direction in response to price signals. In a pollution externality context, one might expect control costs to have a strong positive correlation across sources. A high degree of substitutability in the benefit function between the (externality) outputs of different regulated firms tends to favor price regulation by increasing the focus on aggregate output rather than its components. The degree of substitutability across sources will vary with the specific application. For global or regional pollutants, such as fluorocarbons or acid rain precursors, externalities from a large set of firms may be nearly perfect substitutes. With local pollutants, an increase in externality output at one location coupled with an offsetting reduction elsewhere may lead to large swings in realized benefits.

Weitzman's policy is one example of a general result due to Dasgupta, Hammond and Maskin (1980). They find that the best policy with one-round communication presents each regulated firm with a nonlinear tax function that renders its objective (profit) function identical to the expected social welfare function. Such tax schemes are implementations of the public choice revelation mechanisms of Groves (1973), Clarke (1971), and Vickrey (1960).

Mendelsohn (1984) adds endogenous technical change to the basic Weitzman (1974) model. Technical change compounds the variability of externality abatement outcomes under price regulation. When marginal costs are low, so that abatement overshoots the socially optimal level under price regulation, firms overinvest in cost-reducing technical change, because the returns to technical investment depend on the volume of abatement to which it can be applied. By lowering the cost of abatement, technical progress increases the margin of overshooting. Conversely, when price regulation leads to undershooting the social

optimum there is a tendency to reduce investment in technical change, compounding the undershooting. In sum, the extra degree of freedom in a model with endogenous technical change is used in a socially undesirable manner under price regulation. In contrast, quantity regulation which holds the level of abatement constant results in a stable technical investment decision regardless of the realization of the underlying cost uncertainty.

2.2.4. Revealing regulation

Even though the best one-round policy leads each of the regulated firms to pursue the social objective, the full information social optimum will not be attained because the cost expectations for the entire set of firms on which the tax function for each of them is based differ from the actual cost realizations.

With two-round communication, the regulator can close the information gap by seeking cost information from the firms prior to imposing regulation. If firms can be induced to report truthfully, the regulator can reach the ex post optimum by using the true cost reports rather than expected costs as the basis for regulation. Since the regulator never observes true costs, each firm will provide a cost report that minimizes its total cost of regulation under the regulatory scheme it anticipates will be applied. Pure price or quantity regulation will not induce truthful reporting. If firms anticipate that the center will set an externality tax on the basis of the cost reports, they have an incentive to underestimate costs, so that a low tax is set. If firms anticipate the center will regulate through a quantity target, they will overstate costs to secure a high target. However, if regulators commit themselves to the policy outlined in Weitzman (1978) or Dasgupta, Hammond and Maskin (1980), so that each firm faces the social objective plus or minus a lump-sum payment, truthful revelation will be a dominant strategy. The only difference from the one-round case is that the first best can actually be attained. Such mechanisms have not, to our knowledge, been employed in any public choice or externality context, and it is unclear whether such systems are implementable given the sheer complexity of their administration and the budget balance and equity issues inherent in tailoring a revealing tax for each polluter.

An alternative mechanism in which truth-telling is a Nash equilibrium, but not dominant, strategy, has been proposed by Kwerel (1977). Based on the cost reports of the firms, C, and its own estimate of the damage function, D, the regulator determines the pollution level at which the marginal reported cost of pollution abatement and its own estimate of the marginal benefit of pollution abatement are equal and sets the number of pollution licenses at this level. The licenses are traded competitively among firms with each being required to hold licenses sufficient to cover their actual pollution levels. For licenses held in excess of actual pollution, the regulator pays a subsidy equal to its estimate of the marginal benefit of abatement given full utilization of the license stock it has

issued. Thus, if L licenses are issued the market price of licenses will be $\max[D'(L), C'(L)]$, with the first term reflecting the subsidy rate to holders of excess licenses and the second term reflecting the value of abatement cost avoidance to the regulated firms. If $D''(L) > 0$ and $C''(L) < 0$, so that the marginal benefit of abatement rises and the marginal cost of abatement falls as the aggregate allowable pollution level is increased, the price of licenses is minimized by issuing a quantity of licenses, L^*, equal to the Pareto optimal pollution level based on the cost reports made to the regulator. If the initial distribution of licenses does not depend on reported costs, so that cost reports do not have income effects, the sum of abatement and license costs is minimized when the license price is minimized. Therefore, truth-telling is a Nash equilibrium strategy for firms seeking to minimize their total cost of regulation.

2.3. *Cost effectiveness*

The foregoing discussion is framed in terms of attaining Pareto optimality or of minimizing expected deviations from optimality at a fairly high level of abstraction. Regulatory practice raises separate issues that are not considered in these frameworks. Rather than pursue optimality, the issue is whether we can improve current practice taking into account the political, informational, and institutional constraints present in applied problems. Perhaps the most glaring feature in regulatory practice is the wide divergence of opinion as to the benefits of externality control. When health effects are at issue, the chemical, spatial, and temporal relationships between primary emissions and pollutants may be poorly understood. The dose–response relationship between pollution and health effects, especially where chronic diseases with long latency periods are involved, is also subject to considerable uncertainty [Morgan et al. (1984)]. Finally, even if consensus estimates of the magnitude of mortality and morbidity effects could be attained, their valuation is fraught with controversy. The valuation of aesthetic, vegetation, and materials benefits are also highly controversial, calling into question the notion of a generally accepted benefit function, perhaps surrounded by some uncertainty, that is implicit in discussions focused on the goal of Pareto optimality. Efficiency may be a natural objective in a world where distributional concerns can always be handled through lump-sum taxation. In reality, redistribution is difficult and expensive and so the distributional effects of a program matter a great deal.

Thus, regulatory targets are usually set through the political process, not through the use of some grand optimization calculus. While the political debate can be improved by attempts at calculating social optima, perhaps a greater contribution can be made by taking the politically set objectives as given and

devising a cost-minimizing approach to reaching them, thereby pursuing the goal of cost effectiveness rather than optimality.

Montgomery (1972), following earlier work by Dales (1968), evaluates the role of tradable permits as a means of attaining cost-effective externality abatement. An objective defined in terms of the pollution level measured at a set of monitoring points can be attained at least cost through the competitive trading of pollution licenses among firms whose emissions cause pollution. This least-cost property is independent of the initial allocation of pollution licenses. However, since an individual firm would need to hold licenses for each receptor where its emissions contributed to measured pollution, an important prerequisite for such a system would be a set of commonly accepted dispersion and conversion models that could be used to make the translation from emissions at the plant site to environmental impacts at the receptor sites. Our knowledge of conversion processes varies widely across pollutants. Dispersion is inherently uncertain. The density of the monitoring site network, the importance of long-range transport for the pollutant in question and the cutoff point used for determining de minimis effects would together determine the number of markets in which each emitter would be required to hold licenses.

