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POLICY RESEARCH WORKING PAPER 1260

When Is a Life Too Costly to Save?

Evidence from U.S. Environmental Regulations

George L. Van Houtven
Maureen L. Cropper

Are the amounts spent to save a life under U.S. regulations acceptable to U.S. citizens? Or should those amounts be made more explicit to encourage public debate on health and safety regulation? To the second question, the authors say, "Yes."

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Summary findings

Except for two relatively minor statutes, U.S. environmental laws do not permit the balancing of costs and benefits in setting environmental standards. The Clean Air Act, for example, prohibits the Environmental Protection Agency (EPA) from considering costs in setting ambient air quality standards. Similarly, the Clean Water Act does not allow consideration of benefits in setting effluent standards. When the EPA *is* allowed to balance benefits against costs, it has considerable discretion in defining "balancing."

Van Houtven and Cropper ask two questions: Whether allowed to or not, has the EPA balanced costs and benefits in setting environmental standards? Where has the EPA drawn the line in deciding how much to spend to save a statistical life?

Their answers are based on data about the costs and benefits of regulations involving three classes of pollutants: cancer-causing pesticides used on food crops (1975–89); carcinogenic air pollutants (1975–90); and all uses of asbestos regulated under the Toxic Substances Control Act. These are their findings, in brief:

- The EPA behaved as though it were balancing costs and benefits in its regulation of pesticides under FIFRA and of asbestos under TSCA, the two so-called balancing statutes. The higher the cost of the ban, the less likely the EPA was to ban the use of these products. The greater the number of lives saved, the more likely the EPA was to ban their use.
- But the amount the EPA was (implicitly) willing to spend to save a life was high: $52 million to prevent cancer among pesticide applicators, and $49 million to avoid cancer through exposure to asbestos.
- The value the EPA attached to saving a life was higher for workers than for consumers. The value attached to avoiding a case of cancer through exposure to pesticide residues on food was less than $100,000, in contrast with the $52 million value of preventing cancer among pesticide applicators — perhaps because workers are exposed to higher levels of pollution than consumers.
- After 1987, when the Natural Resources Defense Council sued the EPA for considering costs in setting emissions standards for vinyl chloride, the EPA considered costs in setting emissions standards only after an acceptable level of risk was achieved.
- Ironically, before the vinyl chloride decision, the value per cancer case avoided was only $15 million. The amount the EPA was willing to spend to save a life was thus less under the Clean Air Act than under the balancing statutes. But after this decision, the EPA did not consider costs at all if the risk of cancer to the maximally exposed individual was above one in 10,000.

This paper — a product of the Environment, Infrastructure, and Agriculture Division, Policy Research Department — is part of a larger effort in the department to see what lessons can be learned about efficient control of pollution by examining the U.S. experience with environmental regulation. The study was funded by the U.S. Environmental Protection Agen through Cooperative Agreement CR-818454-01-0. Copies of this paper are available free from the World Bank, 1818 Street NW, Washington, DC 20433. Please contact Anna Maranon, room N5-035, extension 39074 (34 pages). Mar 1994.

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WHEN IS A LIFE TOO COSTLY TO SAVE?

The Evidence from U. S. Environmental Regulations

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WHEN IS A LIFE TOO COSTLY TO SAVE?
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George L. Van Houtven and Maureen L. Cropper

Developing countries, when writing Environmental Action Plans, can learn much from the United States experience in regulating environmental risks. A notable feature of environmental legislation in the U.S. is that, with the exception of two relatively minor statutes, environmental laws do not permit the balancing of benefits and costs in setting environmental standards. In the Clean Air Act, for example, EPA is prohibited from considering costs in setting ambient air quality standards. Similarly, benefits are not to be considered in setting effluent standards under the Clean Water Act. When EPA is allowed to balance benefits against costs, it is given considerable discretion in defining what is meant by "balancing". This is the case under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), which governs pesticide use, and the Toxic Substances Control Act (TSCA), which controls the use and manufacture of toxic substances.

We ask two questions in this paper:

(1) Whether allowed to or not, has EPA balanced benefits and costs in setting environmental standards?

(2) Where has EPA drawn the line in deciding how much spend to save a statistical life?

To answer these question we have gathered data on the benefits and costs of regulations involving three classes of pollutants:

(1) all cancer-causing pesticides used on food crops that went through EPA's Special Review program between 1975 and 1989;

(2) all carcinogenic air pollutants for which EPA set National Emissions Standards (NESHAPs) between 1975 and 1990;

(3) all uses of asbestos regulated under the Toxic Substances Control Act.

In each case the substances regulated are carcinogens, so that we have quantitative estimates of the benefits of each regulation (i.e., the number of lives saved), as well as the costs. [All estimates are provided by EPA.] Using modern statistical techniques we have, for each class of regulations, estimated a model to explain the decisions issued. Since each class of regulations saves lives, we have also estimated a threshold value-per-statistical-life-saved above which EPA was unlikely to issue a regulation.

Our findings are as follows:

1. EPA behaved as though it was balancing benefits and costs in its regulation of pesticides under FIFRA and of asbestos under TSCA, the two balancing statutes. The agency was less likely to ban a use of asbestos (or of a pesticide) the higher the cost of the ban. It was more likely to ban a use of a pesticide (or of asbestos) the greater the number of lives saved.

2. The amount that EPA was (implicitly) willing to spend to save a life was, however, high: The value of avoiding a case of cancer among pesticide applicators was $52 million (1989 dollars), while the value of avoiding a cancer case through exposure to asbestos was $49 million (1989 dollars). When asked to balance the benefits of regulation against the cost, EPA has, implicitly, been willing to spend considerable sums to save a human life.

3. The value attached to saving a life was, moreover, higher for workers than for consumers. The value attached to avoiding a case of cancer through exposure to pesticide residues on food was less than $100,000, in contrast to the $52 million value of avoiding a cancer case among pesticide applicators. A possible explanation for this is the fact that workers are, on average, exposed to much higher levels of pollution than consumers. It is also more likely that occupational cancers can be traced to a particular pollutant than can non-occupational cancers.

4. With regard to emissions standards for hazardous air pollutants, issued under a non-balancing statue, EPA acted as though it had considered both the number of cancer cases avoided and regulatory costs in issuing regulations prior to 1987. In that year, it was sued by the Natural Resources Defense Council, an environmental advocacy group, for considering costs in setting emissions standards for Vinyl Chloride. After the Vinyl Chloride decision, the agency considered costs in setting emissions standards only once an acceptable level of individual risk was achieved.

5. Ironically, prior to the Vinyl Chloride decision the value per cancer case avoided implied by the NESHAPs was only $15 million (1989 dollars). The amount EPA was willing to spend to save a life was thus less under the Clean Air Act than under the so-called balancing statutes. After this decision, however, EPA did not consider costs at all if the risk of cancer to the maximally exposed individual was above 1 in 10,000.

These findings raise two questions. The first is obvious: Are the amounts spent to save a life under the regulations studied here acceptable to citizens in the U.S.? The second is: Should these amount be made more explicit in order to encourage public debate on health and safety regulation? To the authors, the answer to the second question is undoubtedly "yes".

WHEN IS A LIFE TOO COSTLY TO SAVE? THE EVIDENCE FROM U. S. ENVIRONMENTAL REGULATIONS

I. Introduction

Under various environmental statutes the U. S. Environmental Protection Agency (EPA) is responsible for issuing regulations to protect the public from exposure to pollution. These regulations include outright bans of certain products (some pesticides, products containing asbestos) and, more commonly, limitations on the amount of pollution a factory or vehicle can emit.

