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The Emerging Role of Benefit-Cost Analysis in the Regulatory Process at EPA

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Almost since its inception, the U.S. Environmental Protection Agency (EPA) has been using analytical techniques related to the concept of balancing benefits and costs. As a result of the Reagan Administration's Executive Order 12291, benefit-cost analysis is playing an increasingly important role in the EPA regulatory process. Benefit-cost analysis has assisted in organizing information and improving cost estimates. It has influenced the choice of regulatory criteria and aided in the developing degrees of stringency for environmental regulations. The usage of benefit-cost analysis is limited by interpretations of portions of the Clean Air Act and Clean Water Act that restrict consideration of costs or establish technology standards. Benefit analysis is only as reliable as the underlying scientific data in the health effects area. Work by epidemiologists on the relationships between pollutant exposures and adverse health effects will play a vital role in EPA's ability to value in dollars the health improvements attributable to pollution control. EPA's Office of Policy, Planning and Evaluation is currently conducting combined economic and epidemiology research to develop methods and estimates of the health benefits of pollution control.

Almost since its inception, the U.S. Environmental Protection Agency has been using analytical techniques related to the concept of balancing benefits and costs (*1*). In the early 1970s, under the Nixon and Ford administration, technological and economic feasibility studies became an integral part of EPA's regulatory process. By the second half of the decade, under the Carter administration, cost-effectiveness analyses were common, and risk-benefit assessments were incorporated in a few regulatory programs (see Table 1).

While very valuable, these techniques provide only limited assessments of the economic efficiency implications of regulatory options. Benefit-cost analysis is the only technique that attempts to evaluate in commensurate terms as many of the effects of regulations as possible and to identify more efficient alternatives.l

In 1978, the Carter Administration took a major step toward the benefit-cost analysis of regulatory actions with Executive Order 12044 (*2*). It required agencies to identify the potential benefits of various regulatory proposals and to document the rationale for choosing a particular alternative.

In 1980 the Reagan Administration made explicit the requirement for benefit-cost analysis with Executive Order 12291 (*3*). Now a Regulatory Impact Analysis (RIA) must include not only the potential benefits, but also the net benefits of regulatory options. The executive order also expanded the Carter Administration's definition of a major regulation that is subject to an RIA. Lastly, and perhaps most controversially, it enhanced the centralized review and oversight procedures of the Office of Management and Budget.

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Benefit-Cost Analysis Performs Valuable Functions

As a result of Executive Order 12291, benefit-cost analysis is playing an increasingly important role in the EPA regulatory process. Its four major influences have been:

- Organizing scientific and economic information into a consistent framework for evaluating regulations
- Improving the accuracy of cost estimations
- Determining what regulatory criteria decision makers use; and
- Indicating, where appropriate, changes in the stringency of regulations.

Organizing Information Consistently

As with all explicit analytical frameworks, benefit-cost analyses are introducing a new structure and terminology into the regulatory process. As a result, regulatory proposals now integrate scientific and economic information into a more consistent, comprehensive framework that informs decision makers about the expected outcomes of alternative regulatory proposals. A comparison between the analysis prepared for the 1979 primary air quality standard for ozone (*4*), which protects health, and the anticipated analysis for the 1985

revision of that standard (*5,6*) illustrates the changes that are taking place. These changes are particularly evident in the increasing availability of information (see Table 2).

For the 1979 standard, a risk estimate was prepared based on a probability function derived from expert opinion. In the 1985 rulemaking, risks to health will most probably be based on a dose-response function "synthesized" from several published studies as well as from an analysis of the 1979 Health Interview Survey. The 1979 estimate of exposure included only sensitive individuals whereas it is currently planned that for the 1985 estimate, the RIA will utilize the total exposed population. The 1979 effect estimate qualitatively described adverse health effects, whereas it is currently intended that the 1985 estimate in the RIA will document many specific health endpoints, such as minor restricted activity days. The 1979 analysis did not monetize, health or other effects measures, whereas it is intended, the 1985 analysis in the RIA will. The 1979 analysis showed only incremental physical differences among three regulatory options, whereas the 1985 analysis in the RIA is likely to present both incremental physical and monetary changes for as many as six regulatory options.

