ABSTRACT

Title of Document: AN ANALYSIS OF REGULATORY DECISIONS ON FOOD-USE PESTICIDES UNDER THE FOOD QUALITY AND PROTECTION ACT

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To ensure the safety of older pesticides used in the United States, the EPA required the reregistration of pesticide uses which were first introduced before 1984. Using a dataset of reregistration outcomes for 2722 pesticide uses applied to food crops, I analyze the extent to which these decisions were determined by chronic health risks, pesticide expenditures, and other factors. I find that the dietary health risks associated with pesticides are had greater influence on actions to reduce dietary and occupational exposures than on pesticide cancellations.

High population dietary risks are associated with higher rates of pesticide cancellations, though these results are insignificant. There is evidence that the EPA was more responsive to child and infant dietary risks: values above the EPA's threshold of concern were more than 10% more likely to be cancelled than those that

were not (significant at the 10% level). The effects of cancer risks on EPA actions are more ambiguous, though this may be due to data limitations.

The less safe pesticides are for handlers, the more often they are cancelled, but pesticide safety has a more significant correlation with reentry intervals. A one percent decrease in the safety of a pesticide to handlers predicts a reduction in reentry interval of 1.6 days (significant at the 5% level).

Expenditures on individual pesticides have a strong relationship with pesticide reregistration, with an additional half million dollars in expenditures predicting a 2% increase in the probability of reregistration (significant at the 1% level). Expenditures are not so correlated with reentry intervals or changes in pesticide tolerances. After accounting for dietary risk and pesticide expenditures, Monsanto and Dow were most likely to have uses reregistered. Though there was some concern that small crops with low pesticide expenditures would suffer extra cancellations, small crop uses were no more likely to be cancelled than large crop uses. Mentions of individual pesticides in the media had no apparent relationship with the outcome of reregistration decisions.

AN ANALYSIS OF REGULATORY DECISIONS ON FOOD-USE PESTICIDES UNDER THE FOOD QUALITY AND PROTECTION ACT

By

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The research presented here does not necessarily reflect the positions of the USDA or EPA or the opinions of its employees. Furthermore, all errors and oversights are my own.

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List of Abbreviations

- ADD: Average daily dose
- cNOAEL: chronic no observed adverse effect level
- CSFII: Survey of Food Intake by Individuals
- EPA: U.S. Environmental Protection Agency
- FIFRA: Federal Insecticide, Fungicide, and Rodenticide Act
- FQPA: Food Quality and Protection Act
- MOE: Margin of Exposure
- PAD: Population adjusted dose
- REI: Re-entry interval
- USDA-ERS: U.S. Department of Agriculture, Economic Research Service
- PPE: Personal protective equipment
- RfD: Reference dose
- RED: Reregistration Eligibility Decision

Chapter 1: Introduction

How the Environmental Protection Agency (EPA)[1] decides which food-use pesticides are valuable and safe enough to remain on the market affects the potentially conflicting interests of growers, agricultural workers, consumers, and pesticide manufacturers. The goal of this research is to assess the regulatory process for pesticides, and how it weighs the interests of these stakeholders: to what extent do the reregistration outcomes reflect the dietary and occupational risks of pesticides? Are regulatory outcomes protective of infants and children (as mandated by Congress) by restricting use on foods commonly consumed by children? Is the likelihood of reregistration different for crops planted on a relatively small number of acres? Do some pesticide manufacturers appear to be better able to influence pesticide regulations? Does the existence of substitute pesticides on the market (or in the development pipeline) affect reregistration?

The use of modern pesticides[2] has made great contributions to agricultural productivity, but these benefits have been accompanied by significant risks to humans and wildlife. Regulating the availability and use of pesticides on the market in the United States has been the responsibility of the U.S. Environmental Protection Agency (EPA) since the 1970s. The stakes are high: overly protective regulation may result in significant productivity losses; a lack of regulation may result in the unnecessary endangerment of human and animal life. Given the ramifications of

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[1] EPA refers to the U.S. Environmental Protection Agency.

[2] The term pesticide encompasses many agents, such as antimicrobials, wood preservatives, rodenticides, and chemicals for crop protection. Pesticides discussed in this paper are restricted to just three of the types applied to food-use crops: herbicides, insecticides, and fungicides.

pesticide regulation, as well as the public's concern about pesticide safety, an evaluation of the regulatory process is appropriate.

Pesticide use increases crop yields, increases shelf life, and minimizes blemishes on fruits and vegetables. Precise measurement of the benefits of pesticide use is complicated, however. Most studies measure the effect of bans of select pesticides on select crops and date from over a decade ago. A more recent study by CropLife International, an industry group, suggests that the elimination of herbicides would cause a 20 percent reduction in production (Gianessi and Reigner, 2007). More regulation, even if not an outright ban, may have other adverse consequences: Ollinger and Fernandez-Cornejo (1998) find that greater regulatory costs reduce the number of pesticides introduced to the market.

Concerns about the hazards of pesticides to humans and wildlife are numerous. Human health concerns include the propensity of pesticides to cause cancer, endocrine disruption, and neurological damage (Pimentel and Greiner, 1997). Pimentel (2005) estimated $10 billion in environmental, societal, and crop losses from pesticide use, but such an estimate necessarily depends on sparse data and many assumptions. The safety of pesticides is a significant component of how growers value pesticides, but they place far more value on efficacy (Beach and Carlson, 1993). Effects on wildlife populations, particularly birds, have driven pesticide bans and restrictions, most famously the banning of DDT and related products in 1972. Many of the possible dangers of individual pesticides are known, but there is always some public uncertainty about what the actual risks and long-term effects are.

Occupational exposure to pesticides tends to be much higher than that to consumers; however, dietary exposure to pesticides continues to be a subject of interest to the public. Media coverage and public concern about Alar in 1989 were catalysts for its withdrawal (Marshall, 1991). A survey conducted by Horowitz (1994) found consumers to be more concerned about pesticide risks than auto exhaust risks. Another survey by Williams and Hammitt (2001) found that the perceived risk of conventional pesticides was similar to the mortality risk from motor vehicle accidents. Growth in sales of organic products averaged 20 percent per year between 1997 and 2003 (Oberholzer, Dimitri, and Greene, 2005). These findings suggest a lack of trust in the safety of conventional pesticides used in the United States, and indicate that more examination of the regulatory process may be in order.

Earlier research has assessed the regulatory outcomes of EPA decisions, in particular Cropper et al. (1992) and Courbois (2000). Since both of these were completed, the EPA has executed a major reregistration program of older pesticides, guided by a new set of directives under the Food Quality and Protection Act of 1996. Under the act, the EPA made new decisions about hundreds of active ingredients and their use on dozens of crops. This implementation offers the opportunity to evaluate the influence of registrants on the EPA, how closely the EPA followed the directives of the Act, and whether the Act disproportionately affected some crops over others.

- *Do reregistration decisions appear to be protective of dietary risk to consumers?*

    - In the wake of reports in the late 1980s and early 1990s questioning the safety of pesticides, Congress passed the Food Quality and Protection Act of 1996 (FQPA). Rather than continue the previous practice of balancing risks and benefits, Congress made dietary risks subject to a more rigid “reasonable certainty of no harm” standard. This should have resulted in regulations that were more protective of consumers than previous regulations.
- *Are active ingredient and crop combinations with greater risks to children more likely to be cancelled?*
    - A report by the National Academy of Sciences in 1993 pointed out how infants and children were especially vulnerable to pesticide exposure. Infants and children metabolize toxins differently than adults, so pesticide standards developed with adults in mind may not be fully protective for children. Of additional concern is the fact that children’s exposure may be significantly different than adults due to the fact that children weigh less and their diets consist of a relatively small range of crops, some of which are pesticide intensive.
- *Do occupational hazards appear to be significant factors in reregistration outcomes?*
    - The most intensive exposure to pesticides is experienced by agricultural workers, including mixers, loaders, applicators, and all other workers entering the field after application. Although the risk

to the population as a whole is mostly dietary, workers may be exposed through multiple pathways, including dermal absorption and inhalation. In spite of the fact that pesticide poisonings are likely underreported, hundreds of incidents involving pesticide applicators and mixer/loaders were documented in California in 2007 (California EPA, 2007).

- *Are active ingredients more likely to be cancelled on small crops (measured in terms of acreage)?*
    - Registrants of pesticides obtain less revenue from crops planted on fewer acres, which includes many fruits and vegetables. At the same time, pesticides may be used intensively on many fruits and vegetables. Canceling a pesticide on a low-acreage crop may therefore make a significant reduction in exposure and production. Smaller crops may have fewer substitute pesticides, making growers more vulnerable to losses in the event of a cancellation. The EPA is supposed to take the available substitutes into account during the decision process, but the "reasonable certainty of no harm" standard may limit this.
- *Are some registrants more successful at reregistering pesticides than others?*
    - Industry consolidation over the past two decades has reduced the number of major registrants. Major companies have ongoing relationships with both politicians and the agency, and may have

    significant influence on decisions. In addition, they have several chemicals subject to reregistration, and may have more scope for negotiation across pesticides and uses.

- *Is there evidence that products were cancelled when registrants were about to bring substitutes onto the market?*
    - Having a substitute pesticide in the pipeline may have reduced the incentive for registrants to complete reregistration of old pesticides. The registrant may not care to complete the reregistration process to keep a pesticide that will compete with its own future products. The EPA may anticipate that future products will be safer, and therefore may not rush a decision.
- *Did media coverage of pesticides appear to affect reregistration decisions?*
    - Media coverage may drive greater public awareness of pesticide toxicity, and in turn, create additional public pressure for regulation.

To address these questions, I have assembled a dataset encompassing over 100 active ingredients and over 200 food-use crops subject to the reregistration process.

After providing background on pesticide regulation and a broad overview of the dataset in Chapters 2 and 3, I address the research questions in three additional chapters, which focus respectively on dietary exposure, occupational exposure, and other factors influencing pesticide decisions. I will summarize Chapters 4, 5, and 6 below.

Chapter 4: Dietary Risk and Reregistration Decisions

To examine whether the EPA was protective of dietary exposure to pesticides, and especially protective of infants and children, I use two approaches with two different outcome variables. The first approach consists of a probit model of the decision for each active ingredient/crop pair, where the outcome is either a reregistration or a cancellation. The second approach exploits the FQPA mandate that the EPA reevaluate all tolerances (or amount of residue legally allowed on commodities) for each active ingredient/crop pair. In an ordered probit, I examine whether dietary risk has an effect on whether the EPA chooses to decrease, not change, or increase the tolerance level conditional on reregistration. In each model, the explanatory variables consist of measures of dietary risk derived from food consumption estimates used by the EPA and EPA measures of pesticide toxicity.

To address whether the EPA was especially protective of infants and children, I use the same models with EPA's measures of children's consumption of commodities. I find little effect of chronic dietary risk on pesticide reregistration decisions for the population as a whole and for infant and child population subgroups. There is evidence that the EPA mitigated chronic dietary risk in other ways: higher chronic dietary risk pesticide uses were significantly more likely to have reduced tolerances. Congress mandated that the EPA not trade off dietary risk with benefits of pesticides. I find, however, that expenditures on pesticides are a significant predictor of success in the reregistration process. Pesticide expenditures do not predict tolerance changes, however.

Using two separate measures of cancer risk, I find no significant relationship between cancer risk and reregistration decisions, or cancer risk and tolerance changes. The data for dietary cancer risk is more limited than for chronic dietary risk, however.

Chapter 5: Occupational Risk and Reregistration Decisions

Several types of agricultural workers are exposed to pesticides through their occupations. Some of the ways the EPA may mitigate exposure include cancelling a use, reducing the maximum amount of active ingredient that may be applied per acre; increasing the required protective clothing or equipment; or increasing the reentry interval, or amount of time workers must wait before reentering a field after application. To test whether occupational hazards were significant factors in pesticide regulations, I construct measures of occupational risk based on the EPA's assumptions about exposure and toxicity levels.

Occupational risk does not have significant effect on reregistrations when entered in the models linearly. It is possible that the EPA treated pesticide uses with higher levels of risk differently, as there is evidence that riskier uses were more likely to be cancelled. Similar patterns emerge for risks specific to mixer/loaders.

Though the effect of handler MOE on reregistration decisions appears to be minimal, there is evidence that the EPA mitigated risk through increased reentry intervals (REI) on reregistered pesticide uses. All measures of occupational risk predict a more protective REI, and these estimates are generally significant across models.

One more substitute pesticide for a particular use resulted in REIs about six hours longer, though there was no significant effect for the relative prices of these substitutes. Pesticide expenditures were significant in models of reregistration decisions, but had no significant effect on REI. Occupational cancer risks have little to no discernable effect on decisions or REI, though this may be due to measurement error.

Chapter 6: Additional Factors Influencing Pesticide Regulatory Decisions

Several other factors may influence pesticide regulatory decisions beyond dietary and occupational risk. In this chapter, I examine more specifically the impact of individual pesticide manufacturers, the press coverage of pesticides, the size of the crop the pesticide is applied to, and the availability of possible alternatives. It appears that of the major pesticide registrants, Dow and Monsanto were most successful at reregistering pesticides, after controlling for dietary risks and pesticide expenditures. The size of the crop (measured in acres planted) the pesticide is used on also has no bearing on reregistration decision. Finally, media coverage of specific pesticides does not appear to influence EPA decisions.

Chapter 2: History of Pesticide Regulation in the United States

Federal Insecticide, Fungicide, and Rodenticide Act

Early legislation regulating pesticides was intended primarily to protect farmers from ineffectual products or products that caused crop damage. Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947, the United States Department of Agriculture (USDA) registered pesticides before they could be sold between states. Not until FIFRA was amended in 1970 and control of pesticide registrations was transferred to the Environmental Protection Agency did the safety of pesticides become an important factor in registration decisions.[3]

In the 1970s, Congress also directed the EPA to review past pesticide registrations. This reregistration process was intended to put more emphasis on the safety of pesticide active ingredients. In addition, increased knowledge of pesticide products and more sophisticated techniques for evaluating toxicity meant pesticides could be examined more thoroughly than in the past. Although the EPA had the authority to reregister or deny reregistration to pesticides, the process proceeded slowly. During the 1980s, the EPA prepared 'reregistration standards' which

Timeline of Key Legislation Affecting Pesticide Regulation

1947	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) directs USDA to register pesticides and monitor their effectiveness
1970	Responsibility for pesticide regulation transferred to newly created EPA
1988	Amendment to FIFRA mandates a comprehensive reregistration process for all active ingredients first registered before 1984, and empowers the EPA to collect reregistration fees
1996	Food Quality and Protection Act requires that the reregistration process pay special attention to dietary risks, risks to infants and children, and cumulative risks
2006	Reregistration process for pre-1984 pesticides mostly complete

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[3] The EPA summarizes key elements of FIFRA on its website: http://epa.gov/oecaerth//civil/fifra/fifraenfstatreq.html

characterized pesticides and identified data gaps, but were not reregistration decisions.[4] By the time FIFRA was amended again in 1988, the EPA had published reregistration standards for less than a third of active ingredients on the market. Under the Special Review process in the 1970s, the EPA also assessed some pesticides as specific risks came to light, on an ad hoc basis separate from reregistration.

