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THE IMPORTANCE OF TAKING TECHNOLOGICAL INNOVATION INTO ACCOUNT IN ESTIMATING THE COSTS AND BENEFITS OF WORKER HEALTH AND SAFETY REGULATION*

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Abstract

Regulation of worker health and safety is acknowledged to result in health benefits to workers and economic costs to employers. The latter are sometimes shared by workers and consumers in the form of lower wages/salary increases and higher prices. However, the history of occupational health and safety regulation in the United States over the last twenty years reveals that this simplified view of regulation neglects the important role that technological innovation plays in (1) reducing the actual costs of compliance with a new regulation to a fraction of pre-promulgation estimates, (2) yielding a benefit in terms of savings in material, water, and energy costs, and (3) changing the nature of process and product technology, resulting in reduced environmental damage and its associated costs and compliance burden. The U.S. Office of Technology Assessment recently completed an investigation of the technology-forcing aspects of standards promulgated by the U.S. Occupational Safety and Health Administration (OSHA) over the last twenty years and found that (1) technological innovation usually resulted from stringent regulation and (2) traditional cost-benefit analysis performed prior to a standard's implementation failed to anticipate significant economic benefits accruing to the innovating industrial firm. Research done by the author and his colleagues at the Massachusetts Institute of Technology over the last 15 years suggests that there is a strong theoretical, as well as an empirical basis, for predicting that technological innovation will result from stringent standards, and further, that cost-benefit analysis should be revised to include its effects.

Introduction

The reductionist version of neoclassical economic theory predicts that since health, safety, and environmental regulations impose non-productive investment by industry on pollution control, regulation can only be a drag on innovation, and hence on economic growth, because of the diversion of resources from R & D¹. A more modern view currently in vogue is the so-called Porter Hypothesis, put forth in 1991, which argues that regulations may actually stimulate growth and competitiveness². In fact, that suggestion and the empirical evidence that supports

¹ For a recent review of this perspective, see Jaffe, A., Peterson, S., Portney, P., and Stavins, R., "Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us? *Journal of Economic Literature*, Vol. 33, March 1995, 132-163.

² Porter, Michael E., "America's Green Strategy," *Scientific American*, April 1991, p 168.

the hypothesis goes back to a series of publications from researchers at MIT beginning twelve years earlier^{3,4,5,6}, although Porter does not seem to be conscious of it⁷.

There is ample evidence that regulation--if properly designed and implemented--can prompt the kind of technological change that can significantly reduce human and environmental exposure to toxic substances. Prior work at the Massachusetts Institute of Technology has developed models to explain the effects of regulation on technological change. The particulars of this model--the nature of the regulatory stimulus, the characteristics of the responding industrial

³ Ashford, N. A., Heaton, G. R., and Priest, W. C., "Environmental, Health and Safety Regulations and Technological Innovation," in Technological Innovation for a Dynamic Economy, C. T. Hill and J. M. Utterback (eds.), Pergamon Press, Inc., NY, 1979, pp. 161-221.

⁴ Ashford, N.A. and Heaton, G. R., "Regulation and Technological Innovation in the Chemical Industry," *Law and Contemporary Problems*, Duke University School of Law, Volume 46, Number 3, Summer 1983, pp. 109-157.

⁵ Ashford, N. A., Ayers, C., and Stone, R. F., "Using Regulation to Change the Market for Innovation," *Harvard Environmental Law Review*, Volume 9, Number 2, Summer 1985, pp. 419-466.

⁶ Ashford, N. A. "Understanding Technological Responses of Industrial Firms to Environmental Problems: Implications for Government Policy," in Environmental Strategies for Industry: International Perspectives on Research Needs and Policy Implications, K. Fischer and J. Schot (eds.), Island Press, Washington, DC, 1993, pp 277-307.

⁷ Note 1, page 154.

sectors, and the resulting implications of the model for explaining technological responses to regulation and for designing innovative regulatory strategies--are discussed elsewhere⁸.

Cost-Benefit Analysis Examined

During the past two decades, cost-benefit has become the dominant method used by policy makers to evaluate government intervention in the areas of health and safety. As conceived in theory, cost-benefit analysis (1) enumerates *all* possible consequences, both positive and negative, that might arise in response to the implementation of a candidate government policy; (2) estimates the probability of each consequence occurring; (3) estimates the benefit or loss to society should each occur, *expressed in monetary terms*; (4) computes the *expected* social benefit or loss from each possible consequence by multiplying the amount of the associated benefit or loss by its probability of occurrence; and (5) computes the net *expected* social benefit or loss associated with the government policy by summing over the various possible consequences. The reference point for these calculations is the state of the economy in the absence of the government policy, termed the "baseline".

