The Determinants of Pesticide Regulation: A Statistical Analysis of EPA Decision Making

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This paper examines the EPA's decision to cancel or continue the registrations of cancer-causing pesticides that went through the special review process between 1975 and 1989. Despite claims to the contrary, our analysis indicates that the EPA indeed balanced risks against benefits in regulating pesticides: Risks to human health or

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the environment increased the likelihood that a particular pesticide use was canceled by the EPA; at the same time, the larger the benefits associated with a particular use, the lower was the likelihood of cancellation. Intervention by special-interest groups was also important in the regulatory process. Comments by grower organizations significantly reduced the probability of cancellation, whereas comments by environmental advocacy groups increased the probability of cancellation. Our analysis suggests that the EPA is fully capable of weighing benefits and costs when regulating environmental hazards; however, the implicit value placed on health risks—$35 million per applicator cancer case avoided—may be considered high by some persons.

When asked how standards should be set in environmental, safety, and health regulation, virtually all economists would urge that at least some account be taken of economic factors. Most would probably support the view that such standards should be set at levels that equate marginal social benefits and costs. This approach does not command overwhelming support when legislation is written, however. In fact, U.S. environmental policy could be termed schizophrenic with respect to the balancing of benefits and costs in standard setting: Most major statutes appear to *prohibit* such balancing, with the Clean Air and Clean Water acts perhaps being the most prominent examples; however, other important environmental laws *require* that benefits and costs be balanced when decisions are made. This is the case with the Toxic Substances Control Act and also the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the latter being the statute under which most U.S. pesticide regulation is conducted.

What laws require is one thing; what agencies do is another. In environmental regulation, for example, White (1981) has argued that although the Clean Air Act has been construed by courts to prohibit consideration of costs in setting ambient air quality standards (*Lead Industries Assoc., Inc. v. EPA* [1980]), the Environmental Protection Agency has in fact taken economics into account in setting such standards for common pollutants. Similarly, for a time the EPA explicitly balanced health risks against economic costs in regulating certain carcinogenic air pollutants. Others have argued, however, that even when the relevant statutes require the balancing of economic and health considerations, agencies will always take action against cancer risks that exceed certain statistical thresholds, often referred to as "bright lines" (Milvy 1986; Travis et al. 1987; Travis and Hattemer-Frey 1988), regardless of costs.

Finally, still others maintain that no matter what "objective" factors the statutes direct regulatory agencies to consider, the agencies are sure to be influenced in their rule making in important and predictable ways by political considerations (Stigler 1971; Peltzman 1976). This view is of particular interest to us in light of the history of pesticide regulation, the focus of our attention here. Prior to the creation of the EPA in 1970, all pesticides were regulated by the Department of Agriculture. One of the reasons for transferring regulatory responsibility to the EPA was to lessen the influence of farmers and pesticide manufacturers in the regulatory process and increase the influence of environmental and consumer groups (Bosso 1987).

Although there is a substantial literature on the determinants of legislative voting on environmental issues (see Crandall 1983; Pashigian 1985; Yandle 1989; Hird 1990), there exists but one published analysis of EPA decision making to ascertain, ex post facto, the factors that explain the regulatory actions taken (see Magat, Krupnick, and Harrington 1986).[1] This paper presents such an analysis for a particular class of environmental regulations, namely, the EPA's decisions to allow or prohibit the continued use of certain pesticides on food crops. We are interested in whether the economic benefits that pesticides confer are, in fact, balanced against the risks these substances may pose to human health and the environment. We also examine the extent to which these decisions are affected by the active involvement of special-interest groups: on the one hand, the companies that manufacture pesticides and the farmers that use them and, on the other, the environmental advocacy organizations that often oppose the widespread application of pesticides.

We focus on three specific hypotheses. First, is the probability that the EPA will disallow continued use of a pesticide on a particular crop positively related to the risks that pesticide poses to human health and the environment and negatively related to the economic benefits associated with the use of the pesticide? In other words, does the EPA follow its congressional mandate under FIFRA? If both factors are taken into account by the EPA, what is the implicit "price" of the resulting risk reductions? This question is important because of concern that the cost per life saved as revealed in health and safety regulation differs markedly, both within and across agencies (Morrall 1986); this *may* signal an inefficient allocation of resources among lifesaving programs.[2]

Second, do special-interest groups—both business and environmental—affect the likelihood that certain pesticide uses will be

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[1] For analyses of decision making at other government agencies, see McFadden (1975, 1976), Weingast and Moran (1983), and Thomas (1988).

[2] If individuals attach higher values to the reduction of certain kinds of risks (e.g., involuntary vs. voluntary) or if certain regulations save more life-years than others, variations in cost per life saved may be perfectly rational.

banned? If so, when opposite sides both intervene, do their efforts merely offset one another?

Third, can particular political appointees influence the likelihood of regulatory action? During the period covered by our study, the EPA was headed by five different administrators including Anne Burford, a Reagan appointee widely regarded as unsympathetic to environmentalists' concerns. We test the hypothesis that she had a significant impact on pesticide regulation during her tenure.