In contrast to pollution licenses, emission licenses confer a right to emit pollutants. Under an emission license scheme, there is one market for the emissions of each pollutant or pollution precursor. However, one-for-one trading of emissions licenses raises the problem of "hotspots" if emissions become concentrated at certain locations within the relevant airshed or watershed. To avoid hotspots, the regulator must set trading terms for each possible transaction such that no trade results in an increase in measured pollution at any receptor point. Provided that the hotspot problem is avoided, emission licenses appear to provide a simpler mechanism than pollution licenses, since there is no need to hold licenses for each individual receptor site. The cost of this simplicity may be a loss in cost effectiveness: in contrast to the pollution license scheme, competitive markets do not yield cost-effective attainment of the pollution targets. The problem is lumpiness, since avoiding hotspots at one location may require trading terms in the emissions license market that cause the target to be exceeded at other locations. In a pollution license scheme this "excess" attainment could be sold to some other polluter; in the emissions license context it is wasted.

While theoretical models of tradable permits have generally assumed perfectly competitive behavior in permit markets, a small number of large sources are responsible for a large share of some pollution externalities that have attracted regulatory attention. For this reason, individual firms may hold market power in tradable permit markets, especially where the pollutant being regulated has relatively localized effects. Hahn (1984) presents an analysis in which permit trading results in cost-effective abatement under perfect competition but fails to do so when there is a strategic player in the permit market unless the regulator

endows the strategic player with precisely the efficient number of permits before trading opens. Of course, if the regulator knew the efficient allocation of emissions ex ante, there is no need to allow for trades at all. Deviations in either direction from this correct initial allocation will increase the total cost of attaining the target. To minimize the adverse impact of market power on efficiency, Hahn and Noll (1982) propose a zero revenue auction scheme that puts all firms on the same side of the market in the initial market period, but avoids imposing costs on them as a group by reallocating revenues from the initial permit auction according to a fixed rule to avoid income effects.

2.4. Modeling health and safety regulation

This subsection aims to examine the underlying economic basis for safety and health regulation. Several features of occupational choice and consumer product decisions dictate an analysis distinct from that applicable to environmental regulation. Unlike environmental quality, health and safety are not in themselves inherently public goods, so there is no prima facie case that the pre-regulation outcomes place too low a weight on these attributes (exceptions are dams, nuclear power plants, etc. where risk is inherently spread over many people). With heterogeneous preferences and income levels, the set of activities and outputs arising from the decisions of utility-maximizing consumers and profit-maximizing firms could be expected to embody significant variation in achieved health and safety levels.

Another difference from environmental regulation arises in the role of private legal action as a substitute or complement to regulation. Stewart and Krier (1978) note that private lawsuits against polluters have not had widespread impact on polluters' behavior. In health and safety matters, where the relevant parties and the extent of damages can be more readily identified, private litigation plays a significant role, and the potential for litigation may lead parties to alter their behavior. The role of the litigation system and the allocation of rights between the consumer/worker and the producer/employer are considered in Subsection 2.4.1.

A final difference from environmental regulation arises from the greater involvement of individual consumers or workers in the realization of safe or healthful outcomes. It is not enough for firms to offer appropriate products and working environments – consumers and workers should also take an appropriate level of "care" in their activities. Because of the need for care, health and safety regulation raises the question of moral hazard if regulation induces consumers and workers to react to regulation by behaving in a riskier fashion [Evans and Schwing (1985)].

What rationale (aside from paternalism as described below) is available for substituting the judgment of the regulator for that of the individual agents? Two

broad types of market failures form the basis of the argument for intervention. First, since even in a world with efficient information markets, individual agents do not bear the full costs of adverse health and safety impacts, they will undertake an excess amount of unsafe and unhealthful activities in the absence of regulation. Second, the nature of information as a commodity suggests information markets are likely to fail in the absence of government intervention. The demonstration of information market failure alone may justify interventions that provide information directly or force private agents to do so. However, the case for direct regulation of product characteristics as a useful response does not follow from the mere demonstration of informational failure. Consumer heterogeneity and the risks of paternalism weigh heavily against this approach. Despite this, OSHA and CPSC focus almost exclusively on product characteristic regulation. The literature on information is reviewed in Subsection 2.4.2.

2.4.1. Accidents, litigation, and regulation

The goal of consumer product and occupational health and safety regulation is to reduce the occurrence and severity of accidents, a term defined broadly to include unintended harmful effects resulting from exposure to or use of a product as well as product failure. The division of the costs of accidents between the parties involved, and between those parties and society at large, can influence the decisions and behavior surrounding activities that have the potential for resulting in an accident. (Such activities may be called risky.) Two types of decisions are relevant: the decision to engage in a particular activity and the level of care exercised in an activity. Regulation provides an ex ante method of affecting these decisions, while litigation is an ex post tool. From an economic perspective, the primary issue is whether the litigation system provides workers and employers with the proper incentive to engage only in risky activities whose value is sufficiently great to offset the harm they may cause. To the parties involved, the matter of income distribution, not efficiency, appears to be of pre-eminent importance.

Oi (1973) considers the market for products with a positive failure probability to determine the impact of liability allocation across producers and consumers on decisions in an environment where the size of the loss associated with product failure varies across consumers. When they are liable, each consumer's choice among products offering different combinations of price and reliability reflects his information regarding the size of the loss incurred in the event of failure. When they are liable, producers are required to indemnify actual losses in the event of failure, so that the size of losses in the event of failure do not affect consumer decisions. Unless they are allowed to discriminate among consumers, the shift to producer liability forces producers to offer a package of product plus full insurance and affects the market allocation. Although the Coase theorem would hold with symmetric discrimination possibilities across alternative liability

regimes, it does not hold given ordinary barriers to producer discrimination. Oi's demonstration that the adoption of producer liability can actually force reliable products out of the market belies the notion that producer liability necessarily promotes healthier or safer market outcomes.

In Oi's model, as in Shavell (1982) (who considers how insurance affects producer incentives to make socially appropriate expenditures on risk reduction), the consumer/worker and the producer/employer are both perfectly informed regarding the risks inherent in the product or activity. Furthermore, should an accident or product failure occur, it is unerringly associated with one product or activity. Yet, in many risky situations the causation of harm (accidents) is beset with uncertainty. Cancers occur naturally, but may also be induced by personal behavior (smoking and diet) and occupational exposure to carcinogens. The claim of a smoker with a family history of cancer against an asbestos manufacturer for lung cancer presents a classic case of uncertain causation.

Court suits for liability tend to have an all-or-nothing character. The plaintiff must prove by a preponderance of the evidence that his disease was caused by the defendant. When this is done, he is entitled to receive full compensation (some states use contributory negligence to make awards proportional to contribution). Unfortunately, this is too simple a model. Smoking and asbestos exposure are multiplicative factors in causing lung cancer. For an asbestos insulator who smokes, what is the cause of the lung cancer? Precisely this issue has been addressed in asbestos suits with the courts having a difficult time deciding what was responsible for the lung cancer. The same situation has arisen for men who received direct exposure to ionizing radiation during military testing in the 1940s and 1950s. Radiation is known to cause cancer. However, are the cancers that have appeared in some of these men thirty years after exposure due to the radiation or to other factors?