The 1988 amendments empowered the EPA to assess fees on pesticide registrants, which helped to fund the reregistration process and caused registrants to withdraw registrations of chemicals that they no longer sold (Caulkins 2008). The EPA organized the 1,150 active ingredients subject to reregistration into 613 groups, or ‘cases’ which would be decided together. These 613 cases were categorized into List A, List B, List C, and List D. List A consisted of pesticides that had the highest priority for reregistration. The 194 cases on List A included the pesticides of greatest concern to human health and most food use pesticides. Lists B through D categorized the remaining pesticide cases in order of priority.

Of the 613 reregistration cases to be decided, 229 were cancelled in the early years of reregistration.[5] Most often these cancellations were due to the registrant’s unwillingness to pay the fees or provide the required data to support the reregistration.[6] The EPA used data provided by the registrants to compare the hazards

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[4] This is an important distinction. Preparation of reregistration standards meant that much of the assessment of the pesticide was done, but the eligibility decisions were not made until later. Outcome variables for this research draw only from the REDs.

[5] A discussion of the pesticide reregistration process is also available at the EPA’s website: http://www.epa.gov/opp00001/reregistration/reregistration_facts.htm

[6] In cases where the registrant withdrew the use very early in the reregistration process, the EPA generally did not produce a Reregistration Eligibility Decision. As a result, these uses have very limited data available, making these decisions difficult to analyze. For this reason, I restrict my data

of each pesticide with its benefits. A profile of the pesticide along with any risk mitigations (such as limitations on applications or changes in required protective clothing for applicators) and cancellations were published in Reregistration Eligibility Decisions (REDs). By 1998, the EPA had published REDs for 172 of the remaining 384 cases (Status of pesticides in Registration, Reregistration, and Special Review (aka Rainbow Report) 1998).

Food Quality and Protection Act of 1996

FIFRA was amended again in 1996 by the Food Quality and Protection Act. The Delaney Clause, introduced in 1958 as part of an amendment to the Food, Drug, and Cosmetic Act, prohibited any use of any food additive believed to be carcinogenic. Since some pesticides concentrate during processing, they can be defined as food additives and are thus subject to the Delaney standard. In the early 1990s, applying the Delaney standard as part of the reregistration process caused regulatory difficulties, as it would require cancellation of substances with any detectable level of carcinogenicity. There was a possibility that the clause would also block newer, safer pesticides from the market (Osteen 1994). Since pesticides may concentrate during processing, they can be defined as food additives. Improvements in detection technology meant that formerly undetectable residues would have to be prohibited. FQPA was designed to bridge some of these obstacles, and in doing so, made significant changes to the procedures by which the EPA was to regulate pesticides.

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and models only to those uses where the registrant paid the fees and continued participation in the reregistration process afterwards.

By the early 1990s, the EPA had collected fees from registrants wishing that their active ingredients be considered for reregistration, requested data, and issued REDs for a few pesticides. Before 1996, FIFRA dictated that the EPA balance pesticide benefits and risks in making pesticide reregistration decisions. The 1996 Food Protection and Quality Act (FQPA), changed the both the criteria for registration and the ways in which nonoccupational health risks were measured.

The standards of reregistration differ by type of hazard. The pre-1996 FIFRA standard of weighing risks and benefits still applies to occupational and environmental effects. For dietary or household exposure, FQPA restricted the consideration of benefits in the regulatory process, and instead adopted a ``reasonable certainty of no harm" standard. Pesticides with food residues, persisting in the water supply, or encountered in the household are subject to this standard. In addition, EPA was to set new maximum levels of pesticide residues, or tolerances, paying special attention to the effects on sensitive subpopulations. Even pesticides registered after 1984, and not subject to reregistration, had to have their tolerances reevaluated.

Besides changing the standard for dietary and household exposure, FQPA mandated changes in the ways health risks were measured and considered. The EPA was supposed to place more emphasis on the effects of chemicals on infants, children, and pregnant women (1996 Food Quality Protection Act Implementation Plan 1997). Another directive of FQPA was to consider the aggregate lifetime exposure of pesticides. To do this, the EPA was to calculate a ``risk cup," a maximum daily allowable exposure per person given a 70-year lifetime. Projected exposure is aggregated over all pesticides sharing a ``common mode of toxicity." If the risk cup overflows, the EPA was to reduce tolerances for individual chemicals.

FQPA also has special provisions for "minor use" pesticides (Report on Minor Uses of Pesticides n.d.). Marketing pesticides for crops with relatively low acreage generally provides less revenue to pesticide manufacturers, and less incentive for them to complete the reregistration process for those uses. Because of concerns that registrants would choose not to support minor uses, FQPA is more lenient for minor uses, allowing data delivery extensions and waivers, data grants, and expedited review.

User fees were set by FQPA and later in the Pesticide Registration Improvement Act (PRIA 1) in 2003 and PRIA 2 (2007). Fees vary between a few thousand and hundreds of thousands of dollars, depending on the uses of the pesticide and its relationship to existing pesticides. In addition, registrants pay for studies requested by the EPA to support their applications. Rather than having registrants repeat the data collection for similarly formulated pesticides, the EPA allows registrants to use other companies' data. Registrants are supposed to compensate other registrants for the use of their data, although the legislation does not specify the terms of these transactions.

Enforcement of Pesticide Regulations

Pesticide labels, which specify the maximum amount to apply, the methods of application, the allowable crops, and appropriate safety precautions, are law. The EPA imposes fines when they discover the distribution of unregistered or unlabeled pesticides, or pesticides applied in ways not specified on the labels. The EPA has authority over whether pesticides are registered, and can set specific parameters for their use.

Though the EPA sets tolerances, enforcement of tolerance levels falls under the jurisdiction of the Food and Drug Administration (FDA). The FDA and the USDA monitor pesticide residues on food, not the EPA. The setting of tolerances by the EPA does not guarantee their enforcement by the FDA.

How successful the EPA is at enforcing label restrictions is outside the scope of this research. The questions focus on EPA's regulatory choices, not on their methods of enforcement.

Literature on Pesticide Value and Health Effects

The academic literature on pesticide use, benefits, health effects, and regulation spans many disciplines. I summarize the literature pertaining directly to the regulatory process: research that investigates issues of concern to the EPA in making pesticide decisions, and literature directly investigating the regulatory process.

Pesticide Value

For much of the reregistration period, expenditures on agricultural pesticides applied to crops totaled more than $8 billion (nominal) dollars annually (Fernandez-Cornejo, Nehring, et al. 2009). This figure gives some sense of the value of pesticides to pesticide registrants, but calculating the value to farmers is more involved. Pimentel et al. (1992) estimated that farmers receive a return of four dollars to every one dollar invested in pesticides. Though his research was published nearly two decades ago, it remains one of the few broad estimates of pesticide value to farmers available. In a survey of the literature on returns to pesticide use, Fernandez-Cornejo, Jans, and Smith (1998) find positive returns to pesticide use, but point out that these benefits seem to be diminishing over time.

As the EPA generally considers pesticide benefits on a case by case basis, and is instructed to take these benefits into account for some parts of their regulatory decisions. Lichtenberg, Parker, and Zilberman (1988) developed methodology for measuring pesticide benefits, and applied it to individual uses of pesticides. Some EPA decisions make use of data on the benefits of pesticide uses, generally data from the EPA's own impact assessments, the benefits of most individual uses remain unquantified. Even if data on benefits was available for most uses, the benefits of pesticides are not static. Pest pressure can change over time. Availability of alternative pesticides can change. Repeated application of the same pesticide may results in pest resistance.

Environmental costs and benefits of pesticide use are also considered by the EPA, but can be even trickier to identify. Adoption of glyphosate-resistant crops (which are tolerant to the widely-used herbicide) results in reduced tillage of soil (Givens 2009), and therefore reduces erosion. Reduced tillage may also result in a reduction of greenhouse gases through carbon sequestration (Uri 2001).

Studies of Health Effects of Pesticides

The EPA relies on a large body of research studying the effects of pesticides on laboratory animals. This data on toxicity for animals was extrapolated to humans and matched to exposure information in EPA assessments of human health effects. To calculate dietary exposure, the EPA used food consumption data and pesticide residue data; to calculate occupational exposure, the EPA used data on the quantity of pesticide handled, the percent absorbed, and information on formulation and application method. Though animal studies serve as the foundation for all the EPA's analyses of pesticide toxicity and health effects, they are far too numerous to discuss here. The EPA did not typically rely on studies of the direct human health effects of pesticides; below I summarize some of the difficulties in the literature in identifying human health effects.

Research attempting to link human health outcomes and pesticide use faces some serious obstacles. For acute poisoning, many pesticide incidents likely go unreported: an affected person may not realize the source of their illness, may not seek treatment, or the illness may go unreported by health professionals. Tracking chronic health effects due to chronic exposure is even harder, as they require information on pesticide exposure and health outcomes over time for a population, as well as outcomes for a (presumably) unexposed control group. In a survey of the literature by Alavanja, Hoppin, and Kamel (2004), the relationship between health and pesticide use was inconclusive. World Health Organization (1990) suggests there may be additional research that went unpublished because the results were inconclusive.

Given limited data on long-term health outcomes, I instead rely on what the EPA knew about the toxicity and exposure of pesticides at the time of regulation.

Literature on Regulatory Processes in the U.S.

Economists and political scientists have analyzed regulatory processes and their outcomes for several agencies, including the Federal Energy Regulatory Commission (Kosnik 2010), the National Forest Service (Sabatier, Loomis and McCarthy 1995), the Food and Drug Administration (Olson (1995), (1997), (2000)) the Fish and Wildlife Service (Ando 1999), as well as the EPA. There is evidence that a variety of factors that may influence regulators' decisions: regulators' concern for public welfare, interest group lobbying, firm characteristics, congressional pressure, and the regulatory status quo.

Kosnik (2010) finds that direct congressional action has more influence on the Federal Energy Regulatory Commission than does interest group lobbying. In her analysis, FERC decisions also exhibit some path dependence: though decisions on dams would presumably be independent from one another, decisions are correlated to FERC's past actions. My research investigates somewhat similar factors: whether the EPA followed Congress' specific direction in reregistering pesticides, and whether individual registrants received different treatment in the process. Olson (1997) found that the FDA had shorter review times for pharmaceutical companies that were relatively less diversified and more R&D intensive, suggesting that the characteristics of individual firms influenced regulator behavior.

Cropper et al. (1992) found that the comments made by grower groups and academics were significant in the EPA's Special Review decisions on pesticides. Yates and Stroup (2000) extend this analysis to include media coverage, finding that articles on pesticides have a significant effect on EPA decisions. Ando (1999) found evidence that interested parties could delay the process of classifying a species to an endangered list. The Fish and Wildlife Service's action could be slowed by petitions and hearing requests, an outcome beneficial to groups who would incur costs when the species was listed.

Pesticide Regulation

Only a few papers concentrate directly on the EPA's process of pesticide regulation. Cropper et al. (1992) examined outcomes of the EPA’s Special Reviews, ad hoc investigations of individual pesticides that occur when significant risks come to the attention of the EPA. In a special review, the EPA assesses the risks and benefits of the pesticide and determines whether it may stay on the market. Cropper et al. modeled the EPA's decision using risks and benefits, along with the pressure exerted by interested parties in their comments, and showed that the implicit value for avoiding a cancer case was $35 million. They found that while the EPA appeared to balance benefits and risks, they also seemed to be subject to the commentary of interested parties. In addition, Cropper et al. rejected the ``bright line" hypothesis that pesticides exceeding a certain risk limit would be canceled, and calculated the implicit value the EPA was placing on a statistical life.

In his unpublished dissertation, Courbois (2000) took a different approach to explaining pesticide regulatory outcomes. Instead of examining the select group of pesticides that underwent special review, Courbois (2000) looked at a much larger universe of food use active ingredients, and examined the changes in registrations within this group over four years in the 1990s.

Courbois (2000) also made a different choice in modeling the decision process. Rather than attributing the decision to the EPA, he assumed that each pesticide registrant could choose to register an active ingredient for any crop, provided it was willing to allocate enough resources to the reregistration process. The analysis did not focus on a set of EPA decisions, but rather tracked the stock of registered active ingredient/crop pairs over time. Courbois' data allowed him to consider the effects of many different measures of toxicity on pesticide registrations. He included variables to reflect a number of other possible factors, including per-acre crop value. He lacked, however, a way of directly measuring the economic value of pesticides.

Chapter 3: Overview of Data

Scope of the Data

All pesticides complete an initial registration process before they may be introduced to the U.S. market. Older pesticides, defined as those first registered before November 1, 1984, were subject to the EPA's reregistration process. In 1988, the EPA announced 613 "cases," consisting of single pesticides or groupings of similar pesticides, which were a comprehensive listing of active ingredients subject to reregistration. Although all of the active ingredients included in my data were part of these 613 cases, there are several other criteria that had to be met for inclusion in my dataset. Reregistration Eligibility Decisions used in this dataset were published between 1990 and 2008. Over 80% of the decisions were published after FQPA was passed in 1996. Those what were published before the legislation were revisited by the EPA to comply with the new requirements.

Further Participation in the Reregistration Process

In order to continue in the reregistration process in 1988, registrants had to pay a registration fee for each product on the market. For pesticides with significant sales, this fee was nominal; however, there were many pesticide products on the EPA's list that were little used or no longer produced. In 1989 and 1990, products for which fees were not paid lost their registrations. Since no further registration action was taken (and little documentation is available) for these pesticides, they are not included in my sample.

Herbicides, Insecticides, and Fungicides

The same active ingredient can control more than one type of target pest. Ziram, for example, is used as a fungicide but is also used as a bird and rodent repellent.[7] To be included in my data, the active ingredient had to have some herbicidal, insecticidal, or fungicidal uses, which encompass the overwhelming majority of field crop applications. This excludes pesticides designed exclusively for vertebrates, such as rodenticides and bird repellents. It also excludes antimicrobials, which are often used in food preparation settings, but not so often in the field, and fumigants. Though fumigants can be used in the field on food use crops, their method of application and inherent risks are quite different than other agricultural pesticides. In addition, most fumigant uses in my data would have been of Methyl Bromide, the use of which is restricted for reasons separate from the reregistration process.