Similar changes are also evident in the analytical support for the upcoming revision of the secondary standard for ozone, which protects vegetation and materials (see Table 2). For the 1979 rule, a risk estimate was based on a dose–foliar damage function that required additional assumptions to estimate changes in crop yield. For the 1985 rule, crop damages will be based on dose–yield functions estimated from three years of field experiment data that EPA conducted. The 1979 estimate of exposure was an approximation for 103 crops, whereas the 1985 estimate will be county-specific estimates for six major commercial crops. Both the 1979 and 1985 effect estimation will be the same, i.e., crop loss. However, the 1979 analysis used a simple biological valuation approach (crop loss times market value of crop), whereas the 1985 will use a model farm approach (incorporates the effects of price changes on crop quantities and the substitution of ozone-resistant crops). The 1979 analysis provided only 1978 total damage estimates, whereas the 1985 analysis will probably show incremental changes at different ambient concentrations.

Improving Cost Estimates

Before using benefit-cost analysis, EPA's program offices developed worst-case or highest-cost estimates. In so doing, the Agency made sure that the parties having to comply with a regulation would not accuse EPA of underestimating the compliance costs. Today, program offices are beginning to prepare more accurate cost estimates to accompany benefits estimates.

One example of this change is the way EPA's air program office re-estimated the costs of performance standards for new sources of emissions of volatile organic compounds (*7*). It shifted from worst-case assumptions to most-likely assumptions in preparing a new cost estimate. Where the worst case assumed that each process in a given plant would need a separate control device, the new model plant analysis recognized that emissions from several processes could be controlled by a common control device. Once costs were reestimated, the average cost per ton of emissions removed dropped from a high of $1315 under the worst case to estimates ranging between $240 and $930, depending upon the particular process. In addition, some process costs fell much more than others. As a result, some of the control requirements may be made more stringent, while others may be relaxed. In short, reestimating the costs led to significantly different control requirements.

Another example of this change is the anticipated reanalysis of the cost of the recently proposed best available technology effluent guidelines for the organic chemical industry (*8*). At the time of proposal, EPA estimated the capital costs of compliance at $1.4 billion based on 1976 data. After proposal of the rule, EPA initiated a new industry survey to obtain a more current cost estimate. Although the new study is not yet completed, a review of organic chemical plants on the Lower Mississippi River suggests that the estimated costs of the regulation are excessive because the substantial investments that industry has already made in pollution

Table 1. EPA uses several analytical techniques.

Analytical techniques	First used at EPA	Major questions addressed	Present use
Technological feasibility	Early '70s	Is technology available?	Effluent guidelines
Economic feasibility	Early '70s	Are the price changes, job losses, and plant closings too severe?	Economic impact studies
Cost-effectiveness	Mid-'70s	Is the cost per ton of pollutant removed too high compared with the costs of other regulations?	Air/water regulations
Risk assessment	Mid-'70s	Is the individual risk too high?	Hazardous air pollutants
Risk-benefit	Mid-'70s	Are the reductions in risk of exposure (individual risk times exposure) worth the foregone benefits (costs)?	Pesticides
Benefit-cost	Late '70s	Are the economic benefits of the health and welfare changes comparable to the costs?	Executive orders 12044/12291

Table 2. Current ozone regulations have stronger scientific and economic support.

Standard	Estimation of Risk	Estimation of exposure	Estimation of effects	Monetization of effects	Increme damage
1979 Primary	Probability function, Delphi technique	Only sensitive individuals	Qualitative description	None	Three exposure levels
1985 Primary	Dose response	Total population	Health endpoints	Valuation	Six exposure levels
1979 Secondary, vegetation[a]	Dose-foliar damage function	103 Crops	Crop loss	Biological valuation	Current
1985 Secondary, vegetation[a]	Dose–yield function	6 Major crops	Crop loss	Model farm approach	Percentage change in air quality

[a] Commercial crops, forests, and ornamental plants.

control technology. If these results are representative of the industry, the capital costs of the regulation may be as low as 50% of the original estimate.

A third example of the change can be seen in EPA's calculation of the cost of attaining a standard for ambient particulate matter. The original cost of compliance only considered the cost of controlling excess emissions at one future point in time i.e. 1987. However, a recently released cost analysis reflects the control of excess emissions between 1987 and 1995 (*9*). Although limited data prevented a multiyear estimate, the new cost of compliance, higher than the original estimate, more nearly matches the estimate of the benefits that will be accruing between 1987 and 1995.