Most economists would argue that these regulations should be made--at least in part-- on the basis of benefit-cost analyses: an environmental standard should be set where the marginal cost of setting a slightly more stringent standard outweighs the marginal benefit of increased stringency. EPA, however, is sometimes restricted by Congress in what factors it can consider in issuing regulations. For example, under those provisions of the Clean Air Act pertaining to ambient standard-setting, costs cannot be taken into account, whereas for effluent standards under the Clean Water Act, costs are to be considered but benefits are not. Only two environmental statutes--the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and the Toxic Substances Control Act (TSCA)--actually require that the benefits and costs of regulation be balanced in setting environmental standards.

In this paper we investigate whether EPA has balanced costs and benefits in issuing regulations, regardless of whether it is allowed to do so by law. Our definition of "balancing" is as follows. If we examine a class of EPA regulations--for example, emissions standards for toxic air pollutants--do variations in costs and benefits across possible regulatory options help explain the standards selected? We shall conclude that EPA has taken both costs and benefits into consideration if (other things equal) a more costly standard is less likely to be selected, and a standard that saves more lives is more likely to be selected.

Intuitively, however, balancing requires more than this. It requires that the cost EPA is willing to incur to save an additional life be "reasonable". For each class of regulations that we examine, we calculate the implicit cost that EPA is willing to incur to save an additional life--the value of a statistical life implied by the regulations. The most important question is how this value compares with society's apparent willingness to pay to save the lives of people exposed to pollution: Is the value of a statistical life implicit in environmental regulations acceptable? It is also important to ask how this value varies across EPA program offices and across population groups. Is the value of a life saved higher for pesticide regulations than for air toxics? Does the agency implicitly attach more weight to saving the life of a worker exposed to pesticides or asbestos on the job than to the life of a consumer exposed to these pollutants?

A related issue that we examine is how EPA balances high risks to a relatively small number of individuals against smaller risks to larger populations. The definition of life-saving benefits used by economists--the expected number of lives saved in a population--implies that population risk is the regulatory outcome of interest. Much of environmental regulation is, however, based on the notion of reducing <u>individual</u> risk to an acceptable level. The notion of risk equity requires that risk of death to the person who is most highly exposed to a pollutant (the so-called "maximally exposed individual" or MEI) be reasonable. One of the issues we examine is how much weight EPA has given to individual risk versus population risk in its regulations.

To address these topics, we have gathered data on the costs and benefits associated with three categories of pollutants that the agency regulates:

(1) all cancer-causing pesticides used on food crops that went through EPA's Special Review process between 1975 and 1989;

(2) all uses of asbestos regulated under the Toxic Substances Control Act (TSCA);

(3) all carcinogenic air pollutants for which EPA set National Emissions Standards (NESHAPs) between 1975 and 1990.

In each case, data were gathered for each source of the pollutant (each crop in the case of pesticides), giving us a total of 245 pesticide regulations, 39 sources of asbestos regulated under TSCA and 40 sources of four hazardous air pollutants--benzene, inorganic arsenic, radionuclides and vinyl chloride.

Our study is limited to the regulation of carcinogens because quantitative risk data are available more often for carcinogens than for other substances. This implies that the benefits of the regulation (the number of lives saved) can be quantified. We have also purposely selected some regulations issued under the two balancing statutes--TSCA and FIFRA--as well as regulations issued under the Clean Air Act (the setting of emissions standards for hazardous air pollutants) to see whether the enabling legislation makes any difference in the way in which EPA balances benefits and costs.

For each class of pollutants we estimate a model to explain EPA's regulatory decisions. Section II of the paper presents a model to explain whether EPA banned or did not ban each of the 39 uses of asbestos considered for regulation under TSCA. In section III a similar model is estimated to explain EPA's decision to ban or not ban a pesticide (e.g., alachlor) for use on a particular crop (e.g., corn). In the case of hazardous air pollutants, the model presented in section IV explains why EPA selected the regulatory option that it did out of all the options considered for regulating each source of the pollutant. Section V presents our conclusions.

II. Asbestos Regulations Under TSCA

In 1985 EPA announced its intent to ban the use of asbestos in 39 products under the Toxic Substances Control Act. Because TSCA is a balancing statute, EPA's Notice of Intent to Regulate was followed by a detailed assessment of the risks of exposure to asbestos fibers, as well as the costs of the ban (USEPA 1989).

There is well-documented epidemiological evidence (as well as support from animal studies) indicating that some forms of asbestos are human carcinogens. This evidence is particularly strong for lung cancer, gastrointestinal cancer and mesothelioma, a cancer of the lung or abdominal lining. Estimating the number of cancer cases associated with a particular asbestos-containing product (e.g., brakes lined with asbestos) requires estimates of the potency of asbestos--the likelihood of developing cancer as a function of asbestos exposure--as well as an estimate of exposure--the number of fibers inhaled as a result of using the product. In the Regulatory Impact Analysis accompanying EPA's final rule, the agency presented, for each product, exposure estimates (in millions of fibers inhaled per year) for various groups of workers and for consumers, as well as the number of cancer cases associated with each source of asbestos. Table 1 presents EPA's estimates, on a product-by-product basis, of the number of cancer cases that would be avoided if each product were banned in 1992. EPA was able to estimate these, and the cost of the ban, for 31 of the 39 products considered for regulation.

Estimates of cancer cases avoided are based on 13 years of exposure, since the agency assumed that asbestos would be phased out of these products after a 13-year period. Two points about these estimates are worth noting. First, the agency made no distinction as to when the cancer cases would occur. Estimates by Mauskopf (1987) suggest that 50 percent of the cancer cases listed in Table 1 would occur between 2025 and 2054, while 30 percent would occur after 2054, due to the long latency period associated with asbestos. Second, in estimating the number of cancer cases avoided by banning asbestos, EPA assumed that all substitutes for asbestos were riskless, an assumption of dubious validity.[1]

To calculate the costs of the ban, EPA estimated the lost consumer-plus-producer surplus that would result if alternatives to asbestos were used. Column 2 of Table 1 presents estimates of these losses, discounted at 3 percent.[2] The cost per life saved (column 2 divided by column 1) appears in column 3.

A. The Value of A Cancer Case Avoided

A plot of regulatory costs and cancer cases avoided for the 31 products for which complete data are available (see Figure 1) suggests that EPA indeed considered benefits and costs in issuing the asbestos decision: Products in the northwest corner of Figure 1, showing

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[1] Because our goal is to capture the information available to the agency at the time of each decision, we use official agency estimates of risks and benefits, even when these do not accurately measure the risk reduction associated with the ban, or the social costs of the ban.

[2] It is EPA's practice to discount the costs of a regulation but not the benefits. Such a practice is difficult to justify, and was, in part, responsible for the Fifth Circuit Court of Appeals overturning the regulations examined in this section (Corrosion Proof Fittings, 947 F. 2d at 1218.)

low costs and high numbers of lives saved, are almost always banned, while products in the southeast corner, with high costs and low numbers of lives saved are, for the most part, not banned.

Since cancer cases avoided are the only benefits of the asbestos ban mentioned by EPA (i.e., ecological risks were not a factor in the decision to ban asbestos-containing products), it is tempting to infer from Figure 1 a threshold value of a cancer case avoided below which all products were banned. The two solid lines in Figure 1 correspond to values of a statistical life of $10 million and $100 million dollars, respectively. Clearly, neither line fits the data perfectly: The rules "ban all products with cost per life saved ratios below $10 million ($100 million) dollars" yield incorrect predictions for some products.