We have investigated these questions by assembling data on all cancer-causing pesticides that underwent special review by the EPA between 1975 and 1989. Under FIFRA, the special review process is initiated whenever a pesticide is thought to pose a danger to human health (e.g., cancer or adverse reproductive effects) or to wildlife; this review entails a risk-benefit analysis of the pesticide for every crop on which it is used. Following this analysis, the EPA issues a proposed decision and invites all interested parties to submit comments, which are compiled in a public docket. A final decision (or notice of final determination) is issued after the agency has reconsidered its proposed action in light of these comments and any new information it has developed. We have assembled data on the risks and benefits associated with each pesticide from official data published by the EPA, as well as information on which special-interest groups entered comments in the public docket.

These data are used to estimate a model that explains the probability that a pesticide was canceled for use on a particular crop, as a function of the risks and benefits associated with its use and as a function of political variables. Our findings provide both comfort and concern to those interested in improving the efficiency of environmental regulation.

I. An Overview of the EPA's Pesticide Registration Process

In its 1972 amendments to FIFRA, Congress required the EPA to reregister the approximately 40,000 pesticides previously approved for sale in the United States. In the 1978 amendments to FIFRA, this task was simplified by requiring reregistration of the 600 active ingredients used in these pesticides rather than the pesticides themselves.

Reregistration of each active ingredient requires assembling the data necessary to evaluate whether it causes "unreasonable adverse effects on the environment" for each use for which it is registered. By "use" is meant the application of a pesticide to a specific crop (e.g., alachlor on soybeans). If, in the process of data collection, it is determined that the active ingredient poses sufficient risks to humans or animals, it is put through the special review process. The purpose of the process is to determine whether the risks posed by the active ingredient are outweighed by the benefits of its use.

The results of these risk-benefit analyses are published along with the EPA's proposed regulatory decision. The following regulatory outcomes are considered for each use of the active ingredient: (1) cancellation of registration; (2) suspension of registration; (3) continuation of registration, subject to certain restrictions; or (4) unrestricted continuation of registration.

Publication of the proposed decision is followed by a comment period, during which members of the public, including growers, public-interest groups, and registrants, can respond. If cancellation or restrictions on use are contemplated, the U.S. Department of Agriculture and the EPA's Scientific Advisory Panel are asked to review the risk-benefit analyses. Final regulatory decisions, together with the names of all those who commented on the proposed decision, are then issued, and these decisions become law unless a hearing is requested by interested parties.

Between 1975, when the special review process was initiated, and 1989, a total of 68 special reviews were begun (U.S. Environmental Protection Agency 1989). Of these, 18 ended at a pre–special review stage, 37 had been completed by December 1989, and 13 were ongoing, as of that date. Our study focuses on a subset of the 37 substances for which reviews were completed, namely, those that both involve pesticides used on food crops and have been found to cause cancer in laboratory animals. We focus on this subset because health risks other than the risk of cancer are seldom quantified, which makes a statistical analysis of regulatory decisions difficult.

The set of food-use pesticides causing cancer in laboratory animals that have gone through special review is listed in table 1. Note that although there are only 19 such pesticides, there were 245 separate pesticide/crop combinations or uses. What we shall try to explain is the decision to cancel or not cancel each of these uses.[3]

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[3] Of the 245 final decisions in our data base, 39 percent represent cancellations, 4 percent suspensions of registration for failure to provide data, 5 percent unrestricted continuations, and 52 percent continuations with restrictions. The types of restrictions typically imposed consist of measures to protect pesticide mixers and applicators, such as requiring that protective clothing be worn. These decisions are to be made by comparing the risks and benefits of the restrictions; however, the documents the EPA develops typically do not contain enough data to permit an analysis of each restriction. For this reason we consider only two regulatory outcomes: continuation of registration (with or without restrictions) and cancellation. Suspensions for failure to provide data are grouped with continuations since registrations are continued as soon as the data are provided.

TABLE 1

ACTIVE INGREDIENTS IN THE PESTICIDE DATA BASE

Active Ingredient	Year of Decision	Number of Food-Use Registrations	Number of Proposed Cancellations	Number of Final Cancellations
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

II. Factors Influencing the Cancellation Decision

Risks of Pesticide Use

In deciding whether a pesticide should be canceled for use on a crop, the EPA is required to prevent any unreasonable risk to humans or the environment, taking into account the economic, social, and environmental costs and benefits of the use of the pesticide. Paramount among these risks is the risk of cancer to persons who mix and apply pesticides and to consumers who ingest pesticide residues on food.[4] Evidence that a chemical is carcinogenic usually comes from animal bioassays, which produce a relationship between pesticide dose and lifetime risk of cancer. This estimate is extrapolated to humans and multiplied by an estimate of human dosage (exposure) to estimate lifetime risk of cancer to a farm worker or consumer.[5]

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[4] In its official documents, the EPA lists cancer risks to pesticide applicators and to persons who mix and load pesticides (mixer/loaders), but not to farm workers who harvest crops. Risks to farm workers are controlled by adjusting the time between pesticide application and harvest (the preharvest interval).