Influencing Choice of Regulatory Criteria

Benefit-cost analysis is slowly changing the criteria EPA uses to set standards. In the recently proposed rule for inorganic arsenic emissions from copper smelters, EPA used its traditional approach of analyzing cost-effectiveness and economic impact (*10*). It proposed requiring emission controls for existing smelters emitting inorganic arsenic at a rate of 6.5 kg/hr or greater. Six of the 14 existing smelters would have to install a control system for convertor operations at a combined annual cost of $8.6 million. As a result, the highest level of remaining individual risk would be 3.8×10^{-3}, and 0.23 lives would be saved annually at a cost per life saved of $37 million (see Table 3).

In the same regulatory package, EPA acknowledged that its method for determining which sources must apply the best available control technology might result in a lack of additional controls on certain smelters that could pose greater health risks than some of the smelters EPA proposes to regulate. Therefore, EPA asked for comments on two alternatives for setting this standard.

One basis that is being considered in determining which sources to control is the population density around the source. This approach introduces a benefit criterion by considering total number of individuals exposed. EPA would divide sources into high-density (10,000 people or more living within 20 km of the source) and low-density (fewer than 10,000 people) sources. EPA would require control systems at high-density smelters with inorganic arsenic emission rates greater than 25 kg/hr, and at low density smelters with rates greater than 35 kg/hr. As a result, only three of the 14 smelters would have to install a control system, and the combined annual cost would be $3.4 million. EPA estimates that the highest level of remaining individuals at risk would be 3.8×10^{-3}, the same as with the traditional approach. However, the cost per life saved would be only $15 million, and 0.22 lives would be saved annually.

The second alternative is even more consistent with the benefit-cost criterion. The approach would distinguish between sources by jointly considering maximum individual risk and population risk. Sources with emissions resulting in unacceptable combinations of individual and population risks would be classified as high-risk sources and subject to regulation. Conversely, sources with acceptable combinations would be classified as low risks and would not be subject to additional regulation. Given a hypothetical unacceptable combination of individual and population risk described in the regulatory package, five smelters would be classified as high-risk sources and would have to install control systems at a combined annual cost of $7.9 million. Under this approach, the highest level of remaining individual risk would again be 3.8×10^{-3}. However, 0.39 lives would be saved annually at a cost per life saved of $20 million.

Table 3. Benefit analysis for inorganic arsenic provides additional criteria for regulatory decisions.

Regulatory criteria	Number of plants regulated	Annualized control costs, $	Highest remaining individual risk	Lives saved	Implicit cost life saved $
Cost-effectiveness	6	8.6×10^{6}	3.8×10^{-3}	0.23	37×10^{6}
Population density	3	3.4×10^{6}	3.8×10^{-3}	0.22	15×10^{6}
Risks to individuals and total population	5	7.9×10^{6}	3.8×10^{-3}	0.39	20×10^{6}

Table 4. Benefit-cost analysis is influencing EPA's regulatory strategy.

Regulation	1981 or earlier position	1984 position
Proposed benzene standards for maleic anhydride plants, ethyl-benzene/styrene plants, and benzene storage vessels	Reduce emissions by 90% or more	Maintain current level of control
Particulate matter national ambient air quality standard	Relax current standard by 50%	Lean toward maintaining existing standard
Lead in gasoline	Freeze lead in leaded gasoline	Potentially reduce lead in leaded gasoline to 0.1 g/gal

Suggesting Degree of Stringency

The stringency of regulations involves not only the degree of control but also the implementation date of a regulation. Some examples of how the requirement for more rigorous consideration of benefits and costs may be influencing the stringency of regulations are seen in the proposal to withdraw several proposed benzene standards, in the proposed standard for ambient particulate matter, and in the benefit-cost study of removing lead from gasoline (see Table 4).

In March 1984, EPA decided to withdraw earlier proposed standards for maleic anhydride plants, ethylbenzene/styrene plants, and benzene storage vessels (*11*). Since the Agency proposed the standards for the three source categories in 1980, the emission estimates have declined significantly, resulting in reductions of estimated before-control individual and population health risks associated with each source category. For example, for benzene storage facilities, the estimated maximum lifetime risk of dying prematurely from cancer to the most exposed individual has declined tenfold to 3.6 chances in 100,000. The expected cancer incidence for all three source categories is only one case of adult leukemia every 13 years. Moreover, were EPA to issue the proposed standards for these categories, it would eliminate only one cancer every 30 years.