To compute the threshold value of a cancer case avoided implied by the asbestos regulations we estimate a probit model that predicts the probability that asbestos was banned for use in each product. Formally, we assume that the use of asbestos is banned in product i if the value of the cancer cases avoided (aM_i) minus the cost of the ban (bC_i, $b < 0$) are positive,

$$aM_i + bC_i > 0. \qquad (1)$$

This is equivalent to banning asbestos in product i if the cost per life saved, C_i/M_i, falls below $-a/b$, which is the threshold value of a cancer case avoided.

Since equation (1) does not fit the data perfectly, we estimate equation (2),

$$P(Ban_i) = P(aM_i + bC_i + u_i > 0), \qquad (2)$$

where u_i is an error term that captures other factors, e.g., political considerations, that influenced the decision.

When equation (2) is estimated using the data in Table 1, coefficients a and b are statistically significant (see column 1 of Table 2), and the implied threshold value of a cancer case avoided is $49 million (1989 dollars).

It is interesting to contrast this threshold with the average cost per cancer case avoided. In the *Regulatory Budget of the United States*, the Office of Management and Budget (OMB 1993) frequently lists various health and safety regulations in order of their average cost per life saved. The regulations with the highest cost per life saved are often environmental regulations. It is clear from Table 1 that, by focusing on automatic transmission components, with an average cost per cancer case avoided of $500 million, OMB could make EPA's asbestos regulations look bad. We believe that a more accurate description of the regulations is the threshold value computed in Table 2.

A value of $49 million per life saved is, nonetheless, high--especially in contrast to estimates of the value of a statistical life based on willingness to pay for risk reductions. Estimates of the value of a statistical life based on compensating wage differentials (Fisher, Violette, and Chestnut 1989; Viscusi 1992) suggest that workers in risky jobs require compensation on the order of $5 million per statistical life. While this compensation is for risks that are voluntarily borne, it is hard to imagine that the additional premium associated with involuntary risks is $44 million.

The threshold value of life implied by the asbestos regulations may, in fact, be higher than $49 million for three reasons. As noted above, EPA failed to acknowledge the timing of cancer cases avoided, even though it discounted the costs of the ban. If all cancer cases were avoided in 10 years rather than today, and if these cases were discounted at a rate of 3 percent, the threshold value estimated in Table 2 would rise to $65 million (1989 dollars). The threshold value is also biased downward because EPA ignored the risks of asbestos substitutes, and thus overstated the risk reduction that would follow a ban. Finally, many believe that EPA's risk assessment methodology results in "maximum plausible upper bound" estimates of risk. This implies that the expected number of cancer cases avoided is smaller than the numbers in Table 1 and, therefor, that the value of a cancer case avoided is larger.

Both of these factors were considered by the Fifth Circuit Court of Appeals in the Corrosion Proof Fittings case.[3] In this case, which overturned the asbestos ban, the court ruled that EPA had failed to take account of the timing of lives saved, and had ignored the health risks of asbestos substitutes. It was also determined that EPA had given insufficient weight to regulatory costs. In other words, the costs of the asbestos ban were too high relative to the benefits.

B. Occupational v. Non-Occupational Exposure

In Table 1 no distinction is made between cancer cases that result from occupational exposure to asbestos and those that do not.[4] Because workers are, in general, exposed to higher

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[3] Corrosion Proof Fittings, 947 F.2d at 1218.

[4] Although the Department of Labor's Occupational Safety and Health Administration (OSHA) traditionally has the task of regulating worker exposure to toxic substances, EPA has the responsibility for regulating occupational exposures to pesticides and to toxic substances that fall under the jurisdiction of the Toxic Substances Control Act.

levels of asbestos than consumers, EPA may weight worker risks differently from consumer risks in deciding which products to ban. Equation (2) is easily modified to distinguish between occupational and non-occupational cancer cases avoided. Letting M_{1i} represent occupational cancer cases avoided and M_{2i} non-occupational cancer cases, (2) becomes

$$P(Ban_i) = P(a_1M_{1i} + a_2M_{2i} + bC_i + u_i > 0). \qquad (3)$$

The ratios of the coefficients $-a_1/b$ and $-a_2/b$ measure, respectively, the value that EPA attaches to each type of cancer case. The corresponding geometric interpretation, if one plots C, M_1 and M_2 in three dimensions, is that EPA will ban all products whose cost falls below the plane $Z = -a_1/bM_{1i} - a_2/bM_{2i}$.

Unfortunately, reductions in occupational and non-occupational cancer cases are highly correlated. This is reflected in the second column of Table 2, which shows the effect of separating cancer cases avoided into the two categories. While higher values of each benefit variable significantly increase the chances that a product is banned, neither variable is statistically significant at conventional levels. It is, nonetheless, interesting to note that the coefficient of occupational incidence reduction is about twice the coefficient of non-occupational incidence reduction. These coefficients imply, respectively, values per cancer case avoided of \$71 million and \$34 million.

EPA's tendency to value reductions in occupational exposures more highly than reductions in non-occupational exposures is confirmed below, in our analysis of pesticide regulations. The result is not surprising for two reasons. First, workers are, on average, exposed to much higher levels of asbestos than consumers. It is certainly reasonable that risk reductions be valued more highly, the higher is baseline risk.[5] Second, workers constitute an identified group, whose deaths from cancer are more easily linked to a specific source of exposure than are the deaths of consumers. In this sense the cost of not regulating ("making a mistake") is potentially higher for workers than for consumers.

On the other hand, to the extent that workers may already receive compensating wage differentials for exposure to asbestos, and, to the extent that their exposure is more voluntary than consumers', it is hard to justify the higher weight assigned to reducing occupational exposures.

III. Pesticide Regulations Under FIFRA

Under FIFRA, EPA is responsible for insuring that all pesticides used in the United States do not have "unreasonable adverse effects on the environment." If EPA suspects that a pesticide poses risks to human health or to ecosystems, the pesticide--or, more accurately, the active ingredients used in the pesticide--are subject to a Special Review.[6] This entails a formal risk-benefit analysis of the pesticide, after which EPA can either ban the pesticide for use on

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[5] In the game of Russian Roulette, an individual is certainly willing to pay more to remove the first of six bullets from the chamber of a gun than he is willing to pay to remove the last bullet.

[6] In the 1972 amendments to FIFRA, EPA was given the task of reregistering the 50,000 pesticides in use in the United States at that time. In the 1978 amendments to FIFRA, this task was simplified by requiring reregistration of the 600 active ingredients used in the pesticides.

specific crops, restrict the manner in which the pesticide is applied, or allow its continued use, without modification.

Between 1975, when EPA initiated its first Special Review, and December of 1989, Special Reviews were completed for 37 active ingredients. Our analysis is restricted to the subset of these active ingredients that are suspected human carcinogens. Since, in principle, EPA can ban the use of an active ingredient on one crop but not on another, the number of possible regulations that can be issued for each active ingredient is equal to the number of crops on which the active ingredient is used. As shown in Table 3, the 19 active ingredients examined were registered for use on a total of 245 food crops. We have restricted the analysis to food crops so that estimates of dietary cancer risk are available, as well as risk of cancer to mixers and applicators of pesticides.