Congress ordered the National Cancer Institute to figure out the proportional risks for various kinds of cancers: How much of a contribution was made by exposure to radiation during the atomic bomb tests and how much by subsequent exposures, such as smoking, occupational exposures, and heredity? Rall et al. (1985) used the substantial knowledge about the effects of ionizing radiation to come up with just such a model. Lagakos and Mosteller (1986) describe the model and respond to several critics. A similar approach has now been taken for asbestos [Chase et al. (1985)]. There are substantial questions about whether this approach can be used in the current legal system and whether either experts or juries would find it appealing.

The impact of the legal system on behavior depends on its features. Shavell (1985) considers a situation in which activities generate benefits and possibly losses that can both be measured in monetary terms. Under a strict liability standard, parties are held liable for accident losses they cause whether or not they exercised care. If there is no uncertainty as to the causation of accidents, agents

will undertake only those activities whose benefits exceed expected accident losses. Such behavior will maximize the expected value of the activities in question, which is the desired outcome if society is risk neutral. Under a negligence rule, agents cannot be held liable unless they fail to exercise care in a situation where care "should" have been exercised. (The desirability of care-taking can be determined through a criterion that compares the cost of care to the resulting reduction in expected loss.) In this system, agents can protect themselves from liability simply by taking care, even if the costs of care-taking plus expected losses exceed the benefits of the activity in question. Thus, the negligence system fails to promote decisions that favor only those activities with positive expected net benefits.

If there is uncertainty over causation, a situation that arises in many cases of interest, behavior depends on the legal regime (strict liability or negligence), the rule used to resolve the uncertainty, and on the portion of the loss that is paid by the parties that may have caused the accident. Under strict liability, a more likely than not rule (a common criterion for liability) attempts to determine if the probability that an observed accident results from a particular risky activity exceeds a threshold level (often 1/2). If the threshold is exceeded, the party undertaking the activity is held liable for the entire loss. Application of this rule can result in a risky activity being pursued at a level that is either too low or too high depending on whether its probability of causation falls below or above that necessary to trigger liability. Under negligence, where taking care makes a party judgment proof, there may be either too much or too little care taken, with the outcome again depending on the relationship between the triggers and the levels.

A proportional liability standard is shown to induce the correct level of risk-taking and care. Proportional liability is usually developed in the terms of liability-splitting among parties known to be the potential source of damages suffered by the plaintiff, so that, if occupational exposure is thought to cause 20 percent of cancers in a particular category of employees, the employer would be held liable for 20 percent of the resultant damages. *Sindell vs. Abbott*, a recent case involving DES, divided damages to a cancer victim whose mother had taken an unidentified brand of the synthetic cancer-causing hormone among the multiple suppliers in proportion to their market shares, even though none of the suppliers could be held liable under a more-likely-than-not test and only one of them was the actual source of the drug.

Shavell (1984) considers the choice between litigation, regulation, and a mix of the two. In a model where litigation always leads to a "correct" verdict in which the injurer will be held liable for the actual amount of harm caused (no punitive damages), he considers whether parties will undertake optimal expenditures on care. The answer is no for two reasons. First, the injured party may not undertake litigation, especially under American practice where each side is responsible for its own costs in civil litigation regardless of the ultimate verdict.

Second, the potential injurer recognizes that he is "judgment proof" beyond the level of his wealth and insurance coverage, so does not take potential liability in excess of wealth into account in choosing his behavior.

The regulatory alternative involves setting a standard that is the same for all parties engaged in the activity, even though the risk of harm varies across parties. The optimal standard equals the level of care that is first best for a party that poses an average risk of harm. The choice between standards and liability hinges on the same factors that arise in Weitzman's prices and quantities framework. In particular, the more dispersed the potential for harm across parties the less attractive is a uniform standard. Conversely, the more important the wealth constraint as a barrier to recovery, the less attractive is a pure liability system. Shavell finds that a mixed system of liability and standards is at least weakly superior in inducing desirable care patterns to either the pure liability or pure standards approach. In fact, regulatory programs do not foreclose the possibility of private lawsuits, so that parties with a high potential for causing harm have an incentive to exceed the applicable standards.

The real-world litigation system does not always produce correct verdicts, and sometimes provides punitive damages. For this reason it is possible that the pursuit of health and safety issues in the courts alone may result in outcomes that are excessively safe from a welfare perspective. A *New England Journal of Medicine* editorial defined a litogen as a chemical which does not harm health but does lead to lawsuits regarding harm. Several recent actions, such as the withdrawal of contraceptive foams and the anti-nausea drug Bendectin from the market despite the lack of scientific evidence of health or safety problems, and the threatened withdrawal of whooping cough vaccine suggest that in some cases regulation may be needed to temper, rather than supplement, the tort system.

In Shavell's models, the only concern is the cost of the accident itself. Calabresi (1970) posits a more general framework that considers secondary and tertiary costs as well as the primary cost examined by Shavell. The secondary cost concept recognizes that the welfare impact of a given accident will depend on the extent to which accident costs are spread and in some cases on the timing of the mechanism for making accident-related transfers. Thus, one advantage of no-fault schemes is that they allow for the immediate financing of therapeutic measures that may lessen the permanent disability resulting from a given accident injury. Spreading also tends to reduce the secondary costs of accidents, which is one explanation for insurance. However, spreading may attenuate incentives to take care by externalizing the cost of accidents, so that secondary and primary cost avoidance may be in conflict. Tertiary costs arise from the administration of the system for allocating accident costs. The high level of tertiary costs associated with litigation to determine fault in accidents was another prime motivation for the adoption of no-fault systems. Generally, any comparison between regulation and liability as alternative paths to desirable levels of health and safety practice must consider the role of administrative cost.

2.4.2. The market for information

In environmental regulation information considerations add complexity to a market failure that would exist without them. In health and safety regulation information *is* the problem. Information is a "commodity" useful in making product or occupational choice decisions. Many authors have noted that this commodity has features that thwart the operation of efficient markets. First, information is a public good in the sense that the seller cannot appropriate the value of his product. Indeed, each buyer of information instantly becomes a competitor who can provide the product to other potential buyers. For this reason, the seller often cannot anticipate a volume of sales sufficient to justify the cost of gathering information in the first place. Second, even if dissemination among potential buyers can be controlled (say they are geographically dispersed), information is a natural monopoly. Information will likely be sold at a price far in excess of the near-zero marginal cost of dissemination. Third, in many contexts, information about specific products is produced jointly with the products themselves, so that the product supplier is the least-cost source of product information. Yet, product suppliers may not be credible sources of information given the incentive to provide only favorable data to buyers in the product market. Imperfect information also underlies the phenomenon of moral hazard, since due care can be enforced only if worker/consumer behavior can be perfectly monitored.

It is important to distinguish inherent uncertainty that is correctly perceived by all market participants from a situation involving misperceptions. Akerlof (1970) provides examples in which correctly perceived uncertainty disrupts the operation of economically useful markets. The problem of adverse selection is illustrated in the market for automobiles, where the consumers' inability to distinguish "lemons" from good cars drives good cars out of the used-car market. Counteracting institutions, such as warranties and reputations, can provide signals of quality that can help overcome the problem of uncertain quality.