Insecticides comprise the largest share of observations in my data, with 1204. There are 909 herbicides and 609 fungicides. These numbers, however, reflect the total uses for all active ingredients. Of the 120 active ingredients represented in the dataset, only 39 are insecticides while 60 are herbicides, and 21 are fungicides. Herbicides are the most heavily used group by pounds and by acres. The U.S. Department of Agriculture Economic Research Service reports 360 million pounds of herbicides applied to crops in 1997, which is more than six times the pounds used of either insecticides or fungicides (Osteen and Livingston, Pest Management Practices 2006). This disparity is due in part to the types of crops generally treated with each

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[7] EXTOXNET, a database of pesticide profiles hosted by Cornell University, provides useful summaries of the properties of individual active ingredients. See http://pmep.cce.cornell.edu/profiles/extoxnet/index.html

type of pesticide. Herbicides are heavily used on major field crops such as corn and soybeans, which represent a large share of agricultural production. Insecticides and fungicides are most heavily used on specialty crops, such as fruits and vegetables, which represent far less acreage.

Agricultural, Food-use Pesticides with Field Application Only

Since this research focuses on dietary exposure and occupational exposure in agriculture, all other uses of pesticides were excluded. In order to be included, a pesticide had to be applied directly to a food crop while it was still in the field. On the dietary risk side, I wanted only pesticide uses where population would eat the same commodity that had been treated with pesticide. On the occupational side, I wanted applications to occur in the field, so that there would be more opportunity to compare application rates and other common restrictions. In practice, this meant the following types of active ingredients and their uses were excluded:

- Pesticides uses in non-agricultural settings, such as against termites, for mosquito control, or as a weed killer on a golf course;
- Pesticides use on livestock;
- Pesticides use on feed crops, such as corn for silage and alfalfa;
- Non-food crops, such as ornamentals and tobacco. Cotton is included, however, because of the use of cottonseed for oil;
- Pesticides uses that were exclusively post-harvest (applied in food storage facilities, for example, and not in the field);

- Homeowner uses.

Other Exclusions

Some other pesticides, though they met all the above criteria, were also excluded. In a few of the EPA's "cases", such as copper compounds, too many pesticides were combined to make matches with usage and toxicity data accurate. Some compounds, such as sulfur, boric acid, and petroleum distillate, are naturally occurring and were applied in such large quantities that their comparison to other pesticides seemed inappropriate.

Pesticides consisting of or derived from bacteria, viruses, or antibiotics were also excluded. Bacillus thuringiensis was excluded, for example, since the properties of Bt and the quantity applied differ considerably from the other pesticides in the data.

Data on the EPA's Regulatory Choices

During the reregistration process, the EPA had several instruments at its disposal for reducing risk, including cancelling pesticide uses outright, reducing application rates, adjusting pesticide tolerances, changing the level of required personal protective equipment, or restricting the area to which pesticides may be applied.

Data on pesticide reregistration decisions

The data on pesticide reregistration decisions spans 120 active ingredients. During reregistration, the EPA had to declare each pesticide use to be either cancelled or eligible for reregistration. Most cancellations reported by the EPA were voluntary:

the registrant participated in the reregistration process, but at some point withdrew their pesticide use rather than meet the EPA's requirements or face legal action. Whether or not a crop was "eligible" for reregistration was stated in the Reregistration Eligibility Decision (RED) for the active ingredient, accompanied by documentation of the usage and health risks. In cases where an active ingredient was cancelled before a full RED was published, information on decisions comes from the Federal Register or other EPA publications.

All crop uses that met the criteria given above were included in the dataset. Most often, the EPA specified individual crops in the Reregistration Eligibility Decisions. In some cases, however, they specified a crop group, such as Pome Fruit, instead of individual crops.[8] In these cases, I expanded the data to cover significant crops in the category (if Pome Fruit was a listed use, I would create observations for apples and pears). For a detailed listing of crops and their crop groups, see Appendix 3.A.

Table 1 summarizes the reregistration outcomes by crop group. Several fruit and vegetable groups, such as Berry, Brassica, Herbs, Fruiting Vegetables, and Pome Fruit, have reregistration rates below the average of 81%. Large field crop groups, such as Grain and Oilseed, have reregistration rates above 81%. Interestingly, crops for which no group is specified (which are generally small, orphan crops) also have above average reregistration rates.

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[8] Crop groups are based on EPA definitions, from the Pesticide Use Index published by the EPA's Office of Pesticide Programs, October 2006. Crop groups allow the EPA to use data from representative crops, with similar characteristics and cultural practices, rather than requiring data for each individual crop. A more detailed description of the development of crop groups is available at http://ir4.rutgers.edu/Other/USDACropgroupingSymposium.pdf.

Table 1: Reregistration decisions by crop group

Crop Group	*Pct. Reregistered*	*Total AI*
Berry	75%	221
Brassica	77%	214
Bulb	90%	67
Citrus	88%	170
Cucurbit	81%	153
Fruiting Vegetables	73%	110
Fungi	57%	7
Grain	84%	252
Herbs	76%	34
Leafy	81%	124
Legume	79%	213
Nut	86%	160
Oilseed	86%	114
Pome	78%	101
Stone	82%	229
Tuber	81%	237
Total	81%	2,722
No Group Specified	83%	316

Reregistration decisions by crop and crop group are available in the Appendix at the end of the chapter. Crop group definitions are based on EPA classifications of crops. AI refers to active ingredients.

Consumption patterns and cultural practices vary by crop group. Children in the U.S eat relatively high amounts of commodities in the Stone Fruit and Pome Fruit categories. Larger field crops generally have a high level of mechanization, meaning that per acre, fewer workers come into close contact with the crop. Pest pressure and the application rate necessary for pest control vary considerably between crops. The equipment required for application may be quite different for fruit trees, vegetables, and field crops, with different risks to workers.

Pesticide registrations (and crop practices) vary widely by crop group. Large field crops in the Grain and Legume groups have many herbicide registrations, whereas vegetables in the Brassica, Leafy, or Fruiting Vegetables groups have more insecticide registrations. Though more than half the pounds of pesticides used in agriculture in the U.S. are herbicides (Fernandez-Cornejo, Nehring, et al. 2009) there are fewer registrations than for insecticides. This is driven in part by the heavy use of a few herbicides on field crops, such as atrazine and glyphosate.

Table 2: Frequencies by crop group and pesticide type

Crop Group	*Fungicide*	*Herbicide*	*Insecticide*	*Total*
Berry	55	75	91	221
Brassica	60	32	122	214
Bulb	25	18	24	67
Citrus	18	63	89	170
Cucurbit	39	35	79	153
Fruiting Vegetables	24	26	60	110
Fungi	1	0	6	7
Grain	64	106	82	252
Herbs	16	6	12	34
Leafy	34	28	62	124
Legume	43	84	86	213
Nut	16	69	75	160
Oilseed	22	42	50	114
Pome	19	31	51	101
Stone	59	82	88	229
Tuber	56	69	112	237
No Group Specified	58	143	115	316
Total	609	909	1,204	2,722

Crop groups based on EPA definitions. In the data, each pesticide may only have one type. Frequencies are counts of unique active ingredients.

To give context for crops, I also list the total acres planted according to the 1992 Agricultural Census (see Appendix 3.A). Rhubarb and chicory had just a few hundred acres planted each, while corn, the largest crop, had tens of millions of acres planted. Crops with a large number of acres often have dozens of pesticide registrations, while very small crops may only have one or two.

Table 3: Pesticide reregistration by type of pesticide

Type	*N*	*Pct. Reregistered*
Fungicides	609	77%
Herbicides	909	97%
Insecticides	1204	71%

In the data, each pesticide may only have one type. Frequencies are counts of unique uses.

Insecticides make up 1204 out of 2722 observations in the data, but have the lowest reregistration rate of 71%. Herbicides represent about a third of the data, and had nearly all uses reregistered. The number of crop uses for an active ingredient varies substantially: molinate, for example, is used on just one crop in the data, while glyphosate, a widely used herbicide, is registered on 140 crops. In many cases, all uses of a particular active ingredient were reregistered. All uses were reregistered on a majority of active ingredients. Just 11 had all of their uses cancelled, and 31 had a mixture of reregistrations and cancellations. A detailed list of active ingredients by type and their respective reregistration rates is in the Appendix 3.A.

Appendix 3.A

Table 4: Percent reregistered of active ingredients by pesticide type

Pesticide Type	*Active ingredient*	*Year of first reregistration*	*Pct. Reregistered*	*n*
Herbicides	1,2-Dihydro-3,6-Pyridazinedione	1994	100%	2
	2,4-D	2005	100%	30
	2,4-Db	2005	100%	3
	Acetochlor	2006	100%	1
	Acifluorfen	2004	100%	3
	Alachlor	1998	100%	8
	Asulam (Ansi)	1995	100%	1
	Atrazine	2003	100%	4
	Bentazone	1995	100%	10
	Bromacil	1996	100%	3
	Bromoxynil	1998	100%	13
	Butylate	1993	100%	2
	Chloridazon	2005	100%	2
	Chlorimuron-Ethyl	2004	100%	2
	Chlorpropham	1996	100%	2
	Chlorsulfuron	2005	100%	3
	Dcpa	1998	85%	34
	Dicamba	2006	100%	8
	Dichlobenil	1998	47%	19
	Diclofop-Methyl	2000	100%	2
	Difenzoquat Methyl Sulfate	1994	100%	2
	Diquat Dibromide	1995	100%	11
	Diuron	2003	97%	40
	Endothall	2005	100%	3
	Eptc	1999	100%	25
	Ethalfluralin	1995	100%	11
	Fluazifop-Butyl	2005	100%	20
	Fluometuron	2005	100%	1
	Fomesafen	2008	0%	4
	Glyphosate	1993	100%	140
	Hexazinone	1994	100%	3
	Imazapyr	2006	100%	1
	Lactofen	2003	100%	4
	Linuron	1995	91%	11
	MCPA	2004	88%	8
	Mepiquat Chloride	1997	100%	1
	Metolachlor	1995	100%	22

Pesticide Type	*Active ingredient*	*Year of first reregistration*	*Pct. Reregistered*	*n*
	Metribuzin	1998	100%	12
	Molinate	2004	0%	1
	Nicosulfuron	2004	100%	1
	Norflurazon	2002	100%	29
	Oryzalin	1994	100%	16
	Oxyfluorfen	2002	100%	54
	Paraquat	1997	100%	88
	Pendimethalin	1997	100%	39
	Phenmedipham	2005	100%	3
	Picloram	1995	100%	3
	Primisulfuron-Methyl	2002	100%	1
	Prometryn	1996	100%	4
	Pronamide	2002	100%	19
	Propachlor	1998	100%	2
	Propanil	2003	25%	4
	Sethoxydim	2005	100%	56
	Simazine	2006	100%	28
	Terbacil	1998	100%	13
	Thidiazuron	2005	100%	1
	Tri-Allate	2001	100%	6
	Tribufos	2000	100%	1
	Triclopyr	1998	100%	1
	Trifluralin	1996	99%	68
	Total		97%	909
Insecticides	Acephate	2001	100%	12
	Aldicarb	2007	85%	13
	Amitraz	1995	100%	2
	Azinphos-Methyl	2001	23%	44
	Carbaryl	2007	99%	81
	Carbofuran	2006	0%	24
	Chlorpyrifos	2006	98%	54
	Cryolite	1996	80%	35
	Cypermethrin	2006	100%	13
	Diazinon	2004	81%	58
	Dicofol	1998	100%	43
	Dicrotophos	2006	100%	1
	Diflubenzuron	1997	100%	8
	Dimethoate	2007	79%	43
	Disulfoton	2002	62%	26
	Endosulfan	2002	91%	57
	Ethion	2001	0%	7

Pesticide Type	*Active ingredient*	*Year of first reregistration*	*Pct. Reregistered*	*n*
	Ethoprophos	2001	92%	12
	Fenamiphos	2002	0%	26
	Fenvalerate	2003	0%	49
	Fonofos	1999	0%	22
	Lindane	2006	0%	5
	Malathion	2006	90%	110
	Methamidophos	2002	25%	8
	Methidathion	2002	100%	24
	Methomyl	1998	100%	72
	Methoxychlor	2004	0%	53
	Methyl-Parathion	2003	35%	52
	Naled	2002	100%	36
	Oxamyl	2000	97%	31
	Oxydemeton-Methyl	2002	83%	41
	Parathion	2000	0%	7
	Permethrin	2007	98%	41
	Phorate	2001	92%	12
	Phosmet	2001	100%	25
	Profenofos	2000	100%	1
	Propargite	2001	77%	43
	Terbufos	2001	100%	4
	Thiodicarb	1998	100%	9
	Total		71%	1,204
Fungicides	Benomyl	2001	0%	72
	Captan	2004	100%	58
	Carboxin	2004	100%	16
	Chloroneb	2005	100%	4
	Chlorothalonil	1999	100%	38
	Dichloran	2006	100%	21
	Etridiazole	2000	100%	9
	Folpet	1999	100%	1
	Fosetyl-Al	1990	100%	19
	Iprodione	1998	100%	35
	Mancozeb	2005	100%	58
	Maneb	2005	89%	37
	Metalaxyl	1994	100%	65
	Metiram	2005	100%	2
	Propiconazole	2006	100%	31
	Quintozene	2006	50%	14
	Thiram	2004	96%	57
	Triadimefon	2006	20%	5

Pesticide Type	*Active ingredient*	*Year of first reregistration*	*Pct. Reregistered*	*n*
	Triphenyltin Hydroxide	1999	100%	3
	Vinclozolin	2000	6%	17
	Ziram	2003	26%	47
	Total		77%	609