In considering whether or not to ban a pesticide, EPA examines risks of cancer to persons occupationally exposed to the pesticide--pesticide mixers and loaders and pesticide applicators--as well as to consumers of pesticide residues on food. Non-cancer health risks--risks of miscarriages or of possible fetal damage--are also examined. In addition, EPA considers adverse effects of pesticide exposure to fish, birds and mammals. Against the risks of pesticide use, EPA is to balance the benefits of use--the reduction in consumer and producer surpluses that would result if the pesticide were banned.[7]

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[7] In practice, consumer surpluses are rarely computed. Instead, the benefits of pesticide use are measured as the cost of switching to substitute products, plus the value of resulting yield losses. These are usually quantified only for the first year after the proposed ban, and thus overstate the losses that would occur if better substitutes were developed for the banned pesticide.

Table 4 contains the means and standard deviations of risk and benefit variables for 245 pesticide-crop combinations, separated according to whether or not the combination was eventually banned.[8] Cancer risk measures the number of cancer cases, per million exposed workers or consumers, that are likely to develop as the result of a lifetime of exposure to the pesticide.[9] These numbers thus represent the average risk to an individual worker or consumer, and must be multiplied by the size of the exposed population to calculate the number of cancer cases that would result from pesticide exposure.[10] Since data on the size of the exposed population are not always reported, we treat the size of the exposed mixer/loader, applicator and consumer populations as constant across crop/pesticide combinations. The mixer/loader population is assumed to be 1,000 workers, the applicator population 10,000 workers, while the relevant population for calculating dietary risks is the entire U.S. population.

Evidence of reproductive risks (risk of fetal deformity, lowered sperm count, or increased risk of miscarriage) are measured by a dummy variable, as are risks to marine life. EPA also distinguishes risks to birds and mammals; however, if an active ingredient harms mammals (birds), it always harms marine life. The same "subsetting" problem occurs if an active ingredient is a mutagen or a teratogen; i.e., a substance that is a mutagen (teratogen) necessarily causes adverse reproductive effects.

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[8] All data were obtained from official Position Documents that accompanied EPA's Notice of Final Determination.

[9] The measurement of risks and benefits is discussed in more detail in Cropper et al. (1992a).

[10] To illustrate, if dietary cancer risk is 1 cancer case per million exposed persons, and the size of the exposed population is 250 million, we would expect to observe 250 cancer cases in the exposed population.

The benefits of pesticide use are measured as producer losses in the first year after cancellation, as reported by EPA. All benefits are in 1986 dollars. When benefit data are missing, a dummy variable is used to indicate whether yield losses are predicted to occur if the pesticide is banned.

A. A Model of Pesticide Regulation

It is tempting to plot the cost of pesticide bans against the number of cancer cases avoided, as was done for asbestos regulations (see Figure 1); however, such a diagram would be misleading here. Because there are benefits to banning a pesticide besides cancer cases avoided, the threshold inferred from such a diagram would overstate the value that EPA implicitly attaches to reducing cancer risks.

A better approach is to extend the probit model of equation (3) to include non-cancer benefits, and to use the resulting coefficients to infer the value attached to avoiding a cancer case for each of the three population groups. To estimate such a model we must confront the problem of missing data. As Table 4 indicates, data on cancer risks to the three groups of interest are sometimes missing--either because estimates of exposure are not available, or because there are insufficient toxicological studies to quantify the potency of the chemical. In these cases we enter a zero for the risk variable, but include a missing data dummy to distinguish these cases from instances where the actual risk estimate is zero. The coefficient of each cancer risk variable therefore measures the effect of cancer risk, assuming that risk data are available.

A probit model that predicts the probability of a pesticide ban appears in the first column of Table 5. The model suggests that EPA has considered both the risks and benefits of pesticide use in issuing regulations. The benefits of pesticide use, which measure the cost of the regulation, are significant and of the expected sign: the higher the benefits of pesticide use, the less likely it is that a pesticide is banned. The absence of benefit data also reduces the likelihood that a pesticide is banned, regardless of whether the ban will reduce crop yields.

The benefits of pesticide regulation are also important in explaining which uses of a pesticide are banned and which are not. To EPA, the benefits of banning a pesticide are equivalent to the risks associated with its use, since alternatives to the pesticide are, in effect, assumed riskless. Other things equal, higher risks of cancer to pesticide applicators--the group with the highest average exposure--significantly increase the probability that a pesticide is banned. The value of a cancer case avoided among applicators is $45.58 million (1986 dollars). When converted to 1989 dollars this figure--$51.51 million--is remarkably close to the value obtained from asbestos regulations, although it is estimated with less precision. [The standard error for the estimate (in 1989 dollars) is $30.22 million.]

What is perhaps surprising is that neither risks to mixer/loaders of pesticides nor dietary risks are significant in explaining pesticide decisions. Elsewhere (Cropper et al. 1992a; 1992b) we have modified the model estimated here to include comments by affected parties environmental advocacy groups, grower organizations) on the decision to ban a pesticide. We note that, while such modifications increase the predictive power of the model, they do not alter the lack of significance of risks to mixer/loaders. Likewise, dietary cancer cases avoided, while sometimes significant in explaining the decision to ban a pesticide, always have an implied value below $100,000.[11]

The lack of significance of risks to mixer/loaders can, perhaps, be explained by the large proportion of missing observations (69%) for this variable. The negligible value attached to avoiding dietary cancer cases is harder to explain. While one would expect this value to be lower than the corresponding value for applicators, based on differences in baseline risk, one would not necessarily expect the value to be so small. One possible explanation is that regulators discount estimates of dietary risk due to the conservative way in which estimates of dietary exposure are calculated. For example, EPA estimates that 200 cancer cases occur each year as a result of eating macadamia nuts sprayed with benomyl, while an additional 200 cases are caused by ingesting almonds sprayed with the fungicide. These very large numbers assume that benomyl residues will remain on the nuts at the maximum levels allowed by law, whereas, in fact, most residues disappear by the time the product is eaten.

B. Individual v. Population Risk

While economists typically measure mortality benefits by the number of lives that a regulation saves, the language of environmental statutes often refers to the concept of acceptable risk--the notion that no individual should have to bear a large risk of death from any one source. Some observers of environmental regulation (Travis et al. 1987) have gone so far as to suggest

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[11] It is interesting to note that lack of risk data for either dietary or mixer risks significantly reduces the probability that a pesticide is banned, suggesting that the "burden of proof" falls on EPA to prove that a health risk exists.

that EPA balances risks and benefits in issuing regulations only if the level of risk to any one individual is below an acceptable level.

To test this hypothesis against the alternative theory that balancing occurs at all levels of individual risk--the hypothesis implicit in the probit models of equations (2) and (3) --we estimated the model

$$\begin{aligned} P(\text{Ban}) &= 1 && \text{if } R_i > R_{Ai} \text{ for any } i, \\ P(\text{Ban}) &= \text{Eq. (3)} && \text{if } R_{Ai} < R_i, \text{ for all } i. \end{aligned} \qquad (4)$$

where R_{Ai} denotes the level of acceptable risk for group i. Equation (4) implies that a pesticide is banned for use on a particular crop if individual risk to any one group exceeds the acceptable level for that group.

Maximum likelihood estimates of equation (4) appear in the second column of Table 5. The level of acceptable risk for applicators is quite high: Only if lifetime cancer risk to applicators exceeds 1 in 100 does the model predict that a pesticide will be banned, regardless of cost. The corresponding acceptable risk levels for mixer/loaders and consumers are much lower--3 in 100,000 for mixer/loaders and 2 in 10,000 for consumers. Below acceptable risk levels, risks and benefits are both significant in explaining the likelihood that a pesticide is banned, and the implied value per applicator cancer case avoided is $47.46 million (1989 dollars).