⁸ See notes 4-6. See also Ashford, N. A. "An Innovation-Based Strategy for the Environment," in Worst Things First? The Debate Over Risk-based National Environmental Priorities, A. M. Finkel and D. Golding (eds.), Resources for the Future, Washington, DC, 1994, pp. 275-314.

The mechanics of constructing a cost-benefit analysis can be seen with reference to Table 1, which presents a relatively disaggregated matrix of the various positive and negative consequences of a government policy for a variety of actors. The consequences are separated into economic, health and safety, and environmental effects, and those affected are organized into policy-relevant groups of actors, such as firms, workers, consumers, and "others". Initially, the consequences are represented in their natural units: economic effects are expressed in monetary units; health and safety effects are expressed in mortality and morbidity terms; and environmental effects are expressed in damage to eco-systems, etc.⁹

TABLE 1
Matrix of Policy Consequences for Different Actors

Group	Economic Effects	Health/Safety Effects	Environmental Effects
Producers	C _{\$}		
Workers	C _{\$}	B _{H/S}	
Consumers	C _{\$}	B _{H/S}	
Others	C _{\$}	B _{H/S}	B _{Environment}

All of the consequences of a candidate policy (or regulation) are described fully in terms of the times during which they occur. What traditional cost-benefit analysis does is translate all of these consequences into "equivalent" monetary units (since a dollar in an earlier time period could be invested to earn interest over time) by discounting each to present value and aggregating them into a single dollar value intended to express the net social effect of the government policy.

The cost-benefit calculation can be expressed in simple mathematical terms by the following equation:

$$V = \sum_{i=1}^n \sum_{j=1}^m \frac{(B_{ij} - C_{ij})}{(1+r)^i}$$

⁹ Note that a single cell in the matrix could contain both policy benefits and policy costs. Employers, for example, incur the costs of complying with an occupational health regulation, but also derive economic benefits in the form of productivity improvements and reduced risk hazard pay premiums paid to workers. However, in order not to confuse monetary benefits with other health or safety benefits, we would describe the sum of the monetary costs and benefits as net costs C_{\$}.

where B_{ij} and C_{ij} are the j^{th} type of policy benefit and cost, respectively, in the i^{th} year after the policy is introduced and B and C are expressed in monetary units; r is the appropriate discount rate; and V is the (discounted) present value of the policy.

Elsewhere the author has argued that health, safety, and environmental benefits should be treated differently than costs in computing their present value¹⁰. One approach would allow for discounting of non-monetizable benefits, but at a lower discount rate. This approach can be defended in terms of a belief that certain amenities, such as health, become more valuable relative to other goods in this society as time passes and the standard of living improves. The following relationship would separate the factors affecting the present value of health impairment prevented in year n :

$$B_n = \frac{B(1 + \epsilon)^n}{(1 + r)^n}$$

where: B = metric, expressed in person-years of health impairment prevented in any one year, ϵ = the subsequent annual fractional increase in societal value of health impairment prevented, and r = annual discount rate. For small values of r and ϵ , this is equivalent to:

$$\frac{B}{(1 + r - \epsilon)^n}$$

Thus, the "effective discount rate" ($r - \epsilon$), or time rate of preference, will be less than the discount rate used for monetary benefit or cost calculations. Note that, in principle, if the society's valuation of health benefits increases rapidly, the effective discount rate for benefits could even be negative! Thus, instead of the traditional cost-benefit approach which is biased against interventions which require the expenditures of costs early with the yielding of benefits later, such as is the case with chronic disease, this treatment makes long term investments in health much more attractive.

When there is only one policy option, cost-benefit analysis dictates that option should be implemented only if its anticipated net social effect is positive. In general, however, numerous policies or sets of policies are possible, where each policy can be differentiated according to the various features—type of policy instrument, policy level or stringency, firms covered, etc.—that comprise it. In this situation, according to the cost-benefit criterion, the policy with the largest expected net social benefit, when compared to the baseline, should be implemented.