Table 5: Reregistration decisions and acres planted by crop

crop group	*crop*	*percent reregistered*	*acres planted*	*N*
Berries	blackberries	89%	6,994	19
	blueberries	85%	43,184	27
	boysenberries	79%		14
	bushberries	100%		1
	caneberries	83%		6
	cranberries	73%	29,573	22
	currants	63%	317	8
	elderberries	50%		2
	gooseberries	57%		7
	Grapes	71%	867,151	41
	huckleberries	67%		3
	juneberry	100%		1
	lingonberry	100%		1
	loganberries	77%		13
	Raisins	0%		1
	raspberries	75%	15,899	24
	Salal	100%		1
	strawberries	70%	51,548	30
	Total	75%	230,604	221
Brassica	bok choy	0%		1
	broccoli	78%	122,429	32
	broccoli raab	75%		4
	brussels sprouts	77%		31
	cabbage	76%	95,445	37
	cauliflower	77%	62,465	35
	chinese broccoli	100%		4
	chinese cabbage	93%	8,824	14
	Collards	75%	16,062	24
	kale	75%	7,950	20
	kohlrabi	67%		12
	Total	77%	63,602	214
Bulbs	Garlic	89%	21,179	19
	leek	100%		4
	onions	85%	138,060	34
	shallots	100%		6
	green onions	100%	12,395	4
	Total	90%	93,113	67
Citrus	calamondin	100%		1
	citron	100%		1

crop group	*crop*	*percent reregistered*	*acres planted*	*N*
	grapefruit	85%	206,230	34
	kumquat	100%		4
	lemons	85%	67,329	34
	limes	92%	7,697	24
	oranges	86%	915,947	35
	tangelos	91%	14,474	11
	tangerines	92%	21,511	26
	Total	88%	257,697	170
Cucurbits	cantaloupe	80%	106,938	30
	chayote	100%		1
	cucumbers	80%	138,639	30
	muskmelon	80%		5
	pumpkins	81%	63,260	26
	squash	83%	69,029	29
	watermelons	81%	220,244	31
	winter melon	100%		1
	Total	81%	122,202	153
Fruiting vegetables	eggplant	73%	8,097	22
	groundcherry	75%		4
	okra	75%	4,336	8
	pepino	100%		1
	peppers	70%	73,966	37
	tomatoes	74%	397,368	38
	Total	73%	171,900	110
Fungi	mushrooms	57%		7
	Total	57%		7
Grains	barley	84%	6,818,065	31
	buckwheat	100%	64,554	2
	corn	80%	69,339,872	54
	millet	100%		5
	oats	78%	4,187,873	23
	popcorn	87%	321,485	15
	rice	85%	3,117,718	20
	rye	88%	336,248	16
	triticale	89%	22,188	9
	wheat	81%	59,089,472	37
	wild rice	100%	34,437	4
	sweet corn	89%	762,132	36
	Total	84%	25,663,176	252
Herbs	anise	0%		1
	coriander	100%		3

crop group	*crop*	*percent reregistered*	*acres planted*	*N*
	dill	67%		6
	fennel	75%		4
	mustard	80%	12,775	20
	Total	76%	12,775	34
Leafy vegetables	arugula	100%		1
	cardoon	0%		1
	celery	80%	37,007	25
	dandelions	67%		3
	endive	93%	1,942	14
	greens	100%		1
	lettuce	78%	287,468	32
	parsley	88%	5,439	8
	radicchio	100%		1
	rhubarb	100%	861	7
	spinach	68%	40,583	22
	swiss chard	100%		9
	Total	81%	102,719	124
Legumes	cowpeas	75%	32329	4
	dry beans	76%	1,548,766	38
	dry peas	67%	32,329	6
	garbanzos	100%		5
	guar	100%	6,836	2
	legume	100%		1
	lentils	75%		12
	Lima beans	90%	43,056	21
	mung beans	100%		1
	pea and bean	100%		1
	peas	76%	328,287	33
	pigeon peas	100%		1
	Snap beans	74%	272,698	39
	soybeans	80%	56,351,304	49
	Total	79%	14,806,129	213
Nuts	almonds	86%	441,700	35
	beechnuts	100%		3
	brazil nuts	100%		3
	butternut	100%		3
	cashews	100%		3
	chestnuts	100%		6
	chinquapin	100%		1
	hazelnuts	81%	32,674	21
	hickory nut	100%		3

crop group	*crop*	*percent reregistered*	*acres planted*	*N*
	macadamias	92%	23,155	12
	pecans	77%	473,426	30
	pistachios	85%	69,344	13
	walnuts	85%	214,159	27
	Total	86%	270,363	160
Oilseeds	canola	80%	89,777	10
	cotton	84%	10,961,720	58
	crambe	100%		1
	flaxseed	100%	156,630	9
	jojoba	100%	15,010	1
	rapeseed	100%	89,777	2
	safflower	92%	264,837	13
	sesame	100%		1
	sunflower	79%	1,905,088	19
	Total	86%	6,271,248	114
Pome fruits	apples	74%	583,624	43
	crabapples	100%		5
	loquat	100%		4
	pears	79%	83,183	38
	quince	73%		11
	Total	78%	348,849	101
Stone fruits	apricots	85%	26,984	33
	cherries	86%	126,395	42
	nectarines	80%	40,971	41
	peaches	80%	226,029	46
	plums	76%	60,116	37
	prunes	83%	82,002	30
	Total	82%	100,264	229
Tubers	beets	74%	10,523	19
	carrots	83%	108,250	29
	chicory	67%	847	6
	chinese radish	0%		1
	ginger	100%	325	1
	ginseng	100%	1,505	4
	horseradish	100%		6
	parsnips	100%		6
	potatoes	87%	1,351,084	47
	radishes	79%	29,893	19
	rutabagas	58%		12
	salsify	100%		1
	sugarbeets	79%	1,441,815	29

crop group	*crop*	*percent reregistered*	*acres planted*	*N*
	taro	100%	496	3
	turnips	72%	9,256	25
	yam	78%		9
	sweet potatoes	90%		20
	Total	81%	601,456	237
Group not specified	acerola	100%		2
	artichokes	73%	9,193	11
	asparagus	85%	85,929	26
	atenoya	100%		1
	avocados	86%	74,344	14
	bananas	79%		14
	breadfruit	100%		1
	cacao	100%		1
	carambola	100%		2
	casaba	100%		1
	castor beans	100%		2
	cherinoya	100%		1
	chinese mustard	100%		1
	chinese okra	100%		1
	cocoa	100%		2
	coffee	86%	7,783	7
	conifers	0%		1
	crenshaw	100%		1
	dates	100%	5,977	4
	dewberries	63%		8
	eggfruit	100%		1
	feijoa	100%		1
	figs	64%	20,131	11
	gourds	100%		1
	guava	100%	1,350	4
	honeydew	89%	35,005	9
	hops	83%	40,549	12
	jackfruit	100%		1
	kenaf	100%		1
	kitembilla	100%		1
	kiwi	75%	7,398	8
	litchi	100%		1
	longan	100%		2
	mango	71%		7
	manioc	100%		1
	mint	94%	158,433	18

crop group	*crop*	*percent reregistered*	*acres planted*	*N*
	olives	100%	35,636	8
	papaya	91%	3,733	11
	passion fruit	100%	64	4
	peanuts	76%	1,594,611	42
	peppermint	100%		2
	persimmon	100%		3
	pimentos	0%	1,236	1
	pineapples	82%	15,500	17
	plantains	67%		6
	pomegranates	100%		3
	rape	100%		1
	sapota	100%		1
	soursop	100%		1
	spearmint	100%		2
	sugar apple	100%		2
	sugarcane	75%	883,927	20
	tamarind	100%		1
	tea	100%		1
	temples	50%		2
	watercress	75%	505	4
	yautia	100%		1
	youngberries	33%		3
	Total	83%	401,036	316

Chapter 4: Pesticide Regulation and Dietary Risk Mitigation under the Food Quality and Protection Act

Introduction

In the U.S., the public knows that pesticides are used on crops. Articles about pesticide use and exposure appear regularly in the popular press.[9] What most of the population does not know is the level of risk to health that the use of pesticides on food-use crops presents. It would be costly for consumers to investigate the properties, usage, and residues of even a few active ingredients.

Many health, environmental, and economic concerns affect pesticide regulation, but dietary risk has been a primary motivator of government action. In 1996, the Food Quality and Protection Act directed the EPA to increase scrutiny of the dietary risks of pesticides in several ways. First, the legislation directed that instead of balancing pesticide costs and benefits, the EPA should adopt a "reasonable certainty of no harm" standard. Second, the EPA was to assess the cumulative risk of pesticides with similar mechanisms of toxicity—two particularly important classes of pesticides assessed were the organophosphates and n-methyl carbamates. Prior to FQPA, the EPA examined each active ingredient separately. In addition, the EPA was to add an additional layer of safety for vulnerable populations, such as infants, children, and pregnant women. FQPA required that the EPA set a tolerance (allowable level of pesticide residue on commodities) for each reregistered pesticide use.

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[9] Environmental Working Group's annual "Shopper's Guide to Pesticides in Produce" usually receives media attention. A description of their findings and methodology is available online at http://www.ewg.org/foodnews/ (accessed August 17, 2011), but gives an incomplete picture of potential risk. Another example is "Does it pay to buy organic?" *Businessweek,* September 6, 2004.

In examining dietary risk, the EPA considers chronic, non-cancer health risk and cancer risk separately.

I examine the effect of dietary risk measures on reregistration outcome and change in the tolerance. I find that uses with higher chronic dietary health risk are more likely to be cancelled (significant at the 10% level). Among pesticide uses that are reregistered, higher risk uses are significantly more likely to have their tolerances reduced. Pesticide uses with higher chronic health risks to infants and children were less likely to be reregistered, with coefficients and significant levels mirroring that of the population.

Uses with higher cancer risks are more likely to be cancelled, but these effects are not significant across several measures of carcinogenicity. Cancer risk also has an insignificant effect on tolerance changes. Cancer risk data is available for a limited and possibly unrepresentative subset of the decisions, however.

Pesticide expenditures significantly increased the probability of reregistration, though they were not a factor the EPA was directed to consider in dietary assessments. Expenditures were not as important in determining tolerance changes.

How the EPA Assesses Dietary Risk

Chronic dietary risk includes two broad categories of health outcomes: cancer risk and non-cancer health risks. Cancer risk includes tumor growths; chronic dietary risk refers to the risk of noncancer adverse health outcomes due to prolonged exposure to pesticides. Such outcomes include organ degeneration or reduction in reproductive capacity. Both kinds of health outcomes result from prolonged exposure to pesticides, but the EPA assesses them in different ways. For cancer risks the EPA assumes small increments of exposure result in additional risk. For chronic, non-cancer risks, the EPA uses thresholds, which assume exposure below an estimated level is safe.

Assessment of Chronic, Non-Cancer Health Risks

Assessment of chronic dietary non-cancer risk includes two main components: a measurement of the amount of the pesticide actually ingested, and an amount of pesticide considered safe to ingest. Though the EPA may adjust these measures based on the scope and quality of data available, the comparison of actual levels of consumption and safe levels of consumption captures the essence of EPA's analysis of dietary risk.

Measurement of chronic, non-cancer dietary pesticide consumption takes into account two routes of exposure: food and drinking water. Food exposure by active ingredient is the sum of the product of total dietary intake (mg/kg-day) by commodity and pesticide residue (parts per million) by crop *j* and active ingredient *i*:

$$Exposure_{ij} = \sum_{j=1}^{J} intake_j * residue_{ij} \qquad (1)$$

The EPA uses data from the United States Department of Agriculture Continuing Survey of Food Intake by Individuals (CSFII 1994-96, 98) to measure consumption of individual commodities.[10] Dietary intake data is expressed in per day consumption, adjusted for 70 kilograms of body weight to yield mg/kg-day values. Chronic risks and acute risks may be calculated differently, with mean consumption

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[10] U.S. EPA Exposure Factors Handbook (External Review Draft) 2009 Update. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/052A, 2009.

more often used for chronic exposure, and values on the higher end of the distribution used for acute exposure.[11]

In many cases, the EPA assumed the residue was equal to the tolerance (the maximum allowed residue of an active ingredient on a crop). When actual residue data was available[12] and there were dietary risk concerns, the EPA used actual residue values to calculate exposure.

Exposure estimates are then compared to reference doses (RfD), or the level of exposure that the EPA considers safe. The RfD is based on the No Observed Adverse Effect Level (NOAEL), or highest dosage at which no ill effects are found in laboratory animals. The NOAEL is then adjusted with two safety factors: an interspecies safety factor to account for the extrapolation of animal data to humans, and an intraspecies safety factor to account for variations within the human population (The Role of Use-related Information in Pesticide Risk Assessment and Risk Management 2000):

$$RfD_i = \frac{NOAEL_i}{safety\ factors} \tag{2}$$

Usually each of these safety factors is equal to 10, though the EPA may relax the safety factors if the data support a change. The ratio of the RfD to the level of exposure, adjusted for additional safety factors chosen by the EPA, yields a Population Adjusted Dose (PAD):

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[11] Conversation with David Hrdy, USEPA.

[12] The USDA's Pesticide Data Program samples foods at the point of sale to measure the levels of active ingredient residues. Data are collected for several crop and active ingredient pairs, with oversampling of crops commonly eaten by children.

$$\mathrm{PAD_{ij}} = \frac{Exposure_{ij}}{RfD_i} \qquad (3)$$

The EPA considers PADs less than one not of concern.[13]

Assessment of Dietary Cancer Risk

Non-cancer risks are treated as threshold effects: below some safe level of exposure, the EPA expects no adverse effect. Cancer effects, however, are more often handled linearly. Small doses are generally assumed to increase cancer risk by some amount. The EPA uses dose-response models to estimate the 95th percentile of the dose response curve, or an upper estimate of how the probability of getting cancer changes with exposure to the chemical. The q* (cancer cases per million population per mg/kg-day of exposure) is multiplied by the exposure (in mg/kg-day) to yield cancer risk:

$$Cancer\ risk_{ij} = qstar_i * exposure_{ij} \qquad (4)$$

The EPA considers the estimated probability of cancer, or q*, to be not of concern if it is below one in a million ($1 \text{ X } 10^{-6}$).

Routes of Dietary Exposure

The EPA considers several routes of exposure of exposure for the general population, including food, water, household uses, and public areas. Since this research focuses only on crop uses for food commodities and because of the special difficulties of water exposure data, only food routes are explored. The data on drinking water is far less standardized than that for food. The EPA uses several

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[13] A summary of the EPA's procedures for assessing human health risks is "Staff Background Paper #4: The Human Health Assessment Process and FQPA, available at http://www.epa.gov/oppfead1/trac/2umbrel.htm.

models and sources of water monitoring data to assess dietary exposure through drinking water. Since this research focuses on dietary exposure through food, and data points for water are quite disaggregated, drinking water exposure is omitted from this analysis. Household use of pesticides represents another route of exposure for the population, as does treatment of more public areas, such as golf courses or rights-of-way. There is also potential for exposure through commodities such as milk and pork, as pesticides are used on feed crops.

Reregistration Decisions Affecting Dietary Risk

As part of the reregistration process the EPA was required to assess the safety of each crop/active ingredient pair, and decide whether its use should be continued. For each crop/AI pair they also reviewed the tolerance, and made adjustments to the pesticide residue limits (measured in parts per million) on commodities ready for consumption.

Data Description

Reregistration Decisions and Tolerance Changes

Analysis of the effect of dietary risk on regulatory outcomes relies on data from the EPA and the USDA. The two outcome variables indicating the reregistration decision and the change in tolerance originate from EPA publications. The reregistration outcome variable reflects the decision expressed in over 100 Reregistration Eligibility Decisions covering food use pesticides, including 2722 active ingredient/crop pairs. It is a binary variable, and takes a value of zero for cancellation and one for reregistration.