A test of the conventional probit model against the acceptable risk model, however, indicates that the probit model cannot be rejected at either the 1 percent or 5 percent levels.[12] The notion of acceptable risk does not, therefore, provide a better explanation of pesticide regulations than a conventional probit model which assumes lives saved and regulatory costs are balanced at all levels of individual risk.

IV. National Emissions Standards for Hazardous Air Pollutants

In contrast to regulations issued under TSCA and FIFRA, the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) were, according to the 1970 Clean Air Act (CAA), to be set to protect human health, without considering costs. As we shall see, however, EPA did consider costs in setting emissions standards for sources of air toxics, at least before 1987. In 1987 the agency was successfully sued by the Natural Resources Defense Council for that interpretation. The ruling in this case, as demonstrated below, had a pronounced effect on EPA's subsequent setting of standards for air toxics.

Section 112 of the CAA requires EPA to regulate the so-called toxic air pollutants--substances such as benzene, arsenic, asbestos and mercury. These pollutants are not as ubiquitous as the "criteria" pollutants (e.g., particulates, sulfur oxides, carbon monoxide) for which EPA is to set ambient air quality standards, but are nonetheless harmful to human health. According to the 1970 CAA, EPA was first to establish a list of toxic air pollutants and then to set emissions limits for various sources of each pollutant. Between 1970 and 1990 only 7 such

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[12] The likelihood ratio test statistic is 7.80. The critical value of the chi-squared distribution at the .05 level of significance is 7.82.

substances were regulated--asbestos, beryllium, mercury, vinyl chloride, benzene, inorganic arsenic and radionuclides. Five of these are carcinogens, but quantitative risk data are available for only four--vinyl chloride, benzene, inorganic arsenic and radionuclides. It is the regulation of these substances that we examine.

Table 6 lists the various sources of vinyl chloride, benzene, inorganic arsenic and radionuclides that EPA sought to regulate. In each case, the agency considered at least one regulatory option that would reduce emissions of the toxic pollutant, as well as the option of no regulation. For each option, the agency computed the cost of the option, the number of cancer cases that would occur if the option were chosen, and the post-regulation maximum individual risk (MIR). The latter measures the risk to the maximally exposed individual--the person who receives the greatest dose of pollutant from the source. For most sources of air toxics this is not a worker who is occupationally exposed, but rather a resident who lives near the source; for example, the person whose house is nearest to a copper or lead smelter.[13]

One of the distinguishing features of toxic air pollutants, as opposed to the so-called "criteria" (or common) air pollutants, is that they are not as widespread: They tend to pose large risks to a few individuals rather than small risks to many people. The notion of maximum individual risk captures this aspect of air toxics.

To see the importance of maximum individual risk versus population risk in the regulation of air toxics, Figure 2 plots, for each source, the level of maximum individual risk (lifetime risk of cancer to the MEI) and annual cancer cases that would have occurred in the

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[13] Maximum individual risk is quite different from the measure of individual risk computed in pesticide regulations. The latter is based on average rather than upon maximum exposure to the pollutant.

absence of regulation. Recall that, in the case of pesticides, a pesticide was <u>always</u> banned if dietary risk exceeded 1.7 in 10,000. Figure 2 indicates that sources of air toxics were <u>never</u> regulated unless maximum individual risk <u>exceeded</u> 1 in 10,000. This suggests that the level of acceptable risk was considerably higher for air toxics than for pesticides.

To examine the trade off between benefits and costs in the regulation of air toxics we estimated a multinomial logit model. Specifically, we assumed that the utility of regulatory option i was a function of the reduction in cancer cases from choosing option i (rather than doing nothing), M_i, and the cost of the option (compared to doing nothing), C_i,

$$U_i = aM_i + bC_i + e_i. \qquad (5)$$

In equation (5) e_i represents unmeasured costs and benefits of the regulatory option. The model assumes that the regulatory option is selected that yields the highest utility; thus the option with the highest U_i is selected assuming U_i is positive. If U_i is negative for all i, no regulation is undertaken.

The results of estimating the multinomial logit model suggest that EPA in fact balanced cancer incidence reduction against cost. When the model is estimated using all 40 sources of air toxics (see column 1 of Table 7), the coefficients of both cancer incidence reduction and cost are significant at the .05 level. The implied value per cancer case avoided is, however, high--$153 million (1989 dollars).

These results, however, are somewhat misleading, as they fail to distinguish regulations issued before and after the <u>Vinyl Chloride</u> decision. In 1987, the U.S. Court of Appeals for the

District of Columbia, in what has come to be known as the Vinyl Chloride decision,[14] ruled that EPA had improperly considered costs in setting the NESHAPs. EPA was directed to consider costs and technological feasibility only once an "acceptable risk" level had been achieved.

The simplest way in which to incorporate the Vinyl Chloride ruling into the model is to add to the utility function a term that interacts costs with a dummy variable that is equal to 1 if a regulation was issued after 1987. The effect of costs after 1987 is then the sum of the two cost coefficients. When the extra cost variable is added to the multinomial logit model (column 2 of Table 7), the level of significance of each cost variable is reduced compared to the original equation; however, both are marginally significant. The null hypothesis that the sum of the coefficients is zero, i.e., that costs were not considered after 1987, cannot be rejected at the .05 level.

The Vinyl Chloride decision thus appears to have had the desired effect on the setting of subsequent NESHAPs. To illustrate the magnitude of the effect, we note that the value per cancer case avoided implied by regulations prior to 1987 is $15 million, whereas it is $194 million for regulations issued after the decision.

Allowing the Vinyl Chloride decision to alter the weight attached to costs does not, however, capture the "acceptable risk" component of the court's ruling. According to the court, costs were to be ignored only when individual risk was unacceptably high. The dummy variable interacted with costs should therefore equal 1 after 1987 only if option i would reduce Maximum Individual Risk from a level that is unacceptably high.

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[14] Natural Resources Defense Council, Inc. v. EPA, 824 F.2d at 1146 (1987)

The effects of modifying the Vinyl Chloride dummy in this fashion appear in column 3 of Table 7. Statistically, the results are superior to a simple time dummy. Both cost variables, and the reduction in cancer incidence, are significantly different from zero at conventional levels. The results imply that a cancer case avoided is valued at approximately $15 million (1989 dollar) before the 1987 court decision and the same value after so long as maximum individual risk is below 1 in 10,000. After 1987, however, if MIR was above 1 in 10,000, then EPA did not consider costs at all--the sum of the cost coefficients in column 3 is not significantly different from zero.[15]

V. Conclusions

Perhaps the most striking finding of our analysis is that, for all regulations examined, benefit and cost considerations alone explain at least 85 percent of the decisions issued. EPA thus behaved as though it considered benefits and costs in issuing regulations, even when costs were not to be considered in standard setting. The weights attached to benefits and costs, however, imply that EPA has been willing to have consumers and firms incur substantial costs to save one statistical life. Under the two balancing statutes--TSCA and FIFRA--the implicit value per cancer case avoided is in excess of $45 million (1989 dollars). An important question is whether members of society agree with this valuation. Compensation for the loss of one statistical life in the workplace is about one-tenth of the value implicit in the TSCA and FIFRA regulations examined here. Compensation for workplace risks, however, is for voluntary

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[15] A test of the null hypothesis that the sum of the cost coefficients in column 3 is significantly different from zero can be rejected at only the 0.11 significance level.

exposure to immediate risk of death. Exposure to pesticides and asbestos may not be voluntary (even for workers) if people are unaware of the risks that result from exposure.