The maximum individual risk at any benzene source before regulation is 10^{-4}, and at the other two source categories, 10^{-5}. The number of lives saved by regulating these three source categories ranges from 0.005 to 0.015, and the cost per life saved ranges from $87 to $215 million. EPA has determined that the risks to public health are small and that there is no significant health benefit from controlling these emissions. Consequently, the three categories do not warrant regulatory concern at the federal level.

A second example of how examining the benefits and costs of potential regulatory options may be influencing the stringency of regulations is the recently proposed revision of the national ambient air standard for particulate matter. In 1982, the Clean Air Scientific Advisory Committee and the air program office of EPA supported a change in the form of the standard to consider only small particles and a considerable reduction, perhaps as much as 50%, in the stringency of the annual and 24-hr primary (health) standards (*12*). However, by 1984, EPA officials had begun to reevaluate the stringency issue in light of analyses produced by the staff. Although the proposed revision of the standard is a range (150–250 $\mu g/m^3$) rather than a point estimate, the Administrator stated that he favored a point estimate in the lower portion of that range (*13*).

An important factor influencing the staff's opinion about the need for retaining a stringent standard was the quantitative analysis of the implications of alternative, proposed standards (*9*). Studies used in the analysis suggested that adverse health effects might occur below the range of the proposed standard.

Another example of how benefit-cost analysis is beginning to affect the stringency of potential regulatory options is the recently released study of reducing lead in gasoline (*14*). The study's conclusions markedly differ from the Agency's position in the late 1970s and its initial inclination in early 1982 to slow down or reverse the phasing out of lead in gasoline (*15*).

In the 1970s, EPA took several actions that it assumed would restrict and eventually eliminate the exposure of the general population—especially young children—to airborne lead emissions from mobile sources. These regulations were also expected to reduce undue health and welfare damage from gaseous motor vehicle pollutants. First, EPA required that cars, beginning with model year 1975, meet tighter emission limits for carbon monoxide, nitrogen oxides, and hydrocarbons; this usually required catalytic converters and unleaded gasoline. Second, in several actions, EPA mandated that the lead content of leaded gasoline be phased down from over 2.0 g/gal to 1.1 g/gal. However, the growing problem of the misuse of leaded fuels in cars with catalytic converters has significantly slowed progress toward reduced lead emissions and challenged the assumption that leaded gasoline would soon be eliminated because of the lack of demand. These factors, plus the increasing recognition of serious helath effects from even low lead levels and the identification of gasoline as the major source of environmental exposure to lead, all indicated a need for reevaluating the policies of the late 1970s.

EPA's benefit-cost study of reduction of lead below 1.1 g/gal in gasoline has concluded that the benefits of both the low-lead and all-unleaded options significantly outweigh the costs (see Table 5). Eliminating or severely limiting lead would increase manufacturing costs by less than 1%, and eliminating lead altogether might result in excessive valve wear in some trucks or older cars. Meanwhile, maintenance costs for automobiles would decrease, and public health and welfare would improve. Even though some benefits and one cost cat-

Table 5. Comparison of benefits and costs of lead reduction options in 1988; all values in millions of 1983 dollars.

	Low-lead option[a]	All unleaded[b]
Costs		
Manufacturing costs	$503	$691
Nonmonetized damage to engines that need lead	—	D
Total	$503	$691 + D
Benefits		
Maintenance benefits	$660	$755
Environmental and health benefits for conventional pollutants		
Reduced damage by eliminating misfueling	$404	$404
Nonmonetized health benefits[c]	H_1	H_1
Environmental and health benefits for lead		
Reduced medical costs	$41	$43
Reduced cognitive damage	$184	$193
Nonmonetized health benefits[d]	H_2	H_3
Total	$1289 + H_1 + H_2$	$1395 + H_1 + H_3$
Net benefits	$786 + H_1 + H_2$	$704 + H_1 + H_3 - D$

[a] This option would make a low-lead gasoline (0.10 g lead/gal) available only for those few vehicles that require some lead. It assumes no misfueling.