[5] It is well known that the methods used to calculate the slope of the dose-response

Lifetime cancer risks are typically much higher for pesticide applicators than for consumers of food products; for example, in our sample the median estimated incremental lifetime cancer risk for pesticide applicators (as a result of applying a particular pesticide to a particular crop) is one in 100,000 (1.0×10^{-5}), but it is only 2.3 in 100 million (2.3×10^{-8}) for consumers of food products.[6] The number of persons assumed to be exposed to dietary risks—usually the entire U.S. population—is, however, much greater than the number of applicators exposed to pesticides. The latter may range from a few dozen to a few thousand, depending on the particular crop and the number of acres treated, and the number of persons mixing pesticides is typically a few hundred.

This raises a very difficult regulatory issue: Should the EPA's decisions be driven by very high risks to certain individuals (the so-called maximally exposed individuals) or by the overall risk to the entire exposed population (i.e., the expected number of deaths)? Although economists have typically emphasized the latter, regulatory officials at the EPA and other agencies are often more preoccupied with reducing very high individual risks to acceptable levels.

In addition to cancer risks, pesticides may have adverse reproductive effects, causing fetal deformities or miscarriages or lowering the sperm counts of applicators. While there is human evidence for the latter effects, information on the mutagenic or teratogenic effects of a chemical usually comes from animal experiments, and the extent of such effects is generally difficult to quantify. Finally, the EPA is required to consider the possibly adverse ecological effects of pesticides: Is the pesticide toxic to fish, birds, or wildlife or is it likely to contaminate ecologically fragile environments such as wetlands?

Benefits of Pesticide Use

Against these risks, the EPA must weigh the benefits of use, that is, the costs to consumers and producers of banning the pesticide on the crop in question. Losses accrue if producers must switch to a more costly substitute for the pesticide in question or if the substitute is an imperfect one and yield losses will occur on cancellation. Decreases in supply may, in turn, lead to price increases to consumers.

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function, and those used to estimate human exposure to the pesticide, generally err on the side of conservatism (Nichols and Zeckhauser 1986). The slope of the dose-response function is the upper bound of a 95 percent confidence interval rather than the midpoint.

[6] To put this in perspective, we note that the average lifetime cancer risk from all causes is one-third.

Losses to producers from cancellation vary widely for the pesticides and crops studied here. The highest loss expected during the first year following cancellation is \$227 million (1986 dollars) for alachlor on corn. Mean first-year losses, however, are considerably lower: only \$9.1 million. In 35 percent of all cases, losses are negligible because of the availability of substitute pesticides. What is likely to be as important as the magnitude of losses is their distribution among growers. A 0.1 percent reduction in corn revenues will greatly exceed that associated with a 50 percent decrease in mango production; however, since there are relatively few mango growers, the distribution of losses is far more concentrated in the latter case than in the former.

The Role of Political Factors

This raises directly the question of the importance of interest groups in the regulatory process. Pesticide manufacturers are, of course, involved throughout: they are informed when the EPA contemplates a special review and are given an opportunity to rebut the presumption that the pesticide causes adverse effects to humans or to the environment. In addition to negotiating with the EPA, manufacturers are responsible for providing data on the risks of pesticide usage.

Farmers also bear the costs of cancellation and thus have an interest in dissuading the EPA from banning pesticides. One would expect farmers to become involved when the cost of switching to substitute pesticides is high and when the losses that would result constitute a large percentage of profits. An interesting question is at what stage in the regulatory process farmers become involved. While anecdotal evidence suggests communication between the EPA and grower organizations throughout the regulatory process, farmers have no need to exert leverage unless they feel that a pesticide is threatened with cancellation. Thus one would expect grower organizations or their representatives to comment more often when the EPA proposes to cancel rather than to allow continued use of the pesticide(s) in question.

Environmental groups, which attempt to identify and fight for the cancellation of pesticides hazardous to humans or wildlife, can be expected to behave differently. They may, moreover, exert an influence earlier in the regulatory process by bringing pesticide risks to the EPA's attention before the official comment period. Finally, one would expect the views of the EPA administrator to affect the outcome of the special review process since it is the job of the administrator to review the evidence on health and environmental risks and the economic effects associated with the cancellation decision and to issue a final decision.

III. Statistical Analysis of the EPA's Pesticide Decisions

If the EPA follows its mandate under FIFRA to take into account the economic, social, and environmental costs and benefits of the use of any pesticide, one would expect that pesticide i would be canceled for use on crop j if the value of the vector of risks associated with use, $\mathbf{R}_{ij}$, exceeded the weighted sum of benefits of use, $\mathbf{B}_{ij}$. When unmeasured components of risks and benefits, u_{ij}, are treated as random, the probability that pesticide i is canceled for use on crop j is

$$P(\text{cancel}_{ij}) = P(\boldsymbol{\alpha}_1\mathbf{R}_{ij} + \boldsymbol{\alpha}_2\mathbf{B}_{ij} + u_{ij} \geq 0), \tag{1}$$

where $\boldsymbol{\alpha}_1$ and $\boldsymbol{\alpha}_2$ are the vectors of policy weights attached to risks and benefits, respectively.