Spence (1977) develops a model where homogeneous consumers, who may be risk neutral or risk averse, misperceive product quality. After characterizing the socially optimal quality level and risk allocation, he finds that ordinary producer liability cannot be employed to reach the optimum. The addition of a second instrument, in the form of a fine payable to the state in addition to the liability payment to consumers, can be used to reach the optimum. However, the optimal fine depends on the sensitivity of consumer perceptions of quality to changes in actual quality, which may be difficult to assess. With heterogeneous consumers, it is even more difficult to reach the optimum, which can involve the production of multiple qualities that should be consumed by specific groups of consumers. There is also the problem of moral hazard if consumers who are insured by producers can affect the probability of product failure. Alternative approaches that do not require the regulator to perceive consumer perceptions, such as direct

regulation and the provision of official product quality information to consumers, also have shortcomings in realistic settings. Spence's results highlight the near impossibility of reaching an optimum through regulation in a setting where misperceptions play an important role.

Shapiro (1982) looks at the quality choice of a profit-maximizing firm in a dynamic setting involving consumer misperceptions. If a product is purchased frequently and consumers can experience product quality, firms weigh the current cost savings associated with low quality against the adverse effect of a poor reputation on future sales and profitability. The faster consumers update their perceptions, the more closely the quality level offered by profit-maximizing producers approaches the perfect information limit. Informational regulation may be interpreted as an effort to facilitate the learning process. However, the welfare implications of imperfect information, and efforts to redress it, are unclear because imperfect information may occur in tandem with other market failures. For example, if producers with market power set product prices above marginal cost, a social surplus objective may be served when consumers overestimate product quality, which leads them to buy more at the going price than they would if perfectly informed (an example of the theory of the second best). Shapiro also considers the case where firms can adjust quality over time, and shows that firms may choose to either improve quality monotonically towards the perfect information limit or to oscillate quality in cycles of building and milking a reputation.

3. Goal-setting

3.1. Social goals

A significant advantage of the market as a mechanism for allocating goods is that each consumer can take account of his preferences and income level when choosing how much of each good to consume. Individually, we may be unable to "understand" why anyone would choose to buy some of the goods and services offered, but we are not directly affected by the choices. At the opposite end of the spectrum, a family situation where the tastes of one or two adults are imposed on children poses a sharp contrast to the market model. The unfortunate consequences of continuing to attempt to impose parental tastes on older children and adolescents are all too familiar. Any system that increases individual choice for responsible adults has important advantages. When the Food and Drug Administration first banned cyclamates and then saccharin, the public outcry forced Congress to rescind the ban in favor of labeling and individual choice.

Unfortunately, when public or quasi-public goods are considered, decisions made by individuals on the basis of their private incentives do not add up to a

beneficial social decision; individuals must agree on the provision of these goods, even when they are not provided uniformly. For example, air quality is uniform over a neighborhood, but some neighborhoods are much more polluted than others. Air quality cannot be tailored to the preferences of each individual, but instead must reflect the tastes of all who either experience the air pollution or who cause it. In this situation, goal-setting must be collective and there is the problem of defining some sort of social utility function (or its equivalent). Having a small number of actors may not expedite solution because of the issues associated with bargaining.

3.1.1. Setting risk goals

One area of particular controversy involves setting risk goals. Douglas and Wildavsky (1982) show that what is perceived to be risky and what is an acceptable risk are largely determined by culture. While this observation helps to put the current difficulties into perspective, it does not help to manage risks within our culture [Fischhoff et al. (1981)]. Extreme and conflicting views such as Perrow's (1984) position that our technology has increased the potential for disaster, the U.S. Council on Environmental Quality (1980) finding that the Earth's resources were being used up quickly, or Simon and Kahn's (1984) conclusion that the world is getting richer, less risky, and generally better, promote the suspicion that investigators' biases play an important role in many analyses.

Congress's position (in 1958 and the early 1970s) seemed to be that no risk was tolerable [Lave (1981b)]. In this mood it instructed the Food and Drug Administration that "no substance shown to cause cancer in animals or humans could be added to food" (the Delaney Clause). Congress directed the Environmental Protection Agency to set primary air quality standards that "protected the most sensitive group in the population with an ample margin of safety". The Occupational Safety and Health Administration was instructed to "assure insofar as practicable that no employee will suffer diminished health, functional capacity, or life expectancy as a result of his work".

These zero-risk goals have proven dysfunctional to the agencies, since they cannot reduce most risks to zero and are left without a sensible basis for setting priorities. Left to their own devices, several agencies have gone through goal-setting processes. The Food and Drug Administration (1982) decided that a food contaminant estimated to lead to less than one additional cancer per million lifetimes constitutes a de minimis risk and would not be considered a carcinogen under the Delaney Clause. The Federal Aviation Administration (1980) has implicitly set safety goals by adopting a value (approximately $500 000) for the social benefit of preventing a premature fatality. It uses this value in benefit–cost analysis. The Nuclear Regulatory Commission (1983) has gone through an

explicit goal-setting process for commercial nuclear power plants and has set goals. It decided that nuclear power plants should not increase the risk of either immediate death or cancer by more than 0.1 percent (one part in 1000) over the levels prevailing without the plant; it also bounded the likelihood of a core melt, even if such a mishap would cause no injury to the surrounding population.

Most agencies have avoided dealing explicitly with goal-setting, but have not attempted to regulate risks to zero. Almost inevitably, this means that agencies are sued because the regulations they set are not sufficiently protective. In deciding a challenge to OSHA tightening the exposure standard for benzene, the Supreme Court (1980) used a common law doctrine that the "law does not concern itself with trivia" to assert that agencies cannot regulate a de minimis risk. Apparently, the hope was that there would be some general agreement on what constitutes a trivial risk so that agencies could avoid cases where the risk is already trivial and use this as an upper bound for a risk goal.

Unfortunately, defining what is a trivial risk has proved to be no easier than defining a risk goal. Perhaps the most helpful research has been an examination of past federal agencies' decisions, with an attempt to draw a common pattern out of decisions [Milvy (1986), Byrd and Lave (1987), Travis et al. (1987)]. This "common law" approach to inferring risk goals may eventually arrive at helpful generalizations, but there is still a good deal of noise in current decisions.

3.1.2. The political economy of regulation

Most of the early HSE legislation was formulated with a "polluter must pay" principle; it seemed naive, however, to assume that the public would not bear the cost. Measuring even the first round incidence of HSE policies is difficult. Some calculations are shown below in Section 5.

The formulation of HSE goals is supposed to be the task of our elected representatives in Congress and state legislatures. Setting such goals is controversial and, since representatives like to be re-elected, they rarely face the issues and give helpful guidance. In some cases Congress has provided only the most general rhetoric; in other cases, Congress has set specific standards and time tables. Only in rare cases does Congress actually specify goals that would serve to guide a regulatory agency which is supposed to be implementing policy set by Congress. The language of social and economic regulatory statutes, and representatives of the agencies charged with carrying them out, frequently invoke the public interest as the basis for regulation. However, the number of passionate advocates of regulation is not consistent with the diffuse distribution of its public benefits. An explanation is needed of how the political support necessary to implement and maintain programs of regulation is generated.