[b] All lead in gasoline would be banned by 1988.

[c] These include chronic health effects of ozone and CO, and any effects of reduced sulfate particulates.

[d] Since medical costs and cognitive damage were only monetized for children with high levels of lead in their blood (>30 μg/dL), H_2 and H_3 represent other benefits for this group (pain, lost work time to parents, etc.), as well as *all* the benefits (medical, cognitive, behavior, etc.) for the lower-lead group (<30 μg/dL). H_2 and H_3 differ because the numbers of children at risk under the two options differ.

egory were not monetized, the measured benefits exceeded the cost for both options under consideration.

Benefit-Cost Analysis Has Several Limitations

Although benefit-cost analysis is playing essential roles in the regulatory process, these roles are subject to many limitations. Probably the largest stumbling block to its broader use at EPA is legislation passed in the early 1970s (*16*). At that time, the environment was so degraded that legislators assumed that the benefits of any environmental regulations would exceed the costs of bringing them about. As a result, the Agency's interpretation of the Clean Air Act and subsequent judicial decisions have restricted consideration of costs, and thus net benefits in setting ambient air quality standards. And the Agency's interpretation of the Clean Water Act established technology availability rather than economic efficiency as the primary basis for setting effluent guidelines and controlling municipal waste discharge. Although Executive Order 12291 does not have the force of law, it requires such analysis for major regulations.

Some environmental management areas that EPA regulates are incompatible with the requirements of benefit-cost analysis. For example, in the area of hazardous waste, a basic scientific understanding of the causal linkage among pollutants, transport and exposure is not yet available. Similarly, the relationship between toxic pollutants released in effluent streams and ecosystem productivity is not well understood. Benefit-cost analysis cannot be applied in these areas until research provides better causal information.

In the health effects area, benefit analysis itself can only be as reliable as the underlying scientific data. When the scientific community cannot agree on measures of health effects, or in some cases provide only qualitative measures, economists face a wider band of uncertainty which reduces the efficiency of the benefits analysis.

Even when the scientific community is in agreement on dose–response estimates, benefit estimation techniques may not be capable of providing appropriate willingness-to-pay measures of significant health and welfare outcomes. There is currently no consensus within the Agency on valuing changes in morbidity in spite of agreement that it includes pain and suffering, medical care services and lost productivity. The Agency's guidelines for valuation recommend using foregone wages, even though this value is not conceptually correct and excludes values for distress and discomfort associated with morbidity changes (*17*). Nor do the Agency's guidelines offer any practical guidance on how to measure losses or gains in ecological outcomes.

Lastly, benefit analysis, which emphasizes economic efficiency, usually does not account for important distributional effects associated with regulatory decisions. Many people think that the Agency's mandates call for eliminating high levels of individual risk, regardless of the costs (*18*). Others think that an additional concern ought to be reducing the risk to the total population at a reasonable cost. The attempt to include both concepts in the new basis for setting an inorganic arsenic standard for copper smelters shows the Agency has not satisfactorily resolved this issue (*10*).

Epidemiology Can Strengthen Benefit-Cost Analysis at EPA

The work of epidemiologists can eliminate or mitigate some of these limitations. Benefit-cost analysis calls for valuing in dollars the health improvements attributable to pollution control. Economists cannot bridge the valuation gap between health effects and economic valuation in the benefits information chain unless the previous gap—the relationship between pollutant exposures and adverse health effects—has also been bridged. By focusing on establishing dose–response relationships between pollution and disease, the work of epidemiologists and other health scientists can make benefit-cost analysis more accurate and comprehensive.

Typically, economists (and noneconomists) who have acted as environmental epidemiologists have conducted observational studies using cross-sectional data (*19*). The data on pollutant exposure and health effects used in these studies are usually collected independently of each other. For the purpose of analysis, therefore, the exposure data must be matched temporally and spatially with the health effects data. This matching exercise can only provide a very crude indication of individuals' exposures to pollutants. It is obviously a potential source of misclassification or information bias in the analysis. For chronic diseases that are thought to be related to air pollution, exposure history—as opposed to a single contemporaneous exposure measurement—is regarded as being etiologically more relevant in explaining the prevalence of disease.