Special-interest groups enter the model by augmenting the vectors of risks and benefits considered by the EPA, or by altering the policy weights attached to risks and benefits. Suppose, for example, that $\mathbf{X}$ is a vector of variables indicating intervention in the policy-making process by each of several special-interest groups. Then the general model becomes

$$P(\text{cancel}_{ij}) = P(\boldsymbol{\alpha}_1\mathbf{R}_{ij} + \boldsymbol{\alpha}_2\mathbf{B}_{ij} + \delta_1\mathbf{X}_{ij} + u_{ij} \geq 0). \tag{2}$$

An alternative to equation (2) frequently proposed by researchers in the risk assessment area is that risks and benefits are balanced only for intermediate risk levels but not when risks are very high or very low. This so-called bright-line theory of risk regulation hypothesizes that a health or safety regulation will always be undertaken if the risk to the maximally exposed individual, R, exceeds some risk threshold, $R_{\max}$, and will never be adopted if the risk to the maximally exposed individual falls below some critical level, $R_{\min}$. Between these thresholds, the theory holds, the regulation will be adopted if the risks outweigh the benefits. Formally,

$$\begin{aligned} P(\text{cancel}) &= 1 && \text{if } R \geq R_{\max}, \\ P(\text{cancel}) &= \text{eq. (2)} && \text{if } R_{\max} > R > R_{\min}, \\ P(\text{cancel}) &= 0 && \text{if } R \leq R_{\min}. \end{aligned} \tag{3}$$

In adapting this theory to the case of pesticide cancellations, we note that there are three groups of individuals whose health the EPA is supposed to protect: consumers of food products, pesticide applicators, and those who mix and load the pesticides. Because of differences in the magnitude and degree of voluntariness of the risks facing these three groups, it is plausible that the EPA, if it follows (3), sets different risk thresholds for each of the three groups and will cancel a registered use if the risk to the maximally exposed individual in any of the three groups exceeds the relevant threshold. On the other hand, for the substance to be judged "safe," it must fall below the $R_{\min}$ for each group. Because equation (2) is nested in (3), we can statistically test one hypothesis against another.

If sufficient information were available, the models in equations (2) and (3) could be estimated both for the proposed decision to cancel a pesticide registration and for the final decision. Unfortunately, lack of information about the role of intervenors prior to the public comment period makes estimation of either model impossible for the proposed decision. Although it is well known that the EPA meets with interested parties throughout the special review process, it is only since 1985 that information about such meetings was required to be made public. Since we know only about interventions that occurred after the preliminary decision was made, our analysis is confined to explaining whether or not a pesticide was canceled in the EPA's notice of final determination.

Variable Selection and Treatment of Missing Values

To explain the EPA's final decision, we have gathered data on the cancer and other health risks, and the benefits, associated with each food crop for which the 19 pesticides listed in table 1 were registered before entering special review. We have also attempted to measure the participation of interest groups. The variables for which sufficient observations are available are listed in table 2 and are described below.

Risk Variables

The (individual) risk associated with use of pesticide i on crop j is correctly computed as the difference between the lifetime cancer risk associated with pesticide i and the risk associated with the pesticide that will replace it if it is canceled. The EPA's published risk estimates, however, measure the risk of pesticide i as the incremental lifetime cancer risk associated with that pesticide, as though the alternative to using pesticide i were riskless. In this and in other instances cited below, we used the EPA's published figures even if they do not measure the theoretically correct construct, because it is these figures that were available to decision makers.

In addition to measuring the maximum individual risk to applicators, mixer/loaders, and consumers of food products, we would like to measure the number of expected deaths associated with pesticide i on crop j. For cancer risks, however, data on the size of the exposed population are seldom reported. This poses little problem for mea-

TABLE 2

MEANS AND STANDARD DEVIATIONS OF VARIABLES USED IN MODEL

	USES THAT WERE BANNED			USES THAT WERE NOT BANNED		
VARIABLE NAME	Number of Observations	Mean	Standard Deviation	Number of Observations	Mean	Standard Deviation
Whether canceled	96	1.0	.0	149	.0	.0
Dietary risk*	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†	86	2.873	7.637	81	15.685	41.453
Whether yield loss	96	.240	.429	149	.530	.501
Reproductive effects	96	.458	.501	149	.376	.486
Danger to marine life	96	.583	.495	149	.470	.501
Environmental groups comment	96	.729	.447	146	.329	.471
Academics comment	96	.104	.307	146	.390	.490
Growers comment	96	.042	.201	146	.144	.352

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

† Millions of 1986 dollars.

suring dietary risks, which are usually based on total U.S. food consumption and, hence, the total U.S. population, but it is problematic for occupational exposures. Because the size of the exposed population is unavailable, the risk variables in our model represent risks to the maximally exposed individual, which, in practice, is the average applicator or mixer/loader. These can be scaled to represent the expected number of deaths caused by the pesticide annually, as long as it is assumed that the size of the exposed population is constant across all observations.[7]

Noncancer health risks and ecological risks are inherently difficult to measure. Noncancer health effects are measured by a dummy variable indicating that the pesticide exhibits adverse reproductive effects. Ecological risks are measured using a dummy variable that indicates whether a substance is harmful to marine life.

Benefit Data

The only measure of benefits to consumers and producers that is consistently provided in the risk-benefit studies the EPA conducts is the losses that producers would sustain in the first year after cancellation of the pesticide. These are measured as the increased control costs from switching to a substitute pesticide and the value of any yield losses. If yield losses are large enough to raise the price of the product, losses to producers are reduced by the resulting increase in revenues. Because losses to consumers are seldom quantified in the background documents, we rely exclusively on first-year losses to producers.