The second outcome variable is based on the change in published tolerances for pesticide residues, as published in the Code of Federal Regulations (CFR). Under FQPA, the EPA was required to review the legal limit of pesticide residue remaining on food crops. These tolerances are published annually in the Federal Register (40 CFR 180), and specified in parts per million. In theory, adjusting the tolerance changes the level of dietary risk, as it changes the maximum amount of pesticide that an individual ingests.

Table 6: Summary statistics for variables in dietary risk models

Variable	*Units*	*N*	*Mean*	*s.d.*	*Median*
Decision (zero if cancelled, one if reregistered)	Binary	2722	0.812	0.390	
Tolerance change (% change in tolerance from 1994 to 2009)	Percent	1163	0.334	3.368	0
Tolerance decrease dummy	Binary	1675	0.402	0.490	
Population dietary risk (estimated exposure/safe exposure)	Ratio of estimated exposure to safe exposure	1342	4.087	30.384	0.065
Child dietary risk (estimated exposure/safe exposure)	Ratio of estimated exposure to safe exposure	1321	3.698	25.196	0.059
Infant dietary risk (estimated exposure/safe exposure)	Ratio of estimated exposure to safe exposure	1305	6.633	48.855	0.099
Population dietary risk threshold (one if above threshold of concern)	binary	1342	0.192	0.394	
Child dietary risk threshold (one if above threshold of concern)	Binary	1321	0.184	0.388	
Infant dietary risk threshold (one if above threshold of concern)	Binary	1305	0.239	0.427	
NAS infant (crops commonly consumed by infants per NAS report)	Binary	2722	0.149	0.356	
NAS child (crops commonly consumed by children per NAS report)	Binary	2722	0.115	0.319	
Probable carcinogen (classified as probable or known carcinogen by EPA)	Binary	2722	0.192	0.394	
(Log of population risk*Child	Weighted	1300	-3.819	5.689	-2.109

Variable	*Units*	*N*	*Mean*	*s.d.*	*Median*
consumption/population consumption	ratio of estimated exposure to safe exposure				
(Log of population risk*Infant consumption/population consumption	Weighted ratio of estimated exposure to safe exposure	1300	-4.597	6.637	-3.344
Possible carcinogen (classified as possible carcinogen by EPA)	Binary	2722	0.227	0.419	
Unknown if carcinogen (classified as “unknown if a carcinogen” by EPA)	Binary	2722	0.127	0.333	
Non-carcinogen (classified as a non-carcinogen by EPA)	Binary	2722	0.455	0.498	
Tolerance in 1994	Parts per million	1399	3.181	7.533	0.5
Tolerance in 2009	Parts per million	1546	2.734	5.829	0.5
q* (cases per million population per mg/kg-day)	Cases per million per mg/kg-day	1855	0.025	0.102	0.010
Cancer risk (q* x consumption x tolerance; winsorized)	Cases per million	436	119.279	371.550	6.085
Cancer risk >1:1,000,000	Binary	436	0.695	0.461	
Cancer risk > 1:10,000	Binary	436	0.188	0.391	
Cancer risk missing	Binary	2722	0.840	0.367	
Pesticide expenditures (price/acre*pounds/acre)	Millions of dollars	708	3.613	16.421	0.288
Pesticide expenditures missing	Binary	2722	0.740	0.439	

“Risk” measures are intended to be proportional to the EPA’s assessment of risk for individual pesticide uses. They are not necessarily bounded by 0 and 1.

I record the tolerance in 1994, prior to the passage of FQPA, and in 2009, after the last RED in my sample was published, conditional on the use not being cancelled. In theory, adjusting the tolerance changes the level of dietary risk, as it changes the maximum amount of pesticide that an individual ingests. As the characteristics of crops and active ingredients vary widely, it is not appropriate to consider these tolerances in their raw form, but it is possible to calculate a percentage change in tolerance for 1163 observations. This measure depends on both the 1994 and the 2009 tolerances being observed, and as a result is missing values for a large subset of the data. In 1994, not all crop/AI pairs have a published tolerance, and in other cases, the tolerances were defined in crop groups that were difficult to match perfectly to the 2009 data. Since cancelled uses often do not have tolerances published, the data is further limited to crop/AI pairs that were reregistered. Rather than rely on the percentage change in tolerance, I code whether the tolerance decreased (became more restrictive), increased (became less restrictive) or stayed the same. I divide the tolerance changes into three categories (Table 7). Most observed tolerance reassessments (890) resulted in no change, while 158 were reductions in tolerances and 104 were increases in tolerances.

Table 7: Summary of Tolerance Changes between 1994 and 2009

Tolerance Action	*Frequency*	*Percent*
Reduced	**161**	**14%**
Unchanged	**897**	**77%**
Increased	**105**	**9%**
Total	**1,163**	

Numbers may not sum to 100% due to rounding. As reported in the Code of Federal Regulations (40 CFR 180).

Carcinogenicity Measures

The EPA expresses the carcinogenicity of chemicals in a few ways. It labels chemicals as known carcinogens, probable carcinogens, possible carcinogens, carcinogenicity unknown, and non-carcinogens (see Table 8) I use dummy variables for each of these categories, varying by active ingredient (Health Effects Division 2007). Probable and known carcinogens had the highest rate of reregistration, whereas noncarcinogens had about the same rate of reregistration as the whole sample. Categories of carcinogenicity are not independently indicative of the danger of a pesticide; these categories give no indication of the level of exposure of the individual.

The EPA also uses a continuous measure of carcinogenicity, q*. Following the formula in Equation I derive a measure of lifetime cancer risk:

$$Lifetime\ cancer\ risk_{ij} = qstar_i * intake_j * tolerance_{ij} \qquad (5)$$

Unfortunately, the availability of the q*, the dietary intake measure, and the tolerances from 1994 are all limited. The EPA in some cases decided that the calculation of q* was unnecessary, and regarded the reference dose as sufficiently protective for carcinogenic as well as non-carcinogenic effects. I can calculate only 436 values for lifetime cancer risk. Table 9 summarizes decisions by cancer risk levels, where lifetime risks exceeding one in a million are defined as being of concern. For the limited number of observations for which cancer risk measures are available, 88% of uses above the level of concern were reregistered, which exceeds the success rate of uses below the level of concern (83%) and the rate for the population of observations (81%).

Table 8: Decisions by level of carcinogenicity

	AI/crop pairs	*Pct. Reregistered*
Probable Carcinogens	522	97%
Possible Carcinogens	617	78%
Unknown Carcinogenicity	345	70%
Non-carcinogens	1238	80%
Total	2722	81%

The 'Probable Carcinogen' category includes the one 'Known Carcinogen' in the sample, Diuron. Percent reregistered for probable carcinogens is significantly larger than that for any other group (at the 1% level).

Table 9: Reregistration decisions for high and low levels of cancer risk

	Obs.	*Pct. Reregistered*
Below level of concern	133	83%
Above level of concern	303	88%
Total	436	87%

The EPA is concerned about cancer risks exceeding one in a million. Risks above this level are defined as of concern, risks below this level are not of concern. Percent reregistered above the level of concern is not significantly larger than the percent reregistered below the level of concern.

Commodity Consumption Measure

A second measure uses the data actually employed by the EPA to measure consumption. Participants in United States Department of Agriculture Continuing Survey of Food Intake by Individuals (CSFII 1994-96, 98) survey in 1994-1996 completed a two-day food diary. Their consumption was translated to commodities, and tabulated for various demographic groups. Not all crops with reregistration records were also recorded in the CSFII, which results in many missing values.

Calculating Chronic Dietary Risk

Chronic non-cancer dietary risk is a ratio of estimated total dietary exposure to a pesticide via a particular crop to the estimated safe level of consumption. I mimic the EPA's measure as closely as possible with the data I have available. Exposure is based on the mean daily consumption reported in the CSFII data for each commodity. This is multiplied by the 1994 tolerance for each active ingredient and crop pair, which represents a maximum legal limit of residue for each active ingredient and crop pair, and therefore should be an upper bound on exposure. Exposure is then divided by the reference dose, or maximum safe daily exposure. Intuitively, the resulting statistic represents estimated exposure as a percentage of safe exposure; therefore values over one would be in excess of safe exposure, while values under one would not exceed safe exposure.

Sensitive Population Subgroups

The Food Quality and Protection Act directed the EPA to be especially protective of demographic groups likely to be more vulnerable to pesticides. These included infants, children, and pregnant women. The impetus for the extra concern stemmed from the National Academy of Sciences report, *Pesticides in the Diets of Infants and Children* (1993). One reason for the additional concern was that children are not little adults; the fact that they are developing means that pesticide exposure could affect them differently. Second, children tend to eat a narrower range of food than adults, meaning that their diets concentrate on just a few commodities. If these commodities have more pesticide residues, then children would have disproportionate exposure. The National Academy of Sciences detailed the high-consumption commodities for both infants and children. One dummy variable indicates high-consumption crops for children, and another indicates high-consumption crops for infants. Though these measures are crude, they do reflect the intention of the legislation.

The CSFII data also included consumption figures by demographic group. The infant (between one and two years old) and child (between three and five years old) statistics are used to calculate chronic dietary risk in a similar fashion to the population. Table 10 describes the reregistration outcomes above and below the threshold of concern by population subgroup. For all subgroups, uses with higher dietary risk were reregistered less frequently.

Table 10: Reregistration decisions above and below levels of concern for population subgroups

Subgroup	*Level of Concern*	*Pct. Reregistered*	*N*
Population	Below threshold	85%	1,084
	Above threshold	78%	258
	Total	83%	1,342
Children	Below threshold	85%	1,078
	Above threshold	74%	243
	Total	83%	1,321
Infants	Below threshold	86%	993
	Above threshold	75%	312
	Total	83%	1,305

One- and two-year-olds are classified as infants; children are aged 3-5 years. The level of exposure is assumed to be "above threshold" if daily exposure exceeds the maximum safe level, and "below threshold" if the exposure is less than the maximum safe exposure. For each group, the percent reregistered below and above the threshold are significantly different from one another (at the 5% level for the population, 1% level for children and infants).

Expenditures by pesticide use

Data on pesticide expenditures was provided by the ERS, and is a hybrid of price and quantity data collected by the National Agricultural Statistics Service and a private company. Quantities and prices are measured by the pound of active ingredient (net of other ingredients in pesticide products). Expenditure data is matched to a pesticide use if it is the most recent figure available no more than five years before publication of the RED. The scope of the data is necessarily limited by the surveys conducted by the government and by the company, and only about a quarter of the reregistration decisions in the dataset have corresponding expenditures figures. These observations are skewed toward the larger crops and more widely used active ingredients.

Overview of Empirical Models and Estimation Methods

Chronic Dietary Risk and Reregistration Outcomes

To model the relationship between chronic dietary health risk from pesticide ingestion and reregistration outcomes, I begin with a naïve probit. Reregistration outcomes, y, take a value of one when a use is reregistered and a value of zero when they are cancelled. Chronic population risk is x. In all models, I assume the error term is normally distributed and correlated within the observations for each active ingredient.

$$\mathrm{P}(y_{ij} = 1) = P(\beta_0 + \beta_1 x_{ij} + \varepsilon_{ij} \geq 0) \qquad (6)$$

The relationship between dietary risk and reregistration outcome does not have to be linear, however. In fact, it seems reasonable that the EPA may have a threshold of risk, above which it would cancel more decisions. To address this possibility, I use dummies for the quartiles of dietary risk in the probit. These quartiles are noted as the matrix *R.*

$$P(y_{ij} = 1) = P(R\Gamma + \upsilon_{ij} \geq 0) \qquad (7)$$

I am also interested in the relationship between reregistration outcomes and risks to infants and children. I use both models above, substituting my measures of risk for infants and children.

The EPA had many factors to consider in making reregistration decisions, which could have been additional regressors in this model. I omit most of them, however, as the EPA was explicitly directed not to trade off risks in benefits in assessing dietary risk. If the EPA followed this directive, dietary risk should have been a deciding factor on its own, not something to be considered jointly with other factors such as the availability of substitute pesticides or occupational hazards. Even though dietary risk should have been handled separately, I do include a measure of revenue from pesticide sales, *s*, to assess whether the value of the pesticide appeared to change how dietary risk was handled.

Chronic Dietary Risk and Tolerance Changes

Cancellation of a pesticide use is a blunt policy instrument, but the EPA has other regulatory choices as well. One of these choices is to adjust the tolerance for active ingredient/crop pairs. Reducing tolerances should reduce risk, as this reduces the levels of residue allowed on food. If the EPA decreased the tolerance, *c* takes a value of 0; if the EPA did not change the tolerance, *c* takes a value of 1; and if the EPA increased the tolerance, *c* takes a value of two. Cut points are noted as $\propto_1$and $\propto_2$. I estimate the ordered probit model:

$$P(c_{ij} = 0) = P(\delta_1 x_{ij} + \xi_{ij} \leq \alpha_1) \qquad (8)$$

$$P(c_{ij} = 1) = P(\alpha_1 \leq \ \delta_1 x_{ij} + \xi_{ij} \leq \alpha_2) \qquad (9)$$

$$P(c_{ij} = 3) = P(\delta_1 x_{ij} + \xi_{ij} \geq \alpha_2) \qquad (10)$$

As with the probit models above, I can substitute risk measures for infants and children for population risk.

Results

Dietary Risk and EPA's Reregistration Decisions

In the probit models in Table 11, larger risks correspond to a lower probability of reregistration. The use of Methomyl on peas, which is at about the 75th percentile (on the higher end of risk) of population risk, has a predicted reregistration of about 80% in Model 1. The use of Dimethoate on cotton, which is at about the 25th percentile (on the lower end of risk) of population risk, has a predicted probability of reregistration of 87%. The coefficients on population risk are significant at the 10% level.

Model 2 includes interactions between population risk and crops commonly consumed by infants and children, as defined by the National Academy of Sciences. There is no significant difference in the EPA's treatment of these "child and infant" crops than of other crops. In Model 3, I use risk measures that are based on the actual consumption patterns of infants and children. These measures are highly correlated with one another and with population risk (correlations between 0.96 and 0.98), and are therefore highly collinear. In an effort to address this problem with collinearity, in Model 4 I interact a ratio of child to population consumption and infant to population consumption with population risk. These ratios place more focus on the differences between child and infant exposure, though the ratio variables are also highly correlated. The coefficients on the ratio variables are insignificant.

In Model 5, I add crop group dummies to account for unobserved characteristics of crop groups (such as tubers or stone fruits). The inclusion of these dummies makes no difference in the significance of the coefficients, and only a modest difference in magnitude.