As a decision-making tool, cost-benefit analysis offers several compelling advantages. First, cost-benefit analysis clarifies choices among alternatives by evaluating consequences in a systematic and rational manner. Second, it professes to foster an open and fair policy-making process by making explicit the estimates of costs and benefits and the assumptions on which those estimates

¹⁰ Ashford, N. A. "Alternatives to Cost-Benefit Analysis in Regulatory Decisions," *Annals of the New York Academy of Sciences*, Volume 363, April 30, 1981, pp. 129-137. See also Ashford, N. A. and Caldart, C. C. "Economic Issues in Occupational Health and Safety", Chapter 5 in Technology, Law and the Working Environment, Revised Edition, Island Press, 1996, 641 pages.

are based. Third, by expressing all of the gains and losses in monetary terms, discounted to their present value, cost-benefit analysis permits the total impact of a policy to be summarized using a common metric and represented by a single dollar amount.

As a practical matter, however, cost-benefit analysis possesses several serious limitations discussed below. Note, however, that the ensuing dissection of cost-benefit analysis is not intended to suggest a wholesale rejection of the technique, but to caution against the uncritical application of an imperfect methodology and the unqualified acceptance of its results¹¹.

Problems in Estimating Public Policy Benefits

The benefits of a specific government policy concerning occupational health and safety are generally the reduced social costs associated with a decrease in the number (or severity) of job-related injuries and illnesses, where the decrease is brought about by the policy in question. Prominent examples of policy benefits include reductions in medical expenses, productivity losses, physical disability, pain and suffering, and loss of life. Estimation of the policy benefits in cost-benefit analysis is a formidable task because it is difficult to predict the reduced risk of injury and disease and to monetize the associated benefits.

There are many problems in trying to determine the effects of a government policy on the incidence of job-related injuries and disease. The baseline occupational risks may not be scientifically established. In most cases, the precise relationship between exposure and disease is simply not known. Estimating the effects of the policy on worker exposure levels may also be rather uncertain, depending as it does on assumptions about firm and worker behavior as well as on technical production relationships.

¹¹ An alternative approach to cost-benefit analysis, trade-off analysis, has been suggested (see Ashford and Caldart, note 10). In this approach, like cost-benefit analysis, the matrix depicted in Table 1 is a starting point for the analysis. However, in trade-off analysis, the matrix elements are expressed in their natural units, such as monetary costs, mortality and morbidity statistics, etc. No attempt is made to place a monetary value on health, safety and environmental effects. The time period in which each effect is experienced is fully described, but the health, safety, and environmental effects are not necessarily discounted. Trade-offs between worker health and costs to producers, consumers, and others are made in a transparent manner by the politically-accountable decision maker. Thus *accountability*, rather than accounting, is fostered.

Additionally, many of the benefits of government policy, such as reductions in physical disability, pain and suffering, and loss of life, have no clearly-defined economic value (as compared to the market prices established for labor and medical services). The traditional methods of monetizing these benefits—surveys and market studies—have been, to a large extent, unsuccessful. Interviews and questionnaires asking individuals what they would be willing to pay for a stated reduction in risk have inherent limitations since answers to hypothetical questions have been shown to be poor indicators of a person's behavior. Imputing the value of risk reduction from an individual's market behavior is also a seriously flawed approach¹². Individual actions are normally undertaken for a variety of reasons, and it is difficult to isolate what portion is motivated by a desire to reduce the risk of bodily impairment, pain and suffering, or a premature death. Furthermore, consumers are rarely well-informed about the risks confronting them and have a well-documented history of being unable to process the risk information at their disposal in an expected manner^{13,14,15}. As a result, the assumption of economic efficiency underlying attempts to value risks from consumer market decisions is untenable in practice.

Where policy analysts have most frequently turned to derive the value of a reduction in risk is the job market itself. Recall that, according to economic theory, the risk-compensating wage premium represents the workers' valuation of job risk. But, the same job market imperfections that produce a socially-excessive level of workplace risk and create a need for government intervention also undermine the usefulness of the risk premium as a measure of the worker's risk valuation. For example, job-related diseases that the worker does not know about will not be reflected in the wage premium for risk. Moreover, workers may have difficulty in understanding risk information. In theory, they are just as likely to overreact as under-react to hazard information, but in practice, worker risk perception appears to be dominated by an "it-can't-happen-to-me" attitude¹⁶. This results in known risks being understated and therefore undervalued. Another job market defect, externalities, causes the observed wage premium for risk to measure only the *worker's* valuation of an incremental risk, but not the value family members, friends, and other interested parties attach to the risk. Furthermore, models of the risk-compensating wage differential assume a perfectly-competitive job market; violation of this assumption means that the resulting estimates will "misinterpret" the true wage premium for risk. This is a particularly serious problem, since there may be no way to adjust the estimates to correct for the mis-specification.