Even the latter, however, are not available for all pesticides and all crops. It should be emphasized that, although pesticide manufacturers are responsible for data on health risks, the EPA must bear the cost of calculating the benefits of pesticide use. If information on the number of acres treated and on input and output prices is not available from other sources (e.g., the Department of Agriculture), budgetary limitations make it unlikely that benefits will be calculated. Even when such data are available, uncertainty about yield losses makes the cost of pesticide cancellation hard to quantify. When producer benefits are not measured in dollars, we use a dummy variable to indicate whether cancellation of the pesticide would result in yield losses to producers.

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[7] We cannot, however, distinguish the individual contributions of size of exposed population and individual risk to the regulatory decision.

Political Variables

Quantifying the participation of special-interest groups is a difficult task. Because the only information publicly available is whether comments were entered following the proposed decision, we use dummy variables that indicate whether such comments were made by at least one member of each interest group. The interest groups we distinguish include environmental groups, which commented on 49 percent of all decisions; grower organizations, which commented on 10 percent of all decisions; and academics, who commented on 28 percent of all decisions. The results below suggest that academics most often commented on behalf of growers or manufacturers.

One group whose influence we are unable to measure is pesticide manufacturers. Because these manufacturers comment on virtually every decision, the use of a registrant dummy is unproductive. Ideally, one would like to measure the financial stake that manufacturers have in individual pesticides, but such information is proprietary.

To capture the effect of one particularly controversial political administration, a dummy variable is included for the years in which Anne Burford was administrator of the EPA.[8]

Treatment of Missing Values

One problem with the data is the large number of missing values, especially for cancer risks and producer benefits (see table 2). In the case of cancer risks, data may be missing either because an estimate of dietary or occupational exposure is unavailable for a particular crop or because toxicological data are not deemed sufficiently reliable to estimate a dose-response relationship. Although both situations occur in the data, it is the latter that accounts for the majority of missing observations.

A similar problem occurs with producer benefits from pesticide use. Because the EPA does not have the budget to launch a primary data collection effort, lack of information from secondary sources about acres of the crop treated or about input and output prices makes it likely that benefit data will not be quantified.

We handle missing data problems by defining an indicator variable M_{ij} (= 1 if data are missing) and multiplying the variable of interest

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[8] The fact that we have only 19 active ingredients prevents more extensive use of political dummy variables in the probit model. If, for example, a dummy variable were added for each political administration, the Carter administration dummy would explain perfectly all decisions on DBCP, the only pesticide to complete the special review process during that administration.

TABLE 3

PROBABILITY OF CANCELLATION EQUATIONS

	CONTINUOUS MODEL			BRIGHT-LINE MODEL		
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	−.050	−.822	−1.824	.589	−.852	−1.391
	(.344)	(1.091)	(.785)	(.451)	(1.167)	(1.035)
Diet risk per million persons	.003	.009	.012	−.018	−.027	−.030
	(.006)	(.006)	(.006)*	(.030)	(.039)	(.036)
Diet risk missing	−.864	−.626	−.775	−1.020	−.718	−.821
	(.386)*	(.565)	(.540)	(.404)*	(.575)	(.556)
Applicator risk per million persons	4.4E-4	8.2E-4	6.7E-4	4.2E-4	7.8E-4	6.2E-4
	(2.2E-4)*	(3.0E-4)*	(2.7E-4)*	(2.3E-4)	(3.2E-4)*	(2.8E-4)*
Applicator risk missing	.554	−.836	−.529	.471	−1.09	−.869
	(.361)	(.672)	(.630)	(.364)	(.690)	(.667)
Mixer risk per million persons	.005	8.2E-4	1.5E-4	−.053	−.007	−.022
	(.008)	(2.5E-2)	(1.3E-2)	(.027)	(.042)	(.037)
Mixer risk missing	−.860	.681	.540	−1.374	.881	.644
	(.414)*	(.726)	(.683)	(.482)*	(.823)	(.785)
Producer benefits[†]	−.048	−.074	−.066	−.050	−.075	−.069
	(.018)*	(.028)*	(.025)*	(.019)*	(.0282)*	(.025)*
Producer benefits missing × yield loss	−1.984	−2.420	−2.413	−2.043	−2.46	−2.47
	(.361)*	(.454)*	(.446)*	(.379)*	(.460)*	(.458)*

Producer benefits missing × no yield loss	−1.797	−.296	−.934	−1.794	−.273	−.943
	(.446)*	(.889)	(.789)	(.447)*	(1.00)	(.862)
Reproductive effects	.530	.908	1.026	.843	1.03	1.13
	(.324)	(.532)	(.518)*	(.360)*	(.552)	(.537)*
Danger to marine life	.782	−.893	−.283	.617	−.990	−.593
	(.281)*	(.861)	(.701)	(.293)*	(.869)	(.769)
Burford years	...	−1.621	...	...	−1.38	...
		(1.112)			(1.22)	
Academics comment	...	−1.807	−1.333	...	−1.91	−1.58
		(.902)*	(.753)		(.914)*	(.819)
Growers comment	...	−2.017	−1.829	...	−2.42	−2.21
		(.874)*	(.762)*		(1.02)*	(.871)*
Environmental groups comment	...	3.070	3.398	...	3.27	3.48
		(.617)*	(.604)*		(.67)*	(.667)*
$R_{\max}$ diet	...	...	...	1.7E-4	1.7E-4	1.7E-4
$R_{\max}$ applicator	...	...	...	1.1E-2	1.1E-2	1.1E-2
$R_{\max}$ mixer/loader	...	...	...	3.1E-5	3.1E-5	3.1E-5
Log likelihood	−87.0	−44.9	−46.0	−83.4	−42.8	−43.4
Percentage of decisions correctly predicted	86.0	95.0	95.0	84.0	94.0	94.0

NOTE.—Standard errors appear in parentheses below coefficients.