It is also interesting to note that EPA has implicitly attached more weight to saving the lives of those who are occupationally exposed to pesticides and asbestos than to saving the lives of consumers. One reason for this may be that workers, on average, receive much larger doses of pollution than do consumers. In the case of pesticides, for example, the median lifetime cancer risk from pesticide exposure is one in 1,000 for applicators but only one in 100 million for consumers of pesticide residues on food. On the other hand, to the extent that workers may already receive compensating wage differentials for exposure to pollution, the larger weight attached by EPA to saving their lives may not be justified.

Turning to emissions standards for hazardous air pollutants, it is interesting to note that the implied value per cancer case avoided associated with these regulations prior to 1987 is only $15 million (1989 dollars)--less than half the value implied by pesticide or asbestos regulations. After the 1987 Vinyl Chloride decision, however, which admonished EPA not to consider costs unless an acceptable level of risk to the MEI had been achieved, this value jumped to over $200 million (1989 dollars). This raises the question: Do balancing statutes really make a difference? Our analysis of the setting of the NESHAPs suggests that--short of recourse to the courts--prohibitions against considering costs are difficult to enforce. Likewise, Congress may require that the costs of a regulation be balanced against the benefits, but, as long as EPA has discretion in the weights it assigns to costs and benefits, regulations issued under balancing statutes may still be very costly.

Table 1. Costs and Benefits of Banning Asbestos

Product Description	Gross Total Loss (mil. 1989 $)	Cancer Cases Avoided	Cost Per Cancer Case Avoided (mil. 1989 $)
PRODUCTS BANNED			
Drum Brake Linings (A/M)	13.87	136.3872	0.10
Brake Blocks	2.82	12.9784	0.22
Disc Brake Pads LMV (Aftermarket)	5.69	23.2356	0.24
Pipeline Wrap	0.55	1.1196	0.49
Specialty Paper	0.02	0.0330	0.61
Drum Brake Linings (OEM)	7.18	7.6476	0.94
A/C Sheet, Corrugated	0.15	0.0923	1.63
Disc Brake Pads HV	0.32	0.1948	1.64
A/C Sheet, Flat	1.72	0.6752	2.55
Disc Brake Pads LMV (OEM)	3.49	0.9063	3.85
Roofing Felt	4.04	0.9717	4.16
Friction Materials	2.06	0.4719	4.37
Non-Roofing Coatings	2.27	0.3833	5.92
Millboard	5.16	0.7399	6.97
Beater-Add Gaskets	97.94	5.9344	16.50
Clutch Facings	10.93	0.5444	20.08
Roof Coatings	75.63	1.9134	39.53
Sheet Gaskets	85.69	1.9973	42.90
A/C Pipe	178.53	3.9999	44.63
A/C Shingles	31.66	0.4111	77.01
Automatic Transmission Components	0.20	0.0004	500.00
Asbestos Protective Clothing			
Rollboard			
Commercial Paper			
Corrugated Paper			
V/A Floor Tile			
Flooring Felt			
PRODUCTS NOT BANNED			
Asbestos Packing	0.49	0.0114	42.98
Beater-Add Gaskets/2	50.45	1.0472	48.18
Asbestos-Reinforced Plastics	40.58	0.6570	61.77
High Grade Electrical Paper	58.79	0.5107	115.12
Sheet Gaskets/PTFE	31.69	0.2219	142.81
Asbestos Thread, Yarn, etc.	159.15	0.6222	255.79
Sealant Tape	41.19	0.1115	369.42
Acetylene Cylinders	0.08	0.00003	2666.67
Missile Liner	1001.67	0.3161	3168.84
Asbestos Diaphragms	2314.75	0.2140	10816.59
Battery Separators			
Arc Chutes			

Table 2. Factors Affecting the Probability that Asbestos is Banned

Variable Name	(1)	(2)
Intercept	0.31	0.07
	(0.63)[a]	(0.12)
Gross Total Loss[b]	-0.099	-0.17
	(-2.03)	(-1.44)
Cancer Incidence Reduction (No. of Cases)	4.85	
	(2.15)	
Occupational Cancer Incidence Reduction		11.76
		(1.43)
Nonoccupational Cancer Incidence Reduction		5.69
		(1.43)
Log Likelihood	-6.42	-4.91
Percentage of decisions correctly predicted	87.0	87.0
Implicit value of a cancer case avoided[b]	48.61	
	[36.66, 60.55][c]	
Based on non-occupational exposure		34.39
		[6.96, 61.82]
Based on occupational exposure		71.01
		[12.83, 129.19]

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[a] Numbers in parentheses are t-statistics

[b] Millions of 1989 dollars

[c] Numbers in brackets are endpoints of a 95 percent confidence interval

Table 3. Active Ingredients in the Pesticide Database.

DBCP	1978	12	1	12
Amitraz	1979	2	1	1
Chlorobenzilate	1979	3	2	2
Endrin	1979	8	4	4
Pronamide	1979	4	0	0
Dimethoate	1980	25	0	0
Benomyl	1982	26	0	0
Diallate	1982	10	10	0
Oxyfluorfen	1982	3	0	0
Toxaphene	1982	11	7	7
Trifluralin	1982	25	0	0
EDB	1983	18	4	18
Ethalfluralin	1983	3	0	0
Lindane	1983	8	7	0
Silvex	1985	6	6	6
2,4,5-T	1985	2	2	2
Dicofol	1986	4	4	0
Alachlor	1987	10	3	0
Captan	1989	65	65	44
Totals		245	116	96

Table 4. Means and Standard Deviations of Variables Used in Pesticide Model

Variable Name	Uses that Were Banned			Uses that Were Not Banned		
	No. of Observations	Mean	Standard Deviation	No. of Observations	Mean	Standard Deviation
Whether Cancelled	96	1.0	0.0	149	0.0	0.0
Dietary Risk[a]	78	9.6E-4	3.5E-3	94	4.2E-6	1.4E-5
Applicator Risk	63	1.2E-2	2.1E-2	66	1.5E-4	7.3E-4
Mixer Risk	42	2.2E-4	8.8E-4	35	1.2E-5	9.9E-6
Producer Benefits[b]	86	2.943	7.604	81	15.697	41.448
Whether Yield Loss	96	0.240	0.430	149	0.530	0.501
Reproductive Effects	96	0.917	0.278	149	0.517	0.501
Danger to Marine Life	96	0.583	0.496	149	0.470	0.501

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[a] All risks are risks of cancer based on a lifetime of exposure to the pesticide.

[b] Millions of 1986 dollars.