Stigler (1971) and Peltzman (1975) argue that regulation is actually promoted by interest groups seeking private benefits, and that administering agencies are

captured by private interests, whom they serve in return for support in the political arena. This capture theory is most directly applicable to economic regulation. The political economy literature is relevant to goal formulation in terms of who the agency actually serves, who controls the agenda, and the roles played by the courts and other actors. Peltzman (1983), Crandall (1983), and Pashigian (1985) have argued that concern for preserving jobs and other aspects of direct economic self-interest were major factors influencing Congressional votes on the Clean Air Act and other major pieces of environmental legislation. Ackerman and Hassler (1981) describe a coalition of eastern coal producers and environmentalists who put together the 1977 Clean Air Act Amendments so as to force continued use of eastern coal while taking steps to lower emissions in the west and eventually to lower emissions in the east.

Although social regulation is popularly perceived as placing an uncompensated burden on the entire regulated sector, it can yield significant rents to at least a portion of the industry being regulated. Maloney and McCormick (1982) present an event analysis of stock market returns for the cotton textiles and metal refining and smelting industries for periods in which they were subject to new regulations by OSHA and EPA. They attribute their finding of abnormal excess returns associated with regulation to the nonuniformity of its impact across firms. Worker health standards in the cotton textile industry were particularly costly for existing small firms and potential small entrants, providing a competitive edge to the large firms. In the metals refining and smelting industry, regulation blockaded entry, thereby reducing potential competition and raising the returns of existing facilities. Neumann and Nelson (1982), Pashigan (1984), and Bartel and Thomas (1985) also find that regulation imposes disproportionate costs on small or nonunionized firms to the benefit of their large or unionized competitors.

From the earliest stage, it was clear to Congress that HSE regulation would impose major costs and disruptions on the economy. This led to thinking about where to impose the (initial) burden. One general principle was to impose the greatest burden on yet-to-be-built plant and equipment, with mild or no burdens on existing plant and equipment. This "new source" bias has been shown to be inefficient, leading in some cases both to higher costs and to delays in the time required to achieve a given objective that depends on average rather than marginal performance [Gruenspecht (1982)]. It is also a natural source of rents for existing facilities in many contexts.

3.2. Paternalism revisited

Paternalism, not market failure, is the primary motivation behind much HSE regulation. While individuals demand safety, they generally demand less than others desire them to have, particularly for teenagers and young men [Winston and Mannering (1984)]. The installation and use of seat belts provides a clear

example. Recent analyses show that state mandatory belt-use laws have been effective both in increasing safety belt use and in reducing deaths and injuries [Latimer and Lave (1987)]. A benefit–cost analysis of safety belts assuming 100 percent usage shows they are extremely beneficial, while one at 10–15 percent use shows they are not worthwhile [Lave (1981a)]. The federal government has required that all new cars sold since the 1967 model be equipped with safety belts. There has never been a federal requirement that these safety belts be buckled, although about half the states have enacted such laws since 1984. By 1984, only about 10–15 percent of occupants were buckling their belts and so the effectiveness in practice of an extremely helpful device was negligible.

If there are economies of scale in installing safety belts or concern that people other than the first purchaser have their choices constrained by that person's decisions at the time of purchase (e.g. passengers or subsequent owners might not have the opportunity to wear safety belts), there might be justification for requiring that all cars be manufactured with belts. Beyond equipping the cars with belts, there are few externalities associated with individual use of these belts. To be sure, society pays for the medical costs of those who are injured and pays to support the dependents of someone who is killed, but these externalities could be handled via insurance [Lave (1987a)].

Paternalism is also clear in decisions that something beyond providing information to workers about risk is required to optimize occupational safety. The Occupational Safety and Health Administration has favored lowering the concentration of toxic chemicals around a worker, rather than permitting the worker to be protected by a personal protective device (since they fear workers usually will not wear such devices); the agency favors requiring worker training, even though workers know they are in hazardous situations and need information. Indeed, few people other than economists and libertarians seem to regard it as even questionable that governments would not act to regulate large risks rather than provide workers with information.

3.3. Defining social goals through process

The more than 200 million Americans, millions of businesses, and the multiple roles of people as consumers, workers (employed in jobs from heavy manufacturing to personal services), and citizens combine with the cultural diversity of the United States to ensure that no consensus can be reached on nonvacuous HSE goals. Congress has tended to fill the preambles of HSE legislation with rhetoric that reflects wishes rather than goals. In practice, Congress has legislated administrative procedures and decision frameworks, rather than clearly stated goals. By requiring that agencies inform the public that they intend to consider an area,

hold public hearing on proposals, and specify the basis for their decisions, Congress has ensured that decisions reflect the many views in society. However, such complicated procedures eliminate the possibility of quick, simple regulations. By requiring that agencies listen to a broad spectrum of concern and be responsive to it, Congress implicitly asks agencies to make compromises. The Administrative Procedures Act makes it clear that agencies are serving a political function, not just making narrow technical decisions.

In many cases, Congress has directed regulatory agencies to give little or no attention to the costs of abatement. For example, the Clean Air Act precludes examination of the cost implications of achieving the primary air quality standards. Some acts permit indirect consideration of abatement costs by mandating that regulations must be "practicable." In other situations, Congress specifies that agencies find the best available control technology. Occasionally, Congress or the President have required that decision alternatives be scrutinized via benefit–cost analysis.

Implicit in these decision frameworks is Congressional goal-setting, since it constrains the nature of the resulting decisions. Lave (1981b) has set out a series of decision frameworks and identified the nature of the HSE goals implicit in each. Apparently, Congress finds it less controversial to specify a decision process than to specify a sharp goal.

A useful framework for examining HSE decisions recognizes the multiple goals and seeks to determine if all can be satisfied, or what proposals satisfy almost all goals. Four criteria for good policy discussed above are economic efficiency, equity, administrative simplicity, and transparency. These criteria refer to getting the marginal conditions for cost minimization correct, making sure that the proper people pay or receive the benefits, minimizing the level of resources required for administration, and ensuring that the route by which the program achieves its purposes is clear to the public.

In the absence of sharp social goals, we are left with weak, contradictory goals or goals defined by process. A system without sharp goals will appear to lack direction and be out of control, leading to demands that new procedures be instituted to bring it under control and tighten its focus. Since HSE regulation affects many economic and social decisions that had previously been outside government control, such as where to locate a factory and what production technology to use, these demands cannot easily be satisfied.

There have also been calls for broad spectrum regulatory reform, including proposals to implement benefit–cost tests, regulatory budgets, and regulatory calendars [Noll (1971)]. Several books have been written about the attempt to control HSE regulation [White (1981), Miller and Yandle (1979), Viscusi (1983b), Litan and Nordhaus (1983), Wilson (1980)]. These often have a narrow disciplinary focus, with the economists focusing on efficiency and concluding that

HSE regulation is not efficient, or the political scientists noting that HSE regulation is not very different from previous social movements.