* Significant at the .05 level, two-tailed test.

† Millions of dollars.

(e.g., dietary cancer risk) by $1 - M_{ij}$. The missing data indicator also appears as an independent variable. The coefficient of the risk variable thus represents the effects of dietary cancer risk conditional on the availability of such information.

IV. The Determinants of Pesticide Decisions, 1975–89

Estimates of equations (2) and (3) appear in table 3 for three different sets of variables: (i) risk and benefit variables only, (ii) risk and benefit variables augmented by commenter dummies, and (iii) all the preceding variables augmented by a dummy variable indicating the Burford administration at the EPA.[9]

Are Risks and Benefits Balanced?

Table 3 indicates that the EPA does balance risks and benefits in deciding whether or not to ban a pesticide. Indeed, for each set of variables, the bright-line theory of risk regulation, which asserts that risks and benefits are not balanced for very low or very high risk levels, can be rejected in favor of a simple probit model. In examining the so-called bright-line theory (cols. 4–6), we note that there are no risk levels below which all pesticide uses were allowed. For example, some uses of captan were banned even though incremental risks to applicators were 10^{-9} and incremental dietary risks were 10^{-12}, presumably because benefits from captan usage were very small.[10] The maximum acceptable risk levels in our data (levels above which all uses were banned) differ somewhat from the 10^{-4} cutoff often emphasized in the risk management literature (Travis and Hattemer-Frey 1988). For instance, the maximum acceptable risk level is highest for applicators (1.1×10^{-2}) but somewhat closer to conventional levels for mixers (3.1×10^{-5}) and for dietary risks (1.7×10^{-4}).

Because the bright-line models were estimated by maximum likelihood techniques (see the Appendix), likelihood ratio tests were performed to test the null hypothesis that bright lines do not exist (i.e.,

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[9] Equations (2) and (3) were estimated by maximum likelihood methods, assuming that $u_{ij} \sim IN(0, \sigma^2)$ for all i and j. Details on the estimation of the switch points in eq. (3) appear in the Appendix. The three observations on ethalfluralin were dropped from the analysis since no information on public comments was available for these decisions.

[10] The EPA banned the use of captan on 44 fruits and vegetables. In each case, the benefits of captan use were estimated to be negligible. Average dietary risk was less than or equal to 10^{-6} in all cases and less than or equal to 10^{-9} in 28 cases. Risks to mixer/loaders and applicators were 10^{-6} in about half the cases and 10^{-5} in the other half.

that [2] is the correct model) against the alternative that they do. In all three cases the null hypothesis cannot be rejected at conventional levels. We therefore focus our discussion on the simple probit results (cols. 1–3 of table 3).

Given that the EPA does weigh risks and benefits, what weight does it place on risks to different populations? In considering cancer risks, the EPA clearly places most weight on risks to applicators. This variable is significant in all probit equations, and the ratio of its coefficient (suitably scaled) to that of producer benefits implies a value per statistical cancer case avoided of roughly $35 million (1986 dollars).[11] By contrast, risks to mixers are insignificant in determining the probability of cancellation, and dietary risks are significant at conventional levels only in column 3. The value per cancer case avoided implied by this coefficient, however, is only $60,000.

It is interesting to speculate on the reasons for these results. One reason for placing so much weight on reducing risks to applicators is that applicators constitute an identifiable population who face large risks. It is certainly plausible that equivalent risk reductions (in terms of numbers of cancer cases) are valued more highly when the level of individual risk is high (as it is for applicators) than when it is low (as it is for consumers). It may also be the case that decision makers discount risk estimates based on dietary exposure, which are widely known to be upward biased, relative to risk estimates for applicators, which are based on more accurate estimates of exposure.[12]

As far as other risks are concerned, the presence of adverse reproductive effects increases the probability of cancellation, although this effect is only marginally significant in columns 1 and 2. Danger to marine life, however, raises the probability of cancellation only in column 1. One reason for this may be the presence of comments by environmental groups in columns 2 and 3. As will be shown below, environmental groups are more likely to comment when a pesticide poses danger to marine life; hence, the environmental group dummy in equations (2) and (3) may be capturing some of the effects of this risk variable.

Producer benefits significantly lower the probability of cancellation. A $1 million increase in producer benefits lowers the probability of cancellation (with all variables at median values) between 0.7 and 1.1

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[11] The exact figures for cols. 1, 2, and 3 of table 3 are, respectively, $32.1 (14.2), $38.8 (21.2), and $35.5 (19.5) million (standard errors in parentheses). (These calculations are explained in detail in the Appendix.) It is interesting to note that intervenors do not significantly change the value per cancer case avoided.