Table 5. Factors Affecting the Probability that a Pesticide is Banned

Variable Name	(1)	(2)
Intercept	-1.493	-0.818
	(-3.016)[a]	(-1.396)
Diet risk per million persons	2.4E-3	-0.022
	(0.668)	(-0.939)
Diet risk missing	-0.733	-0.697
	(-2.153)	(-2.036)
Applicator risk per million persons	5.6E-4	5.4E-4
	(2.406)	(2.268)
Applicator risk missing	-0.146	-0.222
	(-0.309)	(0.482)
Mixer risk per million persons	0.003	-0.052
	(0.391)	(-1.957)
Mixer risk missing	0.251	-0.257
	(0.499)	(-0.452)
Producer benefits[b]	-0.043	-0.045
	(-2.189)	(-2.168)
Producer benefits missing x yield loss	-2.073	-2.153
	(-5.513)	(-5.455)
Producer benefits missing x no yield loss	-1.941	-1.870
	(-4.212)	(-4.049)
Reproductive effects	2.025	2.182
	(4.706)	(4.999)
Danger to marine life	0.251	-0.096
	(0.833)	(-0.299)
R_{max}diet		1.7E-4
R_{max}applicator		1.1E-2
R_{max}mixer/loader		3.1E-5
Log likelihood	-73.6	-69.7
Percentage of decisions correctly predicted	86.0	87.3

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[a] Numbers in parentheses are t-statistics

[b] Millions of 1986 dollars

Table 6. Regulatory Alternatives for Sources of Hazardous Air Pollutants

Source	Substance	Option Chosen (=1)	Year	Maximum Individual Risk (x 1000)	Cancer Incidence	Annual Cost (mil. 89$)
Benzene transfer operations	benzene	0	90	6	1	0
		1	90	0.04	0.02	32.7
		0	90	0.007	0.009	37.06
Bulk gasoline terminals	benzene	1	90	0.05	0.12	0
		0	90	0.01	0.08	57.12
		0	90	0.006	0.08	142.8
Bulk gasoline plants	benzene	1	90	0.01	0.03	0
		0	90	0.002	0.02	38.08
		0	90	0.001	0.01	41.65
Service station storage vessels	benzene	1	90	0.005	0.13	0
		0	90	0.0002	0.06	58.31
		0	90	0.0002	0.05	238
Benzene waste operations	benzene	0	90	2	0.6	0
		1	90	0.05	0.05	98.31
Rubber tire manufacturing (ISU) benzene	benzene	1	90	0.004	0.0006	0
		0	90	0.001	0.0003	14.74
Pharmaceutical manufacturing (ISU)	benzene	1	90	0.001	0.001	0
		0	90	0.00004	0	0.13
Chemical manufacturing process vents	benzene	1	90	0.04	0.01	0
		0	90	0.01	0.008	3.33
		0	90	0.001	0.0004	46.41
Dept. of Energy (DOE) facilities	radionuclides	1	89	0.2	0.28	0
		0	89	0.1	0.25	0.2
NRC-licensed & Non-DOE facilities	radionuclides	1	89	0.16	0.16	0
		0	89	0.1	0.1599	2.4
Uranium fuel cycle facilities	radionuclides	1	89	0.15	0.1	0
		0	89	0.03	0.0999	31
Elemental phosphorous plants	radionuclides	0	89	0.57	0.072	0
		1	89	0.1	0.024	2.4
		0	89	0.01	0.002	22.4
Coal-fired utility boilers	radionuclides	1	89	0.025	0.4	0
		0	89	0.0001	0.2	4400

Table 6 (continued)

Source	Substance	Option Chosen (=1)	Year	Maximum Individual Risk (x 1000)	Cancer Incidence	Annual Cost (mil. 89$)
Coal-fired industrial boilers	radionuclides	1	89	0.007	0.4	0
		0	89	0.001	0.2	1700
Radon releases from DOE facilities	radionuclides	0	89	1.4	0.072	0
		1	89	0.18	0.04	1.5
		0	89	0.1	0.012	2.8
Phosphogypsum stacks	radionuclides	1	89	0.091	0.95	0
		0	89	0.082	0.79	43
Underground uranium mines	radionuclides	0	89	4.4	0.79	0
		1	89	0.3	0.24	0.4
		0	89	0.1	0.09	0.8
Surface uranium mines	radionuclides	1	89	0.048	0.026	0
		0	89	0.024	0.0038	0.8
Operating uranium mill tailings	radionuclides	0	89	0.16	0.014	0
		1	89	0.09	0.009	0.5
Disposal of uranium mill tailings piles	radionuclides	1	89	0.3	0.07	0
		0	89	0.087	0.026	16
Ethylbenzene/Styrene process vents	benzene	1	89	0.02	0.003	0
		0	89	0.01	0.001	0.26
Benzene storage vessels	benzene	0	89	0.13	0.071	0
		1	89	0.03	0.04	0.13
		0	89	0.03	0.03	1.67
Coke by-product recovery plants	benzene	0	89	7	2	0
		1	89	0.2	0.05	19.04
		0	89	0.2	0.03	26.18
Benzene equipment leaks	benzene	1	89	0.1	0.2	0
		0	89	0.03	0.1	89.6
Primary copper smelters	arsenic	0	86	1.3	0.38	0
		1	86	1.3	0.29	0.49
		0	86	1.2	0.2427	37.35
		0	86	1.2	0.2399	42.83

Table 6 (continued)

Source	Substance	Option Chosen (=1)	Year	Maximum Individual Risk (x 1000)	Cancer Incidence	Annual Cost (mil. 89$)
Glass manufacturing plants	arsenic	0	86	0.9	0.4	0
		1	86	0.17	0.07	4.07
		0	86	1.2	0.2307	78.69
Secondary lead plants	arsenic	1	86	0.4	0.39	0
		0	86	n.a.	0.13	18.22
Elemental phosphorous	radionuclides	1	84	1	0.058	0
		0	84	0.5	0.049	0.83
		0	84	0.1	0.023	2.92
		0	84	0.1	0.017	3.45
Coal-fired utility boilers	radionuclides	1	84	0.01	1.4	0
		0	84	n.a.	0.4	4352
Coal-fired industrial boilers	radionuclides	1	84	0.001	1	0
		0	84	n.a.	0.7	704
		0	84	n.a.	0.6	934.4
Maleic anhydride plants	benzene	1	84	0.076	0.029	0
		0	84	0.011	0.025	0.75
Benzene fugitive emissions (existing)	benzene	0	82	1.46	0.45	0
		1	82	0.45	0.14	0.68
		0	82	0.42	0.126	6.32
Benzene fugitive emissions (new)	benzene	0	82	1.46	0.12	0
		1	82	0.45	0.038	0.17
		0	82	0.42	0.035	1.54
EDC/VC and PVC plants	vinyl chloride	0	75	4.86	11	0
		1	75	n.a.	0.55	149.1

Table 7. Factors Affecting Choice of a National Emissions Standard for Hazardous Air Pollutants

Variable Name	(1)	(2)	(3)
Reduction in cancer incidence	9.93 (1.87)[a]	21.64 (2.28)	21.67 (2.07)
Increase in annual cost[b]	-0.065 (-2.36)	-1.33 (-1.60)	1.47 (-1.96)
Increase in annual cost*post 1987 dummy		1.22 (1.53)	
Increase in annual cost*post 1987 dummy *MIR > .0001 dummy			1.37 (1.96)
Log likelihood	-18.84	-14.54	-11.77
Percentage of decisions correctly predicted	74.0	82.0	91.0
Implied value of a cancer case avoided[b]			
1975 - 1990	152.64 [52.07, 252.94][c]		
1975 - 1987		16.2 [2.22, 30.2]	14.73 [10.6, 18.84]
1987 - 1990		194.06 [123.93, 264.19]	216.70 [80.12,353.32]

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[a] Numbers in parentheses are t-statistics