Table 11: Naive probit of reregistration decisions with chronic dietary risk by population subgroups

	(1)	(2)	(3)	(4)	(5)
Log population risk	-0.0150*	-0.0145*	-0.0055	-0.0165**	-0.0202*
	(0.0090)	(0.0083)	(0.0178)	(0.0081)	(0.0117)
Infant*Log population risk		-0.0088			-0.0059
		(0.0075)			(0.0069)
Children*Log population risk		0.0050			0.0089
		(0.0054)			(0.0057)
Log child risk			-0.0197		
			(0.0211)		
Log infant risk			0.0093		
			(0.0251)		
Log of Population Risk* Child ratio				0.0005	
				(0.0036)	
Log of Population Risk* Infant ratio				0.0005	
				(0.0040)	
Crop group effects	No	No	No	No	Yes
Observations	1300	1300	1300	1300	1300

Marginal effects. Robust standard errors clustered by active ingredient. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled. *** p<0.01, ** p<0.05, * p<0.1 Only observations with data for all categories are included. The child ratio and infant ratio variables are highly correlated (0.85); however, coefficients on these variables are also insignificant when included separately in models (not shown).

In Table 12 I examine how dietary risk variables affect reregistration across several groups: insecticide uses, fungicide uses, uses on fruits and vegetables, and uses on crops not categorized as fruits and vegetables. Insecticides and fungicides have higher levels of risk than herbicides, so I test whether the EPA was more responsive to risk in these two groups. The coefficient on population risk for both insecticides and fungicides is not significantly different than zero.

Risk values are also higher for fruit and vegetable crops than for other types of crops (such as grains and legumes). The EPA does not seem to cancel fruit and vegetable crops with higher risk values more often, however, as these coefficients are again not significantly different than zero. The EPA is more responsive to risk values for other crops, as log of population risk has a negative significant coefficient of similar magnitude to models using the entire dataset. Table 12 provides no evidence that the EPA was more protective of riskier active ingredient or crop groups.

Table 12: Effect of dietary risk on reregistration by pesticide type and crop type

	(1) Insecticides only	(2) Fungicides only	(3) Fruits and vegetables only	(4) Other crops
Log population risk	-0.0041	0.0146	-0.0125	-0.0204**
	(0.0145)	(0.0272)	(0.0125)	(0.0093)
Infant*Log population risk	-0.0127	0.0105	-0.0087	-0.0104
	(0.0137)	(0.0226)	(0.0087)	(0.0170)
Children*Log population risk	0.0258*	0.00256	0.0035	0.0045
	(0.0142)	(0.0111)	(0.0082)	(0.0091)
Constant	0.6681***	0.8434***	0.8872***	0.6495***
	(0.2244)	(0.3407)	(0.1993)	(0.1933)
Observations	625	235	801	499

Robust standard errors clustered by active ingredient. Fruits and vegetables include berry, citrus, pome, stone fruit, cucurbit, brassica, fruiting vegetables, tuber, bulb, and leafy crop groups. Models with only one risk variable as a regressor have similar coefficients (results not shown). *** p<0.01, ** p<0.05, * p<0.1. Marginal effects.

It may be more reasonable, however, to assume that the relationship between dietary risk and reregistration outcome is nonlinear. Perhaps there is a threshold above which the EPA cancels more uses. Or perhaps at low levels of toxicity, small differences in risk should not be material to the decision. I create dummies for the quartiles of infant and child dietary risk, where the fourth quartile is the highest risk. The first quartile, the safest, is excluded in the models in Table 13. Higher quartiles of dietary risk result in fewer reregistrations, with progressively larger effects for the higher quartiles. These coefficients are not individually significant; however, a Wald test rejects the hypothesis that the infant quartiles or the population quartiles are jointly equal to zero. In Model 1, the quartile representing highest population risk is 13 percentage points less likely to be reregistered than the lowest-risk quartile, though these coefficients are not individually significant. Model 2 and Model 3 have quartiles for infant and child chronic dietary risks. For measures of infant and child risk, none of the coefficients are significant. Higher levels of risk do have more negative coefficients, however. A Wald test rejects the hypothesis that all the coefficients are jointly equal to zero for infants, but not for the child quartiles.

Table 13: Reregistrations and quartiles of dietary risk by population subgroup

	(1)	(2)	(3)	(4)
Population Quartile 2	0.0123			0.0140
	(0.0529)			(0.0733)
Population Quartile 3	-0.109			-0.114
	(0.0707)			(0.0812)
Population Quartile 4	-0.130			-0.0683
	(0.0970)			(0.0941)
Child Quartile 2		-0.0264		-0.0514
		(0.0432)		(0.0578)
Child Quartile 3		-0.0953		-0.0637
		(0.0746)		(0.0861)
Child Quartile 4		-0.155		-0.106
		(0.0969)		(0.107)
Infant Quartile 2			-0.0043	0.0359
			(0.0367)	(0.0623)
Infant Quartile 3			-0.0861	0.0636
			(0.0609)	(0.0717)
Infant Quartile 4			-0.140	0.0304
			(0.0915)	(0.0805)
Constant	1.208***	1.250***	1.206***	1.230***
	(0.346)	(0.336)	(0.314)	(0.351)
Observations	1300	1300	1300	1300

Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1 Marginal effects. Category for the lowest percentiles is omitted. One- and two-year-olds are classified as infants; children are aged 3-5 years. Only observations with data for all categories are included. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

It is also possible to look at how EPA's decisions varied above and below the dietary risk threshold. Population dietary risk threshold takes a value of one if estimated exposure exceeds the safe level of exposure, and zero otherwise. Child and infant risk threshold dummies are similarly constructed. In Table 14, the threshold for the population is not a significant determinant of reregistration. Coefficients on child and infant risk thresholds are marginally significant and the effects are of greater magnitude than the population threshold in Models 2 and 3. These coefficients suggest that the EPA suggesting that the EPA may have had a greater response to child and infant risks, with above-threshold values resulting in a greater than 10% reduction in the probability of reregistration.

Model 4 lends further support to the hypothesis that the EPA is more protective of children than of the population as a whole. When including all three risk threshold dummies, the child dietary risk threshold is significant at the 5% level, whereas the population threshold coefficient remains insignificant. Indeed, uses above the risk threshold for the population are reregistered 77% of the time, while uses above the risk threshold for children and infants are reregistered 73% and 75% of the time, respectively.

Table 14: Reregistration decisions and dietary risk thresholds

	(1)	(2)	(3)	(4)
Population dietary risk threshold	-0.0734			0.0822
	(0.0599)			(0.0503)
Child dietary risk threshold		-0.118*		-0.0993***
		(0.0633)		(0.0456)
Infant dietary risk threshold			-0.107*	-0.1106*
			(0.0605)	(0.0633)
Constant	1.028***	1.061***	1.078***	1.0781***
	(0.219)	(0.219)	(0.229)	(0.2294)
Observations	1300	1300	1300	1300

Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1
Marginal effects. One- and two-year-olds are classified as infants; children are aged 3-5 years. Only observations with data for all categories are included. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

Congress instructed the EPA not to take pesticide benefits into account when making regulatory decisions based on dietary risk. Pesticide expenditures turn out to be quite important, however: the coefficient is highly significant across models. Uses with half a million dollars more in pesticide expenditures are more than two percent more likely to get reregistered. The dietary risk coefficient is not sensitive to the inclusion of expenditures (though it may be affected by the differences in sample size across models.)

Table 15: Registration decisions, dietary risk, and pesticide expenditures

	(1)	(2)
Log population risk	-0.0168**	-0.0151*
	(0.00797)	(0.00912)
Log of pesticide expenditures	0.0254***	0.0289***
	(0.00873)	(0.00986)
Expenditures missing		-0.0832*
		(0.0495)
Observations	535	1300

Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1 Marginal effects. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

Expenditures have a highly significant relationship with reregistration decisions in Table 15, but do these expenditures affect how the EPA accounts for dietary risk? In Table 16, I interact population risk with quartiles of expenditures, where the first quartile contains the lowest expenditure uses and the fourth quartile contains the highest expenditure uses. The highest quartile of uses by expenditure actually has the largest and most significant effect on reregistration decisions (Model 1): the EPA appears to be most responsive to dietary risk when expenditures are high. In Model 2, coefficients on dummies for expenditure quartiles confirm that higher expenditures do increase the probability of consumption, while at the same time, higher dietary risk results in more cancellations within each quartile. In fact, the largest (if not most significant) response to dietary risk is still in the highest quartile of expenditure.

Dietary risk is a function of how heavily a particular crop is consumed. Perhaps certain types of crops are widely consumed and widely produced, and have a high level of expenditure on pesticides. In Model 3, I include dummies for crop groups to help account for this possibility, though this does not have much effect on the coefficient on dietary risk for the highest quartile of expenditure. The EPA appears to have applied its dietary risk assessment no less stringently to high expenditure pesticide uses than to low expenditure pesticide uses.

Table 16: Reregistration decisions and dietary risk by expenditure quartile

	(1)	(2)	(3)
Log of Population Risk*Expenditure Quartile 1	-0.00388	-0.0145	-0.0215**
	(0.00792)	(0.00949)	(0.00948)
Log of Population Risk*Expenditure Quartile 2	-0.0210*	-0.0250**	-0.0300**
	(0.0120)	(0.0118)	(0.0128)
Log of Population Risk*Expenditure Quartile 3	-0.0174	-0.0129	-0.0205*
	(0.0106)	(0.00969)	(0.0112)
Log of Population Risk*Expenditure Quartile 4	-0.0540***	-0.0386*	-0.0481**
	(0.0141)	(0.0215)	(0.0194)
Expenditure Quartile 2		0.0230	0.0172
		(0.0417)	(0.0400)
Expenditure Quartile 3		0.0789**	0.0761**
		(0.0373)	(0.0356)
Expenditure Quartile 4		0.170***	0.177***
		(0.0508)	(0.0483)
Constant	0.7900***	0.5021***	0.3751*
	(0.1482)	(0.1847)	(0.2270)
Crop group effects	No	No	Yes
Observations	708	708	708

Robust standard errors clustered by active ingredient. Quartile 1 is the quartile of lowest expenditure. *** p<0.01, ** p<0.05, * p<0.1 Marginal effects. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

Carcinogenicity and Regulatory Outcomes

Cancer risk is the other significant dietary concern in pesticide reregistration. The EPA classifies pesticides into categories of carcinogenicity, and I interact each of these categories with *Log of Population Risk* (Table 17). The coefficients suggest that for probable carcinogens, population risk has a greater effect on cancellation than for other categories of carcinogenicity. The coefficient for probable carcinogens is significantly different than zero and significantly larger than the coefficients on the interactions for other categories. Though the coefficients change in Model 2 after including expenditures, the inclusion in the model makes little difference to the interaction coefficients when a similar sample of data is used in Model 3.

Table 17: Effect of population risk by carcinogenicity category on reregistration outcomes

	(1)	(2)	(3)
Probable Carcinogen*Log of Population Risk	-0.0768***	-0.0500**	-0.0812***
	(0.0257)	(0.0197)	(0.0275)
Possible Carcinogen*Log of Population Risk	-0.00283	-0.00602	-0.00229
	(0.0175)	(0.0127)	(0.0169)
Non-Carcinogen*Log of Population Risk	-0.0115	-0.0193**	-0.0120
	(0.0117)	(0.00958)	(0.0113)
Unknown carcinogen*Log of Population Risk	-0.0326	-0.0314	-0.0343*
	(0.0203)	(0.0202)	(0.0207)
Log of pesticide expenditures		0.0254***	0.0278***
		(0.00848)	(0.00917)
Expenditures missing			-0.0851*
			(0.0463)
Constant	0.795	1.071	1.119
	(0.182)	(0.183)	(0.178)
Observations	1342	535	1342

Probable carcinogen category includes one known carcinogen, Diuron. Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1 Marginal effects. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

A better variable for measuring carcinogenicity should be the q*, or lifetime cancer risk, which captures the number of expected cancer cases per million people exposed. Unfortunately, the q* is missing for most observations of pesticide decisions. In Table 18 I present the results of models using q*, which is winsorized to mitigate the effects of outliers. Model 1 shows that higher cancer risk is associated with a higher probability of cancellation; however, this coefficient is insignificant and the effect is very small. At the median cancer risk of six cases per million people, an increase of one cancer case corresponds to a reduction in the probability of reregistration of only

0.05%. The second model recodes the missing values of log of cancer risk to zero, and adds a dummy variable indicating when the log of cancer risk is zero. In the third and fourth models, instead of a continuous measure of cancer risk, I generate dummies for two thresholds of cancer risk: one in 1,000,000 and one in 10,000. None of these coefficients is significant.

Table 18: Reregistration decisions and cancer risk

	(1)	(2)	(3)	(4)
Log of cancer risk	-0.00333	-0.0042		
	(0.0081)	(0.0109)		
Cancer variable missing		-0.0710		
		(0.0984)		
Cancer risk > 1/1,000,000			0.0466	
			(0.0722)	
Cancer risk > 1/10,000				-0.0464
				(0.0763)
Constant	1.136**	1.136**	0.972*	1.154**
	(0.479)	(0.474)	(0.545)	(0.496)
Observations	436	1342	436	436

Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1
Marginal effects. Model (2) sets missing values of lifetime cancer risk to zero, and includes a dummy indicating the missing values. Lifetime cancer risk is winsorized to minimize the effect of outliers. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

Dietary Risk and Tolerance Changes

The effects of dietary risk measures on whether a pesticide use is cancelled appear small, but the EPA may have mitigated risk through other channels. One such channel is the pesticide tolerance: the EPA limits the amount of pesticide residue that may persist on food-use crops. Lower tolerances are stricter controls, implying a higher level of safety. As part of the reregistration process, the EPA reviewed all tolerances for reregistered uses. I analyze whether dietary chronic health risk and dietary cancer risk predict a change in tolerances.

In Table 19 I use ordered probit models, where the outcome is zero if tolerances were reduced, one if they were unchanged, and two if they were increased. Population dietary risk, infant dietary risk, and child dietary risk all predict more restrictive tolerances, and coefficients on all of these measures are significant. Rather than cancelling pesticide uses in response to dietary risk, it appears that the EPA made adjustments to tolerances to reduce the risk. Log of population risk is significant across models, and changes little when pesticide expenditures are included. In Model 1, a 1% increase in population risk indicates that a use was 1.3% more likely to have its tolerance reduced or a 1% decrease in the probability of an increase in tolerance. The result is similar for infant and child risk measures in Models 2 and 3.

The sign on pesticide expenditures suggests that higher expenditures are correlated with more relaxed tolerances; however, these effects are both small and insignificant. In Model 5, a one percent increase in pesticide expenditures translates to just a 0.3% reduction in the likelihood that a tolerance will be reduced, and this result is insignificant. A one percent increase in pesticide expenditures indicates an (also insignificant) 0.2% increase in the probability the EPA relaxes the tolerance.