[12] Estimates of dietary cancer risk are usually based on the assumptions that pesticide residues are present at the maximum levels allowed by law and that the pesticide is used on all acres of the crop in question.

percentage points. Even when producer benefits are not quantified, merely knowing that yield losses would occur if the pesticide were banned significantly reduces the probability of cancellation.

How Important Are Political Interests in the Regulatory Process?

The dramatic increase in the log of the likelihood function when interest group variables are added to the model attests to the importance of intervenors in the regulatory process. Participation by environmental groups dramatically increases the probability of cancellation, whereas participation by grower organizations and academics reduces the probability of cancellation. From this we infer that most academics are commenting on behalf of growers or registrants.

While having the expected sign, the dummy variable indicating the Burford period at the EPA is not significant at conventional levels, although it alters somewhat the magnitude of the coefficients on the interest group variables. This fact prompts us to examine whether Burford may have exerted influence indirectly by discouraging comments from environmental groups and encouraging comments from growers. To investigate this issue we estimated separate probit models to explain the participation of environmental groups and grower organizations (see table 4). The Burford regime appears to have influenced environmental groups since none of them bothered to enter comments in the public docket during her administration. (The Burford dummy does not appear in the environmental group equation because it would have a coefficient of minus infinity.) By contrast, she appears to have increased the probability that grower organizations would comment. This may reflect the fact that environmental groups felt it futile to intervene during Burford's tenure, whereas grower organizations expected a more sympathetic hearing.

The results of table 4 also shed light on an issue raised earlier. To some extent, participation by interest groups in the regulatory process is motivated by the risks and benefits of pesticide use that an unbiased "social planner" would consider. Environmental groups, for example, are more likely to comment on pesticides that pose a danger to marine life, and grower organizations are more likely to comment the larger are benefits to them from pesticide use. Because some of the factors that the EPA is required to consider under FIFRA may be captured by intervenor dummies, one should not be surprised if, as in columns 2 and 3, variables such as danger to marine life and producer benefits become less significant than they appear in column 1.

Finally, something should be said about the effect of the proposed decision to cancel a pesticide on the likelihood that interest groups

TABLE 4

Probability of Commenting Equations

	Environmental Groups (1)	Grower Organizations (2)
Intercept	-1.073	-2.634
	(.211)	(.381)
Reproductive effects	.077	
	(.218)	
Danger to marine life	.471	
	(.201)*	
Proposed decision = cancel	1.615	1.550
	(.222)*	(.365)*
Burford years		.973
		(.296)*
Producer benefits[†]		.011
		(.004)*
Producer benefits missing × yield loss		-.196
		(.345)
Producer benefits missing × no yield loss		-.334
		(.547)
Log likelihood	-115.0	-62.3
Percentage of decisions correctly predicted	93.0	90.0

Note.—Standard errors appear in parentheses below coefficients.

* Significant at the .05 level, two-tailed test.

[†] Millions of dollars.

comment. While it is certainly plausible that a proposed decision to cancel a pesticide increases the chances that growers will comment, it is puzzling that a proposed decision to cancel increases the chances that environmental groups comment. It is, after all, environmental groups that usually oppose pesticide use. The positive sign here may, however, reflect reverse causality: by exerting influence before as well as during the public comment period, environmental groups may actually increase the chances of a proposed cancellation.

V. Conclusions

We suggested in the Introduction that our findings would both comfort and concern those interested in environmental regulation. With respect to comfort, it appears that the EPA is indeed capable of making the kind of balancing decisions that economists presumably support and that FIFRA clearly requires. Our results convincingly demonstrate that the existence of risks to human health or the environment increases the likelihood that a particular pesticide use will be canceled by the EPA; at the same time, the larger the economic beliefs associated with a particular use, the lower the likelihood of cancellation.

On the other hand, our results also provide some cause for concern. For instance, we find that the value of a statistical life implicit in the 242 regulatory decisions we consider is $35 million for applicators but only $60,000 for consumers of pesticide residues on food. Why is the EPA apparently willing to spend nearly 600 times as much to protect those who apply pesticides as those whose exposures come through food residues? Two explanations seem likely. First, although they are much fewer in number, each applicator faces a much larger individual risk than a typical consumer—on average about 15 times larger. The EPA may be especially concerned about allowing larger individual risks. Second, because they are fewer in number, applicators are more identifiable than the more than 200 million consumers of food in the United States. As with the proverbial baby in the well, society stands willing to spend much more to save the lives of identifiable victims than mere "statistical lives," and this may be reflected in our findings.

There are other aspects of the pesticide regulatory process that provide some cause for concern. First, although hardly unique to pesticide regulation, the procedures used to assess risks to all parties are almost sure to lead to upwardly biased estimates. To take but one example from the decisions analyzed here, risks to applicators and consumers are predicated on the assumption that no other active ingredient will be substituted for one banned in a particular use. Since such substitutions are the rule rather than the exception, however, a more accurate measure of risk reductions would reflect the *differential* riskiness of the two substances. (It is conceivable, in fact, that a more hazardous—yet to date untested—ingredient could be substituted for one whose use was discontinued by the EPA.) This suggests, incidentally, that groups of active ingredients be considered together in the regulatory process. This would encourage more accurate estimation of both risks and benefits since it would make clear those situations in which simple substitutions are no longer possible. Finally, the EPA should be given the resources to make more accurate estimates of the benefits of pesticide usage. It is simply not sufficient to calculate losses to growers and call this the "cost" of restricting a particular pesticide use. More sophisticated measures, which include forgone consumers' surpluses, must become a standard part of FIFRA regulation.