[b] Millions of 1989 dollars

[c] Numbers in brackets are endpoints of a 95 percent confidence interval

Figure 1. Cost-effectiveness of Asbestos Ban

Cost vs. Cancer Cases Avoided

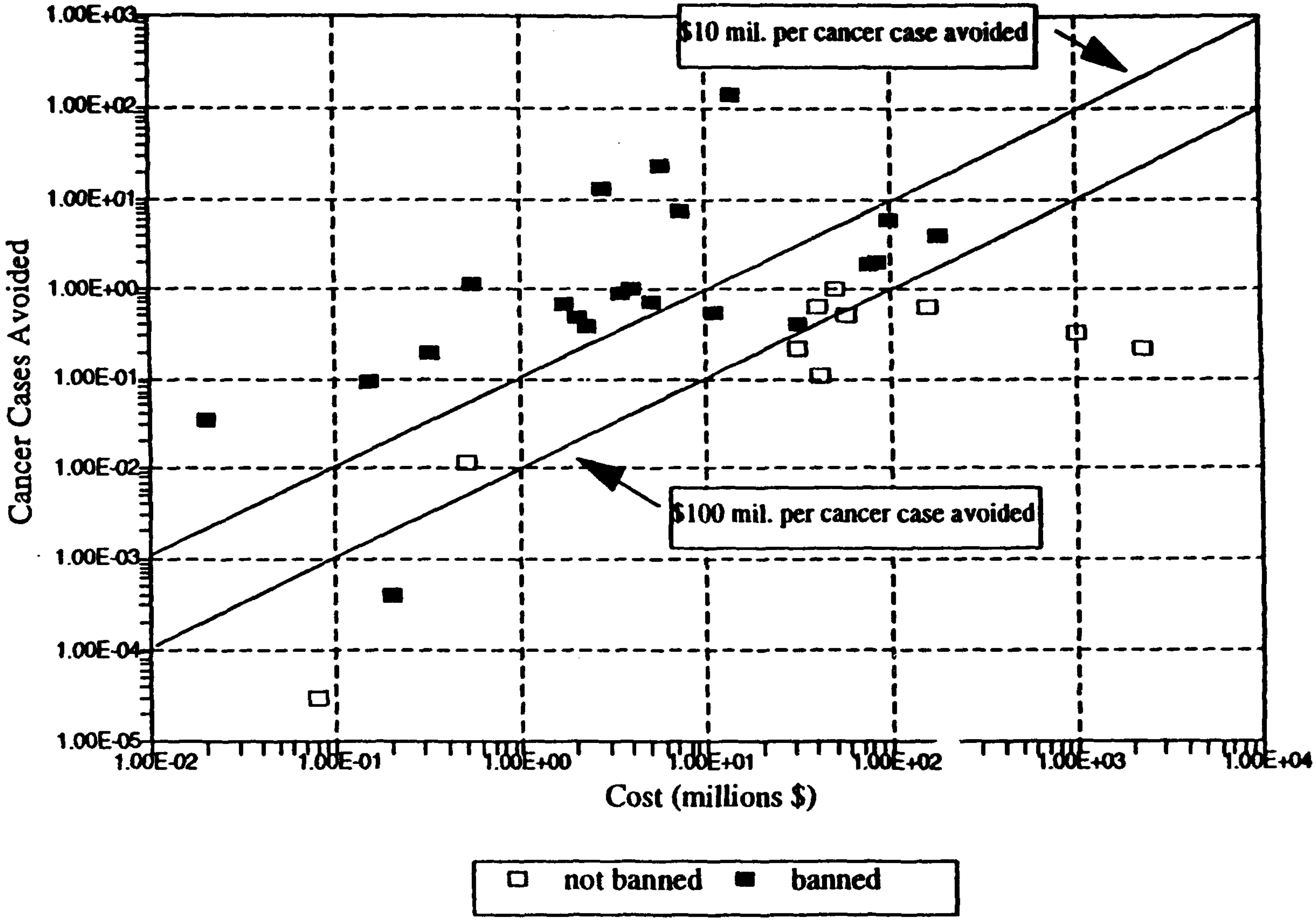
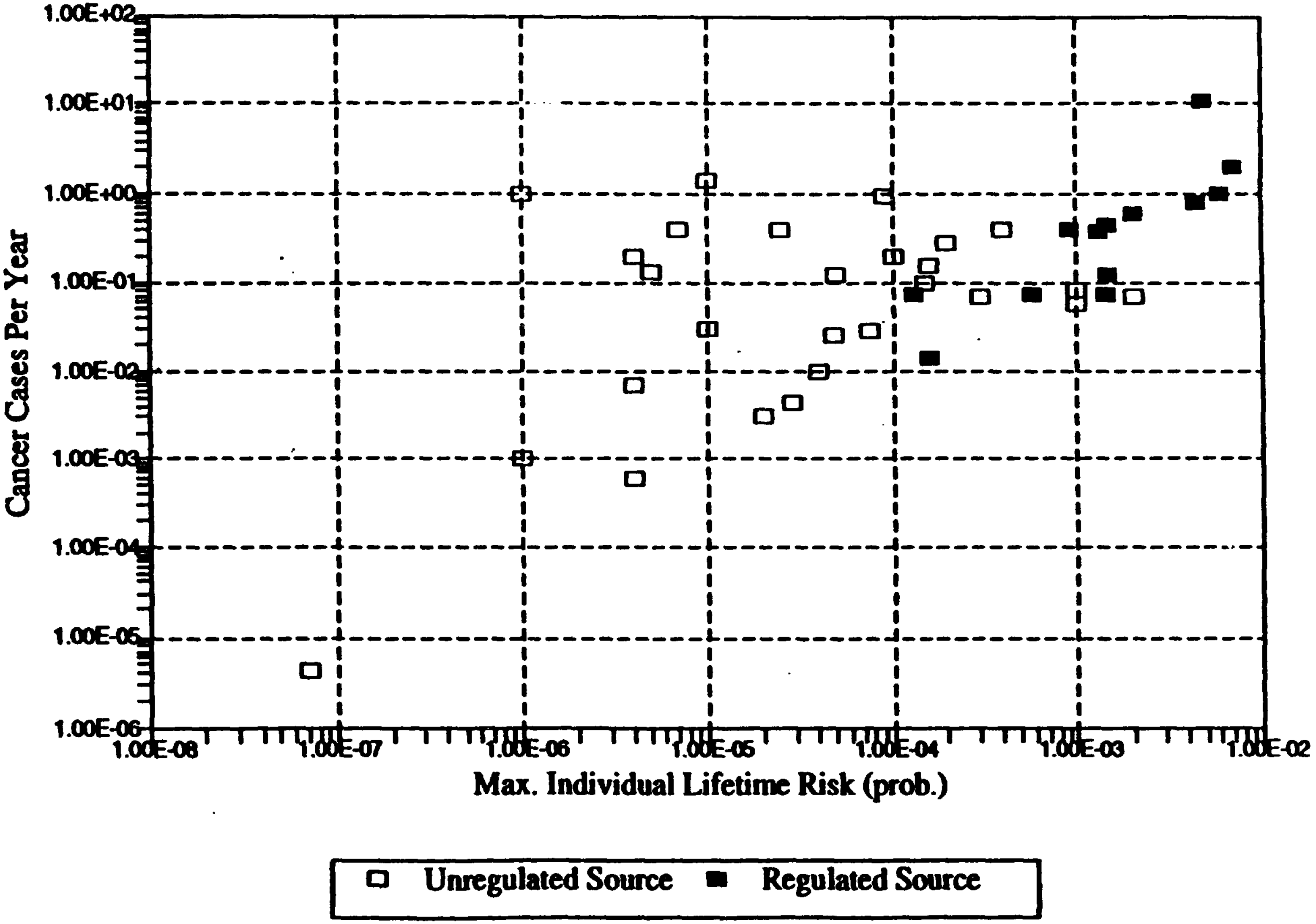


Figure 2. Baseline Risks at Sources of Hazardous Air Pollutants



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