¹² Fischer, G. W., "Willingness to pay for probabilistic improvements in functional health status: A psychological perspective." In: Mushkin, S. J and Dunlop, D. W., eds. Health: What Is It Worth? Measures of Health Benefits. New York: Pergamon Press; 1979.

¹³ Tversky, A. and Kahneman, D., "Judgment under uncertainty: Heuristics and biases." *Science*. 1974;185:458-468.

¹⁴ Fischhoff, B. "Cost benefit analysis and the art of motorcycle maintenance". *Policy Sciences*. 1977;8:177-202.

¹⁵ Machina, M. J., "Choice under uncertainty: Problems solved and unsolved." *Journal of Economic Perspectives*. Summer 1987;1:121-154.

¹⁶ Ashford, N. A., Crisis in the Workplace: Occupational Disease and Injury. Cambridge, Massachusetts: MIT Press; 1976, 579 pages.

Problems in Estimating Public Policy Costs

Although the costs imposed by a government policy seem rather easy to identify and to express in economic terms, they are usually no more certain or reliable than the benefits. One reason is that policy analysts rarely have access to detailed, independent information about actual—and potential—production relationships and associated costs in an industry. Instead, they must depend to a large extent on industry-provided data to develop estimates of the costs to industry of complying with the public policy. Since higher compliance costs make a policy less attractive, industries adversely affected by the policy may choose to inflate their reported compliance costs.

In addition, compliance cost estimates often fail to take three significant factors into account: (1) economies of scale, which reflect the fact that an increase in the production of compliance technology often reduces unit costs; (2) the ability of industry to learn over time to comply more cost-effectively—what management scientists refer to as the learning curve; and (3) compliance costs based on present technological capabilities ignore the role played by technological innovation in reducing those costs¹⁷. The last factor is particularly crucial. A recent retrospective analysis of eight OSHA regulations issued between 1974 and 1989 by the U.S. Office of Technology Assessment concluded that the agency's estimates of economic impacts systematically and significantly overestimated compliance costs by ignoring the innovative response of industry to the enacted standards¹⁸. Five of these regulations addressed toxic substances and are discussed in detail below.

The OTA Study

The results of the OTA study are summarized in Table 2 for the five health standards investigated. The study concluded that:

OSHA's current economic and technological feasibility analyses devote little attention to the potential of advanced or emerging technologies to yield technically and economically superior methods for achieving reductions in workplace hazards... Opportunities are missed to harness leading-edge or innovative production technologies (including input substitution, process redesign, or product reformulation) to society's collective advantage, and to achieve greater worker protection with technologically and economically superior means.

[I]ntelligently directed effort can yield hazard control options--attributes that would, no doubt, enhance the "win-win" (for regulated industries and their workforces) character of OSHA's compliance requirements in many cases and support the achievement of greater hazard reduction .

¹⁷ See note 5.

¹⁸ Gauging Control Technology and Regulatory Impacts in Occupational Safety and Health—An Appraisal of OSHA's Analytic Approach. Washington, DC: U.S. Congress, Office of Technology Assessment (OTA-ENV-635); September 1995.

Thus, there is overwhelming and convincing evidence that failure to include technological innovation in assessing the costs and benefits of workplace regulation renders cost-benefit analysis of minimum use in efforts to protect workers from occupational health hazards. Estimates of costs using traditional approaches over-estimate the costs of protecting workers and under-estimate the health benefits that would be achievable by developing or adopting superior technologies. Thus, reliance on traditional cost-benefit analysis leads to a suboptimal level of occupational health and safety¹⁹.

¹⁹ Full application of cost-benefit analysis dictates that solutions to worker health and safety problems be "economically efficient", i.e., that intervention is justified until the marginal benefits of further protection no longer equal marginal costs. Using the costs of existing technology in this calculus leads to *static* efficiency. Instead, if the costs of new technology were factored into the calculus, a different, *dynamic* efficiency would be achieved, with a greater level of worker protection at lower cost, leading to a "win-win" situation (see Ashford and Caldart, note 10). See Figure 1 for a graphical representation of dynamic versus static efficiency.