In the hierarchy of epidemiologic studies of pollution-induced diseases, statistically significant associations obtained in cross-sectional, observational studies are regarded as merely being suggestive of hypotheses concerning likely cause-effect relationships. Such hypotheses must be confirmed in retrospective or, better yet, prospective studies that have better exposure measurements.

Epidemiologists are particularly needed for resolving uncertainties and inconsistencies in dose–response functions estimated from secondary data. Epidemiologists, of course, have knowledge of clinical and experimental studies that may verify or contradict the findings of the observational studies. In addition, econometricians, with guidance and interpretation from epidemiologists, may use the results of clinical and experimental studies as prior information in improving the precision of the statistical dose–response estimates.

Where there is some professional consensus on the relationship between pollution and exposure health effects, as in the study on lead in gasoline (*14*), benefit analysis is much more credible and is a more effective component of the decision process. However, where there is little professional consensus on the relationship between pollutant exposure and health effects, as in the case of many standards for hazardous air pollutants, the benefit analysis is more uncertain and has less impact in the decision process because it cannot identify, with reasonable certainty, a likely range of values.

Another critical area where epidemiologists can play a role is in assessing the medical and, hence, potential economic significance of various health measures that may be related to pollution. For benefit-cost analysis, economists need to assign values to the health damages from pollution. Epidemiologists have in many instances measured the physiological effects of pollution, such as lung function, forced expiratory volume or forced vital capacity. But these measures are not as readily evaluated in economic terms as are health outcomes that have readily identifiable behavioral ramifications. These outcomes include morbidity and lesser manifestations of bad health such as days of restricted activity. Economists need to know the relationship between human behavior and air pollution exposure rather than lung function effects and air pollution exposure.

Lastly, cooperative efforts between epidemiologists and economists to gather and analyze data can help economists prepare more accurate and credible measures of individuals' willingness-to-pay to avoid adverse health effects. In these efforts, economists consider two approaches: cost of illness and willingness-to-pay (*20,21*). The former approach generates a lower bound estimate of health benefits because it excludes evaluation of pain and suffering and nonwork-related motives for protecting human health. Economists use this approach because data, for example wage rate and medical care cost data, are readily available. The willingness-to-pay approach is more inclusive and generates a more complete measure of health benefits. However, obtaining the necessary data to estimate willingness-to-pay is difficult.

EPA's Office of Policy, Planning and Evaluation is currently conducting health econometric research under several cooperative agreements that involves collaboration between economists and epidemiologists. The principal goal of the research is to develop methods and estimates of the health benefits of pollution control that are based analytically and empirically on individual preferences for health. Following are examples of current projects:

- Health Econometric Methods For Multimedia Pollutants (National Bureau of Economic Research and University of Pittsburgh). This research involves the development and application of microeconomic models for evaluating the individual and household impacts of environmental pollutants on health status. To achieve this end, the project team is utilizing the concept of a health production function as the basis for making and interpreting statistical estimates of relationships between multimedia (air, drinking water, diet) pollutant exposures and measures of health outcome.
- Health Econometric Methods For Air Pollution (Rand Corporation). The research objectives of this project are identical to the National Bureau-Pittsburgh effort, but the project scope is more narrowly focused on the economic evaluation of the adverse health effects of air pollution. In this instance, the project team is conducting statistical analyses of relationships between exposure to air pollutants and several measures of health outcomes, including the use of health care services, sick-loss time and general health status.
- Economic Consequences of Body Lead Burdens in Children (University of Pittsburgh and University of Wyoming). The primary objective of this research is to develop and demonstrate methods for evaluating the physiological and neuropsychological benefits of reducing children's exposures to environmental sources of lead. Because of lead's potential for causing intellectual impairments in children, the project team is utilizing a health production function approach that accounts for the adverse effects of lead on child health and educability

and, in turn, the effects of educability on lifetime earnings.

- The Use of Time Allocation Information in Exposure Estimation and Economic Benefit Analysis (University of Maryland). The objective of this exploratory project is to design a epidemiological survey in which measurements of pollutant exposure, health outcome and economic responses to pollutant-induced health outcomes are all collected simultaneously.

As a result of these and other efforts, we hope that epidemiologists will become increasingly aware of the regulatory implications of their work. As a result, they may find ways to modify their studies in order to make them more compatible with the needs of economic benefits analysis. EPA, for its part, will continue to encourage and support cooperative efforts between the two professions.

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