It is less clear how one should view our findings concerning the political variables we examined. Clearly, intervention in the regulatory process—by both business and environmental groups—affects the likelihood of pesticide use restrictions. All other things being equal, interventions by environmental groups have about twice the impact on the likelihood of cancellation as those by growers (although the combined effect of growers and academic commenters, who weigh in against cancellations, outweighs that of environmentalists). Moreover, Anne Burford's short and controversial tenure at the EPA is seen to have had a negative effect on the likelihood of pesticide cancellations. To those who view pesticide or other similar regulation as the proper province of scientists, engineers, and economists alone, these findings may be discouraging. On the other hand, those taking the view that regulation—like government taxation or spending—is inherently a political act may find it encouraging that affected parties not only participate actively in the regulatory process but do so quite effectively.

Appendix

Maximum Likelihood Estimation of Bright Lines

Our risk levels $R_{\max}$ have been chosen by ordering observations from most to least risky and finding the lowest risk level in each category (diet risk, applicator risk, or mixer risk) above which all uses were canceled.

It can be argued that this is equivalent to picking $R_{\max}$ to maximize a likelihood function for which the individual terms are

$$\begin{aligned} P(\text{cancel}) &= 1 && \text{if } R \geq R_{\max}, \\ P(\text{cancel}) &= \Phi(\alpha_1 R + \alpha_2 B) && \text{if } R < R_{\max}, \\ P(\text{don't cancel}) &= 0 && \text{if } R \geq R_{\max}, \\ P(\text{don't cancel}) &= 1 - \Phi(\alpha_1 R + \alpha_2 B) && \text{if } R < R_{\max}, \end{aligned} \qquad \text{(A1)}$$

where Φ is the standard normal distribution function.

The argument that our procedure maximizes the likelihood function is as follows: If one were to raise $R_{\max}$, this would take observations that were canceled and now contribute a "1" to the likelihood function and reduce their contribution to $\Phi(\alpha_1 R + \alpha_2 B) \leq 1$, thus lowering the value of the likelihood function. If one were to lower $R_{\max}$, observations that were not canceled would now be above $R_{\max}$. From equation (A1), the contribution of these observations to the likelihood function would fall to zero from $1 - \Phi(\alpha_1 R + \alpha_2 B) \geq 0$, thus lowering the value of the likelihood function. Our procedure thus maximizes the likelihood function.

We can, therefore, view the threshold model as consisting of 242 observations and $k + 3$ parameters, where k is the number of parameters estimated in the continuous model. A test of the threshold model can be conducted by comparing 2[ln L(threshold) − ln L(continuous)] with the critical value of the χ^2 distribution with three degrees of freedom.

Calculation of Implied Value per Cancer Case Avoided

Equation (1) in the text indicates that pesticide i will be canceled for use on crop j if the risks associated with the pesticide, R_{ij}, plus other considerations, u_{ij}, outweigh the benefits of use, B_{ij}:

$$\alpha_1 R_{ij} + \alpha_2 B_{ij} + u_{ij} > 0.$$

Equivalently, the pesticide will be banned if the value of the risks outweighs the dollar value of the benefits:

$$-\frac{\alpha_1}{\alpha_2}R_{ij} - \frac{u_{ij}}{\alpha_2} \geq B_{ij}. \tag{A2}$$

If R_{ij} is the number of cancer cases avoided by banning the pesticide for a year and B_{ij} is the annual value of benefits, then $-\alpha_1/\alpha_2$ is the value per cancer case avoided.

In the estimation of α_1 and α_2, R_{ij} has been replaced by N_{ij}, the number of cancer cases avoided per million exposed persons, based on a lifetime (T years) of exposure. The relationship between R_{ij} and N_{ij} is thus given by

$$R_{ij} = \frac{N_{ij}}{T \times 10^6} \times \text{number of persons exposed}, \tag{A3}$$

where the first term on the right-hand side of (A3) is the risk to a single person from a year of exposure to the pesticide. Equation (A3) implies that the coefficient of N_{ij} must be multiplied by $T \times 10^6$ and divided by the number of persons exposed to equal α_1.

To calculate the value per applicator cancer case avoided, the coefficient of applicator risk (N_{ij}) must be divided by the number of applicators exposed and multiplied by 35×10^6. (A lifetime of exposure for an applicator is assumed to be 35 years.) The resulting estimate of α_1 must then be divided by minus the coefficient of producer benefits. To illustrate the calculation, we use the coefficients in the third column of table 3 and assume an exposed applicator population of 10,000. This implies a value per applicator cancer case avoided of $35.53 million (1986 dollars):

$$-\frac{\alpha_1}{\alpha_2} = \frac{6.7 \times 10^{-4}}{.066}\frac{35 \times 10^6}{10{,}000} = 35.53.$$

In calculating the value per cancer case avoided associated with dietary risks, $T = 70$ and $N = 2.1 \times 10^8$, that is, the U.S. population during the period of study.

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