TABLE 2
OTA CASE HISTORIES

- Vinyl Chloride
 - significant process (polymerization) innovation
 - final compliance costs = 1/4 of pre-promulgation best estimates

- Cotton Dust
 - aggressive re-tooling of entire production process yielding significant productivity improvements
 - final compliance costs = 1/3 of pre-promulgation best estimates

- Lead (secondary smelters)
 - lack of enforcement, plus exercise of the option of paid medical removal of workers, yielded a small fraction of predicted compliance costs

- Ethylene Oxide
 - because of fear of legal liability, the hospital industry chose to replace existing sterilization equipment with innovative technology, thereby reducing the ambient level well below the required standard
 - engineering costs were, however, about the same as predicted, although new technology was adopted

- Formaldehyde (metal foundries)
 - significant innovation by formaldehyde resin suppliers
 - costs = 1/2 of pre-promulgation best estimates

Source: Gauging Control Technology and Regulatory Impacts in Occupational Safety and Health—An Appraisal of OSHA's Analytic Approach. Washington, DC: U.S. Congress, Office of Technology Assessment (OTA-ENV-635); September 1995.

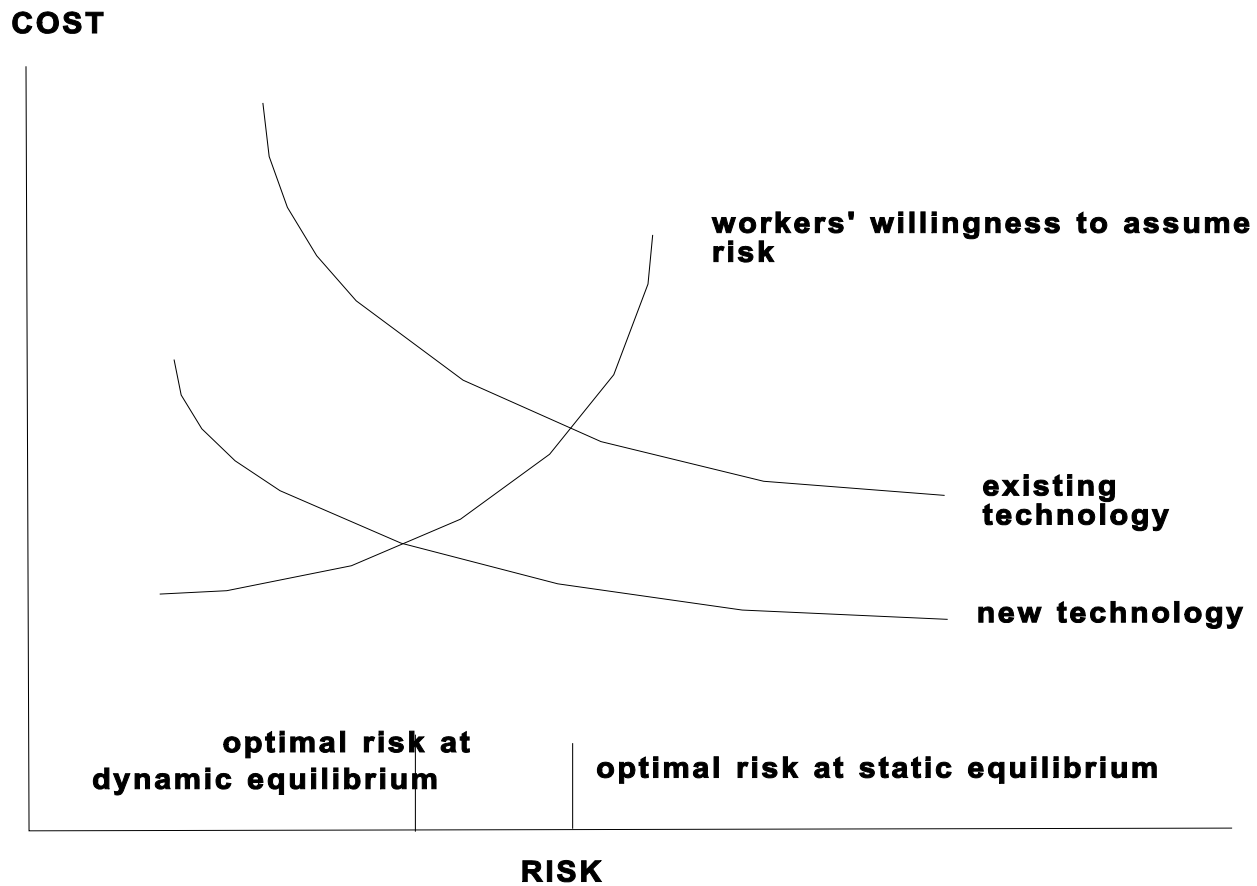


Figure 1: Optimal Risks at Static and Dynamic Equilibrium