Table 19: Tolerance changes and dietary risk by population subgroup

	(1)	(2)	(3)	(4)
Log population risk	-0.0614**	-0.0533***	-0.0802***	-0.0652***
	(0.0187)	(0.0181)	(0.0201)	(0.0197)
Infant*Log population risk		-0.0554		
		(0.0406)		
Children*Log population risk		-0.0249		
		(0.0287)		
Log of pesticide expenditures				0.0123
				(0.0341)
Log of Population Risk*Child ratio			0.0109	
			(0.0123)	
Log of Population Risk*Infant ratio			0.0027	
			(0.0090)	
cut1				
Constant	-0.918***	-0.928***	-0.919***	-0.917***
	(0.169)	(0.169)	(0.169)	(0.168)
cut2				
Constant	1.522***	1.521***	1.522***	1.350***
	(0.150)	(0.151)	(0.150)	(0.140)
Observations	1083	1083	1083	455

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Outcome variable takes a value of zero if tolerance decreased, one if it stayed the same, and two if it increased between 1994 and 2009. Conditional on successful reregistration.

Alternatively, I can examine whether values above and below a risk threshold resulted in a change in tolerance (Table 20). The coefficients are somewhat less significant than those on the continuous measures of dietary risk. Population dietary risk values above the threshold of concern were 9% more likely to have their tolerances reduced than those below the threshold of concern.

The coefficient on log of population risk is also robust to the inclusion of crop group dummies (Model 2), so it does not seem likely that the effect of dietary risk is driven by the characteristics of a few crops. I also look at the effect of log of population risk for insecticides and for fruits and vegetables. For fruits and vegetables (Model 4), the EPA seems to be similarly responsive to dietary risk as it is to all crops. For insecticides (Model 3), the EPA appears to be somewhat less responsive: the coefficient on log of population risk is both smaller and less significant than in other models. Though the coefficients on dietary risk are significant, they are not particularly large: a 10% increase in dietary risk translates to an increase in the probability of a tolerance reduction of less than half a percent.

Table 20: Tolerance changes and dietary risk, alternative models

	(1)	(2)	(3) Insecticides only	(4) Fruit and vegetables only
Population dietary risk threshold	-0.362* (0.157)			
Log Population Risk		-0.0807*** (0.0264)	-0.0489* (0.0255)	-0.0773*** (0.0253)
Crop group effects	No	Yes	No	No
cut1				
Constant	-1.152*** (0.158)	-0.901*** (0.250)	-0.938*** (0.216)	-0.911*** (0.185)
cut2				
Constant	1.264*** (0.118)	1.614*** (0.248)	1.615*** (0.222)	1.640*** (0.183)
Observations	1083	1088	472	673

Outcome variable takes a value of zero if tolerance decreased, one if it stayed the same, and two if it increased between 1994 and 2009. Conditional on successful reregistration. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ Threshold dummies take a value of one if estimated exposure exceeds safe exposure, zero otherwise. Thresholds for infant and child dietary risk (not reported here) are highly correlated with population risk (correlations of about 0.7 and 0.8). Entered separately in the model, their coefficients are very similar to those for the population. Fruits and vegetables include berry, citrus, pome, stone fruit, cucurbit, brassica, fruiting vegetables, tuber, bulb, and leafy crop groups.

In Table 21, I break down the effect of dietary risk by level of expenditure. In the first model, dietary risk has a highly significant and negative effect on tolerance changes, whereas the coefficient on expenditures is not significantly different than zero. In Model 2, I test whether the EPA's response to dietary risk in setting tolerances is sensitive to expenditure, and find that the effect does vary. For every level of expenditure, higher levels of dietary risk are associated with lower, more protective tolerances. These coefficients are larger and more significant for the higher expenditure quartiles. It appears that the EPA did not give preferential treatment to high-expenditure uses in setting tolerances, but it is hard to say whether the strictness of the tolerance was commensurate with the risk. The higher quartiles of expenditure may have merited more regulation, as the mean value of population risk also increases for each quartile.

Table 21: Tolerance changes and dietary risk by level of pesticide expenditure

	(1)	(2)
Log of Population Risk*Expenditure Quartile 1		-0.0220
		(0.0188)
Log of Population Risk*Expenditure Quartile 2		-0.0555**
		(0.0242)
Log of Population Risk*Expenditure Quartile 3		-0.0965***
		(0.0351)
Log of Population Risk*Expenditure Quartile 4		-0.0720**
		(0.0317)
Log population risk	-0.0652***	
	(0.0197)	
Log of pesticide expenditures	0.0123	
	(0.0341)	
Cut1	-0.917***	-0.907***
Constant	(0.168)	(0.168)
Cut2	1.350***	1.368***
Constant	(0.140)	(0.144)
Observations	455	455

Robust standard errors clustered by active ingredient.. Quartile 1 is the quartile of lowest expenditure; Quartile 4 has the highest. *** p<0.01, ** p<0.05, * p<0.1. Conditional on reregistration.

Using carcinogenicity categories rather than cancer risk increases the number of available observations (Table 22). I allow log of population risk to have a different coefficient for each category of carcinogenicity. Across models, non-carcinogens and unknown carcinogens are likely to have their tolerances reduced. A 1% increase in population risk for non-carcinogens equates to a 1.8% increase in the probability that the tolerances will be reduced; for unknown carcinogens, the probability of a reduction in tolerance goes up by 2%. The magnitude of the effect of population risk is smaller for possible carcinogens (1.3%) and less significant; probable carcinogens are actually less likely to have tolerance standards strengthened, though this coefficient is insignificant.

As in previous models, pesticide expenditures do not appear to have an effect on how the EPA responds to population risk. Though the coefficients in Model 2 are different than those in Model 1, this seems to be a result of how the expenditures data restricts the sample, as the coefficients in Model 3 with the larger subset of data are close to Model 1.

Table 22: Tolerance changes and carcinogenicity classification

	(1)	(2)	(3)
Probable Carcinogen*Log of Population Risk	0.0124	0.00236	0.00885
	(0.0252)	(0.0373)	(0.0258)
Possible Carcinogen*Log of Population Risk	-0.0633^{*}	-0.0437	-0.0630^{*}
	(0.0268)	(0.0243)	(0.0268)
Non-Carcinogen*Log of Population Risk	-0.0873^{***}	-0.119^{***}	-0.0891^{***}
	(0.0230)	(0.0337)	(0.0247)
Unknown carcinogen*Log of Population Risk	-0.0941^{**}	-0.0881^{*}	-0.0977^{**}
	(0.0304)	(0.0373)	(0.0308)
Log of pesticide expenditures		0.0137	0.0139
		(0.0348)	(0.0384)
Expenditures missing			-0.140
			(0.109)
cut1			
Constant	-0.938^{***}	-0.921^{***}	-1.022^{***}
	(0.167)	(0.173)	(0.180)
cut2			
Constant	1.544^{***}	1.384^{***}	1.464^{***}
	(0.155)	(0.139)	(0.152)
Observations	1117	455	1117

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Outcome variable takes a value of zero if tolerance decreased, one if it stayed the same, and two if it increased between 1994 and 2009. Conditional on successful reregistration. A Wald test fails to reject the null hypothesis that the interaction terms are jointly equal to zero.

I also use ordered probit models to investigate the relationship between cancer risk and changes to tolerances (Table 23). The coefficients on cancer risk are negative in all models, indicating the EPA took a more protective action when cancer risk is higher. In Model 1, the coefficient on cancer risk indicates that one more cancer case per million in population results in 1% more probability of a reduction in tolerances, though this result is insignificant. Cancer risks above the EPA's level of concern (one cancer case per million) are 10% more likely to have their tolerances restricted in

Model 3. Since only a subset of q* values are available, these results should be interpreted with caution.

Table 23: Tolerance changes and log of cancer risk

	(1)	(2)	(3)	(4)
Log of cancer risk	-0.0470	-0.0484		
	(0.0282)	(0.0292)		
Cancer variable missing		0.394*		
		(0.159)		
Cancer risk > 1/1,000,000			-0.393*	
			(0.168)	
Cancer risk > 1/10,000				-0.239
				(0.279)
cut1				
Constant	-0.851***	-0.875***	-1.065***	-0.820***
	(0.208)	(0.158)	(0.195)	(0.218)
cut2				
Constant	1.564***	1.615***	1.357***	1.579***
	(0.176)	(0.159)	(0.168)	(0.165)
Observations	378	1163	378	378

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Outcome variable takes a value of zero if tolerance decreased, one if it stayed the same, and two if it increased between 1994 and 2009. Conditional on successful reregistration.

Bivariate probit

Many of the same factors affect both reregistration decisions and tolerance changes. These two models might be more efficiently estimated together. I employ a bivariate probit model to jointly estimate two outcomes: whether the pesticide use was reregistered, and whether the tolerance was decreased. Cancelled uses were coded as decreased, as a cancellation implies that a tolerance will decrease to zero. Results of the bivariate probit are similar to those when the two models are run separately. In addition, rho is not significantly different than zero, implying that there may not be much to gain from estimating the models jointly.

Table 24: Bivariate probit of reregistration decisions and tolerance reductions

	(1) Reregistration decision	(2) Tolerance decreased
Log population risk	-0.0794**	0.113***
	(0.0365)	(0.0303)
Log of pesticide expenditures	0.109***	-0.0556*
	(0.0249)	(0.0313)
Constant	1.052***	-0.443***
	(0.180)	(0.147)
Observations	534	534

Robust standard errors clustered by active ingredient. Rho is insignificant (-6.51, with an error of 12.09).
*** p<0.01, ** p<0.05, * p<0.1

Conclusion

It appears that the EPA responded protectively to dietary health risks when regulating older pesticides through reregistration. There is limited evidence that dietary health risks spurred cancellations of pesticide uses. Higher levels of population risk predict lower reregistration rates, though these predictions are not highly significant. It seems likely that the EPA more often mitigated risk through adjusting pesticide tolerances than by eliminating pesticide uses.

There is weak evidence that the EPA was more protective of infants and children than of adults in making reregistration decisions. Measures of dietary risk that are specific to infant and child exposures have similar coefficients to population risk measures for both reregistration decisions and for tolerance changes. Crops commonly eaten by children did not have significantly different reregistration outcomes than other crops when accounting for population risk. However, dietary risk values for children and infants above the threshold of concern were 10% more likely to be cancelled than those below the threshold of concern.

Congress explicitly directed the EPA not to consider benefits of pesticides when assessing dietary risk. Though higher pesticide expenditures do have a highly significant and positive effect on reregistration, there does not appear to be any tradeoff between pesticide expenditures and dietary risk, suggesting that the EPA followed Congress’ directive in this regard.

The importance of cancer risks in pesticide regulatory decisions is difficult to establish. Probable and known carcinogens were more likely to be reregistered than possible carcinogens, unknown carcinogens, or non-carcinogens. It appears that the EPA was more likely to cancel uses in response to the chronic dietary risks of probable carcinogens, yet non-carcinogens with higher chronic dietary risks were more likely to have their tolerances restricted. It should however, be noted that these categories do not capture the extent of exposure to the pesticide. A cancer risk of more than one in a million resulted in a (slightly significant) 10% increase in the probability that tolerances would be restricted. A direct measure of cancer risk was not available for most pesticide uses in the data, however.

Chapter 5: Occupational Hazards and Registrant and Grower Interests

Introduction

Pesticide use has material implications for human health, productivity, and profit. Farmers, pesticide manufacturers, and pesticide handlers all have interests in the availability of pesticides for agriculture[16] and the rules governing their application, and their interests do not always intersect. CropLife America, a crop protection industry group, claims that "crop protection products increase productivity by 20-50%" and that "farmers get back at least $14.60 for each $1 invested on fungicides."

Pesticides have significant economic value, but their use poses risks to the mixers, loaders, and applicators who handle the chemicals, as well as to other workers who perform tasks in treated areas. A recent study found that pesticide applicators have an elevated risk of certain cancers relative to other mortality risks (Waggoner, et al. 2011). As workers handle pesticides in concentrated form, and in much larger quantities than encountered by the general population, the potential for acute exposure is high. The range of possible health risks from handling pesticides is broad: there is suggestive evidence of neurologic effects, cancers, and reproductive effects, among others (Weisenburger 1993).

The incidence of pesticide poisoning among agricultural workers is not well documented, making it difficult to draw broad conclusions about acute health effects.

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[16] Here, pesticides refer to herbicides, insecticides, and fungicides applied to crops grown for food. The definition of pesticides is generally broader that this; I exclude many pesticide types, such as wood preservatives, antimicrobials, and rodenticides, as well as pesticide uses such as those for livestock, feed crops, mosquito control, pets, and turf.

There are several reasons occupational pesticide illness would be underreported. Workers may not realize that illnesses stem from pesticide exposure, or have limited access to health care. Health care providers may not recognize pesticide poisonings, or may fail to report pesticide poisonings to the health department. Only a few states have significant systems in place for the surveillance of occupational pesticide poisoning (Schnitzer and Shannon 1999). The EPA's role of protecting pesticide handlers and farm workers is all the more important due to the problems with monitoring health effects as pesticides are used.

Pesticides and Worker Exposure

Workers can be exposed to pesticides while performing a variety of tasks in the field. Depending on the pesticide and on the circumstances, farmers may handle their own pesticides or hire applicators to treat their fields. Pesticide handlers experience the most direct exposure to pesticide active ingredients. Mixers and loaders prepare the pesticide (often by diluting it in water or oil) and transfer it to the appropriate application equipment. The exposure to mixers and loaders is determined by the formulation of the active ingredient, the mixing and loading system they use, their level of protective equipment, and the quantity of active ingredient they handle.

Once the application equipment is ready, applicators treat the target area. Common application methods include aerial, where pesticide is distributed by airplanes or helicopters; ground application, where liquids or granules are sprayed on the target area; chemigation, where pesticides are distributed through an irrigation system, and many types of hand application, where the applicator treats the area with a wand or other handheld apparatus. The exposure of applicators is determined by the amount of pesticide used, the method of application, the equipment used, and the amount of protective equipment used.

Other agricultural tasks may also result in pesticide exposure. Tasks such as thinning, weeding, scouting, and picking generally require workers to enter the field, though they do not typically wear protective equipment.

It is worth noting that there are many more possible scenarios of occupational exposure, including livestock treatments, in home extermination, treatment of food storage and processing areas, lawn treatments, and extermination. As this research focuses only on field treatment of food-use crops, other occupational exposures are not included.

How FIFRA Treats Occupational Risk

Under the Federal Insecticide, Fungicide, and Rodenticide Act, health concerns stemming from occupational exposure can be balanced against the pesticide’s benefits. This differs fundamentally from the “reasonable certainty of no harm” standard established for dietary risk. It is to be expected, therefore, that grower interests would be taken into account when factoring in occupational risks.