4. Quantification and valuation of benefits

4.1. Quantifying the benefits

Any systematic approach to reforming HSE regulation requires that both benefits and costs be quantified. Laying out the costs is relatively straightforward, although far from trivial. Quantifying the benefits is much more difficult [Freeman (1979), Kneese (1984), National Science Foundation (1985a)]. While people could be expected to know a dirty environment or unsafe workplace when confronted with it, a major regulatory program requires more precise and objective measurement of the externalities and identification of the causes of harm. But even measuring air or water quality requires a judgment as to which pollutants are of interest [National Academy of Sciences (1984), Lave and Upton (1987), Peskin and Seskin (1975)]. Even where this appears easy, further judgment is required regarding measurement targets and techniques. For example, the sulfur dioxide and particles that are emitted when burning coal were recognized as important pollutants at an early date [Ruff (1978)]. Yet, the focus of concern has shifted from sulfur dioxide itself to acid sulfates, the products of sulfur dioxide reacting with other gases in the atmosphere. Similarly, the initial way in which particles were measured, total mass per unit volume, put the focus on the largest particles, since a particle of diameter 100 micrometers has one million times the mass of a 1 micrometer particle. However, it is the smaller particles that have the greatest effects on health and visibility, requiring a different set of measurements and different control standards.

Although the textbooks assume that economists get their quantification of effects from scientists and engineers, in fact economists play a leading role in estimating the effects of air pollution [Chappie and Lave (1982), Lave and Seskin (1977), Mandelbaum (1985), Mendelsohn and Orcutt (1979), Watson and Jaksch (1982)], water pollution [Page et al. (1976)], auto safety [Arnould and Grabowski (1981), Crandall and Graham (1984), Crandall et al. (1986), Lave and Weber (1970)], and in other areas [O'Byrne et al. (1985)].

To date, the predominant benefits of HSE regulation come from mitigating human health problems. Health effects are quantified via risk assessment using a diverse set of tools to analyze the effects of air pollution on health, the number of lives that might be lost from a nuclear mishap, the effects of environmental

carcinogens on health, and the risks of highway transport (see Section 6 on risk assessment below).

4.2. Valuation of nonmarket goods and services

Once the risks have been quantified, the next step is to translate them into a single metric, presumably dollars. If valuing injury and disease in dollars is offensive, one metric might be used for benefits while another (dollars) could be used for costs. Even this approach requires a way of comparing slight with serious injury and disease with death. How many broken legs are comparable to paraplegia? How many days of being confined to bed are equivalent to death? Some people answer that these degrees of injury are not comparable, that any number of broken legs is better than paraplegia and that being confined to bed permanently is better than death. Is there some level of pain over some period of time that would be worse than death [Zeckhauser and Shepard (1976)]?

A further problem involves comparing injury across people. For example, would having a million people with broken legs for 70 years each be worse than one of them being a paraplegic? Is one death not better than a million people being confined to bed all of their lives? Indeed, a principal difficulty is constructing a weighting function that relates all injury and disease states to each other. Given such a function, it is less difficult to translate the outcomes into dollar terms.

Economists manage to present their ideas in the worst possible light by speaking of this as the "dollar value of life", managing to confuse premature death with slavery and other ethical issues. Schelling (1968) shows that valuation should be conceptualized as a lottery whose payoffs include no untoward outcome with high probability and injury or death with low probability. The correct question is then: How much would each person be willing to pay to lower the probability of death or injury?

Most economists are aware of the distinction and accept Schelling's concept, but still refer to the "dollar value of life". This sort of insensitivity, as well as the bizarre discussions about the equivalence of broken legs and cancer deaths and dollar value of making a species such as the snail darter extinct, leads environmentalists, politicians, and the public more generally to be extremely suspicious of benefit–cost analysis [Kelman (1981), Campen (1986)].

The history of attempts to model these issues is filled with muddled concepts [Rice and Cooper (1967), Hartunian et al. (1981)]. For example, one of the earliest questions was: What dollar amount should be paid to an injured worker or his heirs after an unfortunate event? Before this question can be answered, a more important question is: Who was at fault? If the employer was negligent,

there is outrage that he did not take greater care to prevent the injury. Indeed, there is the real possibility of criminal prosecution for negligence. If the fault was the employer's, the worker should receive a generous settlement. If the fault is the worker's, the employer would not have to pay any amount. If fault has been put aside in favor of a no-fault system, the amount that should be given would be intermediate between the previous two cases.

To be able to decide how much of a settlement the worker and his heirs should receive, one needs to specify the issues with some care and precision. Unfortunately, economists have been searching for general purpose answers that would fit all circumstances in which someone was hurt.

An improvement on the original approach, but one that is not generally useful, is to infer the implicit valuation put on premature death in the work setting. A number of studies have estimated the increment in wages associated with an increase in risk, after accounting for other relevant factors affecting the wage rate [Thaler and Rosen (1976), Jones-Lee (1976), Linnerooth (1979), Bailey (1980), Graham and Vaupel (1981), Arthur (1981), Viscusi (1983b, 1986a), Olson (1981), Smith (1982), Dickens (1984)]. These studies find that workers have put actuarial values on their lives that range from about $250 000 to $10 million. The valuation is sensitive to the risk level of the job being considered, since the worker population already reflects self-selection of workers into jobs with risk characteristics that match individual preferences. In any case, these estimates are sensitive to the precise circumstance and question asked, and so are not readily generalized to other circumstances.

People can be asked for their willingness to pay to avoid premature death [Schelling (1968)]. Again, the question presumably must be quite precise to get a meaningful estimate. There is also the difficulty of posing a hypothetical question in a form that the respondent has never encountered [Cummings et al. (1986), Kahneman et al. (1982)].

Still more controversial than valuing injury and premature death in dollar terms is valuing extinction of a species or deteriorations in environmental quality in dollar terms [Cummings et al. (1986)]. How much is it worth to prevent extinction of the snail darter? How much is it worth to have an additional sunny day in which one can see 20 miles instead of 10? How much is it worth to have a remote lake, rarely visited by people, not become so acidic that fish are killed? At the very least, it is difficult to pose these questions so that people find them meaningful and can give answers in which they would have confidence. The difficulty is probably deeper, making a willingness-to-pay survey inappropriate for such abstract issues.

The willingness-to-pay literature has developed many estimates of relevant parameters. However, it is unclear what to do with the resulting estimates. Are college sophomores in Cheyenne, Wyoming, representative of the entire population? How sensitive are the valuations to the precise event that is the focus? How

sensitive are they to the background level, e.g. one additional clear day among 50 as against among 250? Several methods are used to derive estimates, from analysis of actual choices to surveys or interviews. Inevitably, one has reservations about the responses people give when asked how many hypothetical dollars they would be willing to pay to stop a hypothetical event.

5. Implementation issues

5.1. How much room for improvement?

Economists tend to emphasize efficiency, giving less attention to such other attributes as equity, administrative simplicity, and transparency. Some proposals promise efficiency, but are so complicated to administer that the promise could never be fulfilled. Thus, the key question for regulatory reform is the extent to which current regulation is inefficient. Unless there is a great deal of room for improvement, more efficient alternatives will not be politically attractive.

While we know of no direct estimate of the efficiency losses from design standards and occupational licensure, we believe they are large. Design standards are enacted to control quality but serve to impede innovation; the temptation is great to write standards that eliminate competition. While occupational licensure is motivated as a quality assurance mechanism, it quickly gets directed toward limiting entry and creating monopoly rents. Regulation and licensure also pose barriers to innovation, since innovators must persuade regulators as well as customers that their product is safe and desirable. Regulation might be thought of as imposing a vast amount of inertia on the system.

Economists have sought mechanisms to handle the externalities and information problems that do little to restrict competition. For example, performance standards can achieve the desired level of quality and protection with fewer restrictions than design standards. Requiring people to disclose their training and qualifications can substitute for licensure. Information disclosure is one of the more important alternatives to regulation [Baram (1982)]. As we saw in Subsection 2.4, tort law will not generally result in optimal efficiency when a product or occupation has health and safety risks. It is an open question whether tort law will give rise to a more efficient solution than direct regulation.

In evaluating water pollution control regulation, Kneese and Schultze (1975) found that an effluent fee system would save 40 percent over the system of point-by-point effluent limits used to protect water quality. The Federal Aviation Agency, in moving from a system of direct and nontransferable allocation of landing slots at congested airports to a scheme allowing for trades and sales among airlines, was able to accommodate expanding air travel despite the

disruptions caused by airline deregulation and the mass dismissals of air traffic control workers in the aftermath of an illegal strike.

Both simulation evidence and analyses such as those cited above emphasize the static benefits of adopting economic approaches to regulation. Yet, the limited use of approaches based on fees or trading of rights has been exclusively motivated by dynamic concerns – such as how to accommodate new pollution sources in areas where existing sources are already pushing against inflexibly set environmental quality targets. In the complete absence of transferability, existing sources can be induced to "make room" for new polluters only by tightening the standards they face. In addition to drawing the opposition of existing sources, such an effort will inevitably spark disputes over the distribution of the extra reductions.

Starting from a position in which existing sources have already made irreversible investments in particular technologies and operate activities of widely varying economic value, a planner would face great difficulty in devising an efficient plan even if there were no distributional effects to account for. Faced with the Scylla and Charybdis choice between revising standards or spurning growth opportunities, regulators have opted for a limited market mechanism – the offset system. In areas where environmental constraints are binding, new sources can enter provided that offsetting emissions reductions from other polluters are obtained. Relying on a voluntary transaction between the "buyers" and "sellers" of offsets circumvents the difficulty of imposing new standards, and provides an incentive for those existing sources able to accommodate growth at relatively low cost to reveal themselves. The offset system serves to promote incremental, but not global, rationality. The bubble policy, another quasi-market approach used in environmental programs, allows for intraplant trading of emission rights across point sources so long as the aggregate externality output is kept below the sum of the individual point source standards. A single bubble at a New Jersey chemical plant was estimated to have saved $12 million in capital costs and $3 million in annual operating costs. Total bubble savings to date are estimated to be in the $1 billion range.

5.2. Dynamic issues in regulation

Virtually all of the models discussed in Section 2 are intended to provide insights of the "comparative statics" variety. The usefulness of comparative statics as a guide to policy may be limited by the importance of the adjustment process in the actual implementation of programs. For example, tightening new source standards beyond some point may actually increase the aggregate level of

externalities. Such an outcome is possible because a differentiated regulatory structure may extend the economic lifetime of existing sources subject to less stringent regulation. In a regime of differentiated regulation, short- and long-term regulatory objectives may be in conflict.

5.2.1. Technology-forcing

The modern view of innovation focuses on the importance of demand pressure in determining the direction of innovation, of having a ready market for the innovation. In the absence of regulation, there is little or no demand for abatement technology and so no R&D effort. Even when the law specified that EPA will require the "best available control technology", there is a long step between innovation, regulatory change, and orders for the new control technology. One common method of spurring technology development is to impose regulations that cannot be met using existing technologies (as with automobile emissions), or to mandate a particular technology rather than a specific performance level (as with scrubbers for coal-fired boilers). While "technology-forcing" might be justified by attainment of a highly valued target, it poses credibility problems that are not generally considered in the prices versus standards literature. In the event that unforeseen difficulties or foot-dragging result in the failure of new abatement technologies to become available when needed, the regulator must either shut down those firms that cannot comply or back off from the standard. Knowledge that the latter approach will inevitably be favored over the former retards technology development efforts. The best known example of such a "credibility crisis" in regulation, the failure of the domestic automobile industry to comply with the scheduled 1977 standards, was solved through statutory action to revise the standard under pressure of a threatened shutdown of the industry. Price-type systems are inherently less subject to such dynamic inconsistency considerations but are not immune. Ford and General Motors have lobbied hard to secure the rollback of corporate fuel economy standards rather than pay substantial fines for failing to attain the mandated level of fuel economy. The fines would have been costly, but would not have shut down the industry.

The requirement for specific technologies poses other difficulties. Obviously, it focuses R & D on specific approaches even though a more diffuse effort might uncover better alternatives. Second, it places little emphasis on operating and maintenance behavior, even though these are key determinants of the effectiveness of abatement. Crandall (1983) finds that a significant fraction of mandated pollution control equipment is not even hooked up. The notion substituting technology standards for monitoring effort is a poor tradeoff in most cases.

5.3. Risk compensation

Will people react to regulation by changing their behavior? Peltzman (1975) examines the impact of automobile safety regulation on realized safety. He finds evidence of risk compensation behavior in the form of driving less carefully. Although drivers themselves are safer despite their offsetting behavior, pedestrians and bicyclists who do not directly benefit from the safety equipment on cars experience a rise in fatalities and injuries. Overall, Peltzman finds that safety measures do not have a net safety payoff. While providing a striking example of the need to consider human feedback to regulation and more generally the importance of the level of care, there is significant controversy surrounding Peltzman's empirical findings [Graham and Garber (1984), Evans and Schwing (1985)]. Other studies have not found evidence of significant risk compensation, or have even found evidence of positive feedback whereby safety equipment, by reminding drivers of safety concerns, actually induce them to drive more safely. A recent study by Viscusi (1985) examing the impact of child-resistant safety caps on poisoning rates found strong evidence of risk compensation on the part of parents in the form of less safe placement and leaving drug bottles open. Indeed, the proportion of aspirin poisonings involving safety capped bottles actually exceeded the proportion of aspirin sold in such bottles by the end of Viscusi's observation period, suggesting that safety topped bottles increase rather than decrease the poisoning rate.

5.4. Contradictory regulation

Since Congress and the regulatory agencies deal with one case at a time, there is no reason to expect even rough consistency among actions. For example, in 1966 Congress expressed its concern for highway safety by creating a federal agency that would regulate safety-related design of automobiles and have the power to mandate safety equipment. In 1970 Congress expressed its concern for air quality by setting emissions constraints for automobiles. In 1975 Congress expressed its concern for fuel economy by mandating fuel efficiency standards for cars. Each piece of legislation was a logical reaction to the conditions prevailing at the time and what the public desired. At first sight, they appear to have nothing in common save that they all deal with automobiles.

However, enhancing safety generally requires increasing the weight and size of automobiles; other things equal, larger cars are safer [Lave (1981a, 1984)]. Unfortunately, fuel economy is inversely related to vehicle weight. Thus, increasing fuel economy leads to smaller vehicles which, other factors held constant, are

less safe. Finally, curtailing vehicle emissions lowers the efficiency of the engine and hurts fuel economy.

The contradictions or secondary implications are important. For example, the fuel economy penalty from the increase in weight due to the package of safety features essentially doubles the implicit cost of preventing a premature death. The situation can be thought of as attempting to maximize social welfare as a function of safety, emissions, fuel economy, performance–comfort, and price, where the factors are not independent. Congress's actions were each equivalent to taking a simple derivative, as if social welfare were a function of only one of the attributes. The resulting solution is demonstrably inefficient. A better solution could be achieved by recognizing the structure of the problem and optimizing by taking partial derivatives, i.e. recognizing the spillover effects. Inevitably, this requires assuming values for the various interactions, but even choosing somewhat arbitrary values is better than assuming the interactions are zero. The systems' optimization comes from recognizing the interdependence explicitly and solving the set of equations of partial derivatives simultaneously.

5.5. Effects on the economy

Denison (1979, 1985) has estimated the effect of HSE regulation on productivity. Pollution abatement was estimated to lower productivity growth by 10 percent over half a decade. Smith and Sims (1985) estimate the effects of environmental regulation in Canadian breweries to be large; unregulated firms had productivity growth of 1.6 percent per year while regulated firms had growth of -0.008 percent. Crandall (1981) also finds a large effect of regulation on productivity. Hartman, Bozdogan and Nadkarni (1979) examine the effects of environmental regulations on the copper industry in the face of increasing demand; the regulations imposed a large burden on the industry which was largely shifted to consumers through an inelastic demand [see also, Gallop and Roberts (1983), Highton and Webb (1984), Maloney and Yandle (1984), Peskin et al. (1981), Viscusi (1983a)].

The effects on inflation can be estimated by examining the direct increase in cost due to this regulation. There is much casual speculation about the effect on international competitiveness, unemployment, and growth, but little formal investigation. Clearly, if some nations have less stringent HSE regulations, their direct manufacturing costs would be lower, until they created an environment so polluted that workers were sickened. These nations would have a comparative advantage in exporting dangerous, environmentally polluting goods. The quantitative advantage is likely to be small given that the estimated increase in the cost

of HSE regulation for various products is small [Denison (1979), Environmental Protection Agency (1979), Ruff (1978)].

5.6. *Distribution of HSE benefits and costs*

Since the cost of environmental programs run in the tens of billions of dollars per year, and since it is unlikely that the costs would be spread uniformly or in proportion to income across families, economists have been interested in estimating the distribution of costs and benefits by attributes such as geographic location and income. Knowing the costs borne by each industry, budget studies can be used to estimate how the immediate costs will be borne. Longer run adjustments are almost impossible to predict. These techniques have been applied by Freeman (1977), Gianessi and Peskin (1980), Gianessi, Peskin and Wolff (1979), Harrison (1975), and Peskin (1978). As might be expected, they find that those living in some areas pay more than four times the national average, while those living in other areas pay almost nothing. Although amounts rise with family income, as a proportion of income, they fall sharply. This result leads to asking whether some of the pollution control efforts should not be paid for out of general tax revenues so as to get a more equitable distribution of costs. Benefits are also quite unevenly distributed, both geographically and by income.

Great care must be taken with these estimates of distributional implications. Carried to extremes, they could indicate the net cost to each Congressional district, each income group, and so on. Such calculations will goad people to focus on these particular costs and benefits, rather than on the national interest.

6. Noneconomic issues

Noneconomists view HSE regulation as almost entirely unrelated to economics. For the most part, economics enters only as a constraint on how stringent the regulation can be. Perhaps the most important of the environmental requirements has been requiring environmental impact statements. Although these are regarded as having no economic content, they are so central that they must be discussed.

Estimating the benefits of health and safety regulation requires quantifying the risks. While risk estimation is normally outside the province of economists, there is such large uncertainty associated with the estimates that economists must understand the nature of these estimates in order to use them sensibly.

6.1. Environmental impact statements

The environmental impact statement (EIS) was introduced by the National Environmental Policy Act of 1969. An EIS is required of all federal government projects that might affect environmental quality. The EIS has been attacked as time-consuming, wasteful, and as serving no useful purpose, other than delay. Taylor (1984) makes the case that the EIS was designed to sensitize federal decision-makers to the impact of their projects on environmental quality and that it has done an admirable job. Thus, Taylor uses a satisficing framework to examine what will get bureaucrats to give attention to environmental concerns. He sees government officials as either exceedingly busy or otherwise occupied. It takes a Congressional or Presidential act to change their behavior and get them to extend their consideration to a wider class of issues.

6.2. Risk analysis and management

Much of the early HSE legislation was intended to lower risks to zero. It quickly became apparent that zero risk was unattainable so that good decision-making requires knowing the risks associated with various concentrations of toxic chemicals or situations in which injury could occur. A large literature has grown up on assessing the risks of accidents, chronic disease, and acute disease [National Science Foundation (1985b), Covello et al. (1986)]. The methods used include fault and event trees, probabilistic risk assessment, and statistical analysis.

A good deal of work has been done on estimating the risks to people [Office of Technology Assessment (1977), Lave (1982, 1987), Marcus (1983), Office of Science and Technology Policy (1985)]. Unfortunately, the uncertainty associated with the point estimates is generally large.

One of the particular problems has been estimating the risks associated with hazardous facilities, such as nuclear plants or toxic waste dumps. Although the risks are generally low compared to risks commonly faced, people do not want these risky facilities nearby. Economists have taken an active role in trying to find ways to transfer some of the social benefit to the individuals who must bear the risk [Kunreuther and Kleindorfer (1986), Mitchell and Carson (1986), Smith and Desvousges (1986a)].

7. Conclusion

Public concern and scientific research on health, safety, and environmental externalities finally lured a number of economists to apply their tools and models

to these issues. The materials balance model of Kneese, Ayres and d'Arge (1970) and the environmental models of Baumol and Oates (1982) are examples of incorporating HSE externalities into standard economic models. These enriched models have attracted a good deal of attention from both theorists and applied economists.

Nonetheless, our review of the economics of health, safety, and environmental regulation cites work of a large number of people trained in disciplines other than economics. The lesson appears to be that we economists are narrowly bound by our models and view of what are interesting problems and approaches. When a movement as sweeping and important as the environmentalist–consumerist movement occurs, economists should not be complaining two decades later that government programs are not efficient; we should have done more to show how to improve the efficiency and effectiveness of these social programs.

Tackling HSE issues is inherently difficult, since they involve some of the thorniest issues in economics: paternalism, public goods, information, incentives for innovation, uncertainty, valuing nonmarket goods and services, and modeling unanticipated consequences of actions. Indeed, the set of issues is so large and fascinating, it would provide employment for a great many theorists. At the danger of missing the most important issues, we suggest that investigations of setting social goals, pursuing the valuation of nonmarket goods and services, and some of the interaction mechanisms between firms and regulators are worth greater attention.

In less than two decades, the economics of HSE regulation has come from somewhat sterile arguments about Coase versus Pigou to a rich array of models, parameter estimates, and policy advice. Experience has shown that sometimes taxes and subsidies were the best route, sometimes direct bargaining among concerned parties was best, and more often a wide range of new approaches was needed. We hope and expect that current problems will continue to intrude in economic models to enrich our thinking and remind us how much we are needed.

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