How the EPA Considers Toxicity of Pesticides in the Occupational Context

Though much of the public’s concern about pesticide risk centers on dietary exposure, pesticide handlers experience higher rates of exposure than the general public. The EPA is concerned with cancer risk and non-cancer chronic health risk as well as acute toxicity.

Cancer Risk

The EPA uses dose-response models to estimate the 95th percentile of the dose response curve, or an upper estimate of how the probability of getting cancer changes with exposure to the chemical. The q* (cancer cases per million of population per mg/kg-day of exposure) is multiplied by the exposure to yield cancer risk:

$$Cancer\ risk_{ij} = qstar_i * exposure_{ij} \tag{1}$$

The EPA considers the estimated probability of cancer, or q*, to be not of concern if it is below one in a million (1 X 10^{-6}).

In addition, the EPA classifies chemicals into categories by carcinogenicity. It labels chemicals as known carcinogens, probable carcinogens, possible carcinogens, carcinogenicity unknown, and non-carcinogens. This data includes dummy variables for each of these categories, varying by active ingredient.

Calculating Measures of Occupational Risk

The standard EPA measurement for occupational, non-cancer health risk from pesticides is Margin of Exposure, or MOE. The MOE compares estimated exposure with a “safe” level of exposure.

Calculating exposure requires several pieces of data. The EPA multiplies the application rate, or pounds of active ingredient per acre, times the number of acres likely to be treated by the handlers. The total pounds handled are multiplied by unit exposure, or the proportion of the pesticide expected to be absorbed by the handler (Keigwin 1998). It is then divided by body weight, which is assumed to be 70 kilograms, to yield the average daily dose (ADD) per kilogram of body weight:

$$ADD = \frac{UnitExposure * App.Rate * AcresTreated * \%Absorption}{BodyWeight} \qquad (2)$$

While the actual calculation of the daily dose is simple, the underlying assumptions are less so. Maximum application rate is mandated by the EPA for each active ingredient, crop, and method. The EPA assumes that pesticides are applied at the maximum rate. The EPA may assume absorption of the pesticide by the worker to be 100% or, if studies support it, a smaller number. Acres treated is based on data on application practices.

Unit exposure is derived from the EPA's Pesticide Handler Exposure Database (PHED), which is a repository of studies of worker exposure to active ingredients. Unit exposure depends on several parameters, which vary depending on whether the handler is a mixer/loader or an applicator, and takes different values for dermal and inhalation exposure. For applicators, selecting the relevant unit exposure depends on the application method and the level of protective equipment. Hand application has higher unit exposures than aerial application or groundboom applications. For mixers and loaders, unit exposure depends on the formulation of the pesticide, the mixing and loading system, and the level of protective equipment. Wettable powders, for example, have higher unit exposure for mixer/loaders than do liquids or granules. Since a use (active ingredient and crop pair) may have several methods of application and formulations, there are several possible estimates of daily dose for each use (Office of Pesticide Programs 1998).

To calculate the MOE, the EPA uses the daily dose and the No Observed Adverse Effect Level (NOAEL). The NOAEL is the dose at which laboratory animals experienced no adverse effects. The MOE is the ratio of the NOAEL to the daily dose:

$$MOE = \frac{NOAEL}{ADD} \tag{3}$$

It is important to note that in contrast to EPA’s measures of population risk (described in Chapter 4) higher values of MOE represent safer pesticide uses. The EPA considers MOEs below 100 to be of concern.

The MOEs in this paper use the chronic NOAEL, or levels of exposure that can be tolerated over a long period of time. It is also possible to calculate MOEs using acute NOAEL, a higher level of exposure that can be tolerated for a short period of time. For this dataset, the acute MOE and the chronic MOE are highly correlated (0.87 for applicator MOE and 0.77 for mixer/loader MOE), so there is not a large difference in what they measure. There are more observations of chronic MOE in my data, so this is the measure I use.

Data Description

Occupational Risk Mitigation Measures

The EPA has several options for mitigating occupational risks from pesticides. The most obvious instrument is cancellation. Though cancellation may be appropriate for pesticides with relatively low economic benefits or that have good substitutes, there may be compelling reasons for a pesticide to remain available to a particular crop. If the pesticide use is to remain on the market, the EPA has the option to restrict the ways the pesticide is used. I discuss three types of restrictions: limiting the application rate, setting the re-entry interval (REI), and requiring personal protective clothing (PPE).

Table 25: Summary statistics for variables in occupational models

Variable name	*Units*	*N*	*mean*	*s.d.*	*Median*
Reregistration decision (one if reregistered, zero if cancelled)	Binary	2722	0.81	0.39	
Reentry interval	Days	1931	2.60	6.96	1
Dermal Toxicity Dummy (one if highly toxic)	Binary	2722	0.12	0.33	
Inhalation Toxicity Dummy (one if highly toxic)	Binary	2722	0.09	0.29	
Maximum application rate	Pounds/acre	1861	3.05	5.55	1.56
Acres per farm	Acres	2339	69.40	117.19	29.0
q* (proportion of population affected per mg/kg-day)	Cases per million per mg/kg-day	1855	0.025	0.102	0.01
Handler MOE[a] (cNOAEL/(reported application rate*acres per farm))	Ratio of safe exposure/estimated exposure	611	0.90	6.31	0.03
Handler MOE[a] (cNOAEL/(maximum application rate*acres per farm))	Ratio of safe exposure/estimated exposure	1405	0.75	4.26	0.03
Applicator MOE[a] (cNOAEL/(unit exposure*CA application rate*CA acres per application))	Ratio of safe exposure/estimated exposure	969	60.59	359.33	1.51
Mixer/Loader MOE[a] (cNOAEL/(unit exposure*CA application rate*CA acres per application))	Ratio of safe exposure/estimated exposure	649	14.02	267.00	0.01
Mixer/Loader MOE Missing	Binary	2722	0.76	0.43	
Applicator MOE missing	Binary	2722	0.64	0.48	
ERS data missing (includes expenditures, price per acre, reported application rate)	Binary	2722	0.74	0.44	
Handler cancer (reported application rate*acres per farm*qstar)	Cancer cases per million[b]	245	2.47	5.16	0.33
Handler cancer (maximum application rate*acres per farm*qstar)	Cancer cases per million[b]	563	3.22	9.51	0.33
Applicator cancer (applicator unit exposure *CA application rate*CA acres per application*qstar)	Cancer cases per million[b]	385	13.15	132.93	0.01
Mixer/loader cancer (mixer/loader unit exposure*CA application rate*CA acres per application*qstar)	Cancer cases per million[a]	272	205.35	1626.02	0.43
Substitute (number of additional pesticides available of the same type for the crop)	count	2722	10.77	6.37	10
Price per acre/max price per acre	Percent	708	0.38	0.31	0.28
Du Pont	Binary	2722	0.11	0.32	
Bayer	Binary	2722	0.13	0.34	
BASF	Binary	2722	0.06	0.23	
Dow	Binary	2722	0.09	0.29	

Variable name	*Units*	*N*	*mean*	*s.d.*	*Median*
Syngenta	Binary	2722	0.06	0.23	
Monsanto	Binary	2722	0.06	0.23	
Expenditures	Millions of dollars	708	3.61	16.42	0.29
cNOAEL (chronic no observed adverse effect level)	Mg/kg-day	2336	16.18	46.47	1.8

MOEs are not identical to EPA calculations, but should be proportional to EPA measures.

[a] Handler MOE is calculated without unit exposure, as there is no indication of application method or formulation in the ERS data to allow for matching to unit exposure. Mixer/Loader MOE and Applicator MOE do have this information, and do use unit exposure. Handler MOE is therefore less precise than Mixer/Loader MOE or Applicator MOE, and not directly comparable.

[b] Though cancer measures mimic the EPA's measure of cancer cases per million, my data limit the precision of this measure. It is more accurate to think of these measures as proportional to cancer cases per million rather than literally cancer cases per million.

One of the most direct ways the EPA can influence pesticide exposure is through the maximum application rate. For nearly all active ingredients, crops, and methods of application the EPA specifies a maximum number of pounds per acre that may be applied for one application and over the course of a year. Since the observations in my data do not vary by method, I selected the highest per acre value specified by active ingredient and crop in the Reregistration Eligibility Decision (RED). Unfortunately, maximum application rate does not make a good outcome variable for two reasons: first, values are reported only *after* the reregistration process; there is no observation of how the EPA changed the rate to mitigate risk. Second, application rate is an important component of occupational risk measures. Using it as an outcome, even when conditioning on reregistered uses, is problematic.

A second restriction set by the EPA is the reentry interval, which also varies by crop and active ingredient. This is the amount of time in days before workers not wearing protective clothing may reenter the field, and is not observed if the AI/crop pair was cancelled during the registration process. If the EPA's concerns about the toxicity of the pesticide are minimal, the REI is set to half a day (12 hours). Half the

REIs in the data are a day or less, but they do range as high as 87 days. The importance of REIs varies by scenario; some crops require few tasks in the treated area, so a long REI matters little to production. Other crops benefit from pesticide application soon before harvesting. In this case, reducing the REI may have a negative effect on production. REI is observed only for pesticide uses that are reregistered.

The EPA may also specify PPE and engineering controls. The EPA usually starts with a base layer of nonspecialized clothing (shirt, pants, socks and shoes). For more toxic pesticides, the EPA will require more PPE, which may include gloves, aprons, protective headgear, protective footwear, and coveralls. In this data, there are three categories of PPE: only baseline clothing is required, baseline clothing plus gloves is required, or any additional PPE beyond gloves is required. Mixer/loaders and applicators may have different levels of PPE required for the same active ingredient and crop.

Additional protective measures that may be required by the EPA include the use of respirators and engineering controls. These are handled separately in the data from the PPE, with the respirator variable taking a value of one if handlers are required to use a respirator (not just have one handy). Engineering controls include mechanical safeguards such as enclosed cockpits for aircraft, enclosed cabs for ground equipment, and water soluble packaging. If at least one engineering control is required, the engineering variable takes a value of one; otherwise it is zero.

In my data, all variables describing protective measures vary only by active ingredient. In reality, they may vary by formulation and application method. Also, PPE, engineering controls, and respirator requirements are observed only when the active ingredient is reregistered for use on some crops.

Measures of Occupational Toxicity: Margin of Exposure

To match the EPA's assessment of occupational risk, I would need a dataset in which risk varied by method of application and formulation. Many of the variables I use to construct the daily dose are approximations; because of this, I take three separate approaches to calculating daily dose.

Constructing a measure of the daily dose that corresponds both to the EPA's methodology and to the structure of the regulatory outcomes data requires some simplification. At minimum, I need to know the amount of active ingredient a worker may encounter in a day. I use different data sources to approximate this exposure, which yield three separate measures, each with its own strengths and limitations.

The Economic Research Service (ERS) of the USDA maintains a database of pesticide usage, which is a composite of the National Agricultural Statistics Service's chemical usage data and Doane's Countrywide Farm Panel Survey. The ERS data includes application rates reported in farm surveys. Since not all crops are surveyed every year, I select the nearest observation up to five years prior to the respective RED publication. This data has some significant drawbacks, however. Application rate data is available for only 708 observations. These observations are not representative of all the crops and active ingredients dataset, as the farm surveys focus on larger crops and widely-used pesticides. Second, the EPA's calculation of risk is based on the maximum application rate, not the reported rate of use. If applicators are compliant with label restrictions, then the maximum application rate should be greater than the reported application rate. In the data, the actual application rate is greater than the maximum rate for about a third of the observations, but does not necessarily indicate noncompliance. In some cases, maximum application rates are missing because no application listed in the RED was in compatible pounds/acre units. Maximum application rates reflect the rates set *after* reregistration, whereas use rates are recorded *before* reregistration. Measurement error in actual application rates could also be a factor.

To complete the calculation of ADD in Equation 2, I need a value for the acres treated per day per worker. The EPA does not publish detailed information on their assumptions, only some very broad guidelines that do not correspond directly to the crops in my data. I choose instead to use a measure of acres per crop per farm, taken from the 1992 Agricultural Census. My assumption is that the number of acres on a farm corresponds to the number of acres that an applicator would be likely to treat in a day. The EPA assumes that the number of acres an applicator treats is the same as the number of acres for which a mixer/loader prepares pesticide (Evans, Jeff, email, December 27, 2010). Unfortunately, since I cannot distinguish in the ERS data between formulas and methods, I cannot include the unit exposure. I assume dermal absorption to be 100 percent. Body weight is constant at 70 kilograms.

It may be preferable to use the maximum application rate. I collected these application rates by active ingredient and crop from the REDs, including only the rates measured in pounds per acre.[17] There are 1861 observations available, more than for the ERS data. Unfortunately, maximum application rates are not available for

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[17] Pesticide usage may be on different scales, such as ounces per tree. Pounds per acre are the most common units for agricultural crop uses, however, and make most sense in the context of this research.

cancelled uses, making it impossible to use this data to predict the overall reregistration decision. I can and do use it when I model the REI, however. As these application rates vary in the REDs by active ingredient, crop, and method of application, coding them required some simplification of the data: I chose the highest value of pounds per acre available for the active ingredient and crop pair. The lack of information on method and formula means calculating the ADD follows the same assumptions and has the same limitations as it did for the ERS data. The ERS data is sparse; only about a quarter of observations in the dataset have values for actual application rates.

To better capture differences in exposure between mixers/loaders and applicators and differences in formulation or application method, I use the 1994 Pesticide Use Report data from the California Department of Pesticide Regulation. California mandates that every agricultural application of pesticide be reported to the state. These reports include acres treated, pounds applied, formulation, active ingredient, crop, and whether the application was aerial or ground. I use this data to calculate usage patterns by crop and active ingredient. For mixers/loaders, I calculate the mean pounds per application for active ingredient *i*, crop *j*, and formula *k*, where *N* is the number of applications*:*

$$MeanMixerExposure_{ijk} = \frac{\sum_{n=1}^{N} lbs_n}{N} \qquad (4)$$

The exposure of mixers and loaders is determined largely by the formulation of the pesticide, whereas applicator exposure is determined largely by application method.

To calculate applicator exposure, I sum the mean pounds applied over *l* applications by active ingredient, crop, and method of application, *m*:

$$MeanApplicatorExposure_{ijm} = \frac{\sum_{l=1}^{L} lbs_l}{L} \qquad (5)$$

When a crop and active ingredient pair has more than one method or formulation available, I choose the one with the most reported applications.

Using these means to calculate ADD in Equation 2 requires some important assumptions. First, I assume that California crop practices must be representative of national crop practices. In many cases, this data should be representative; in 1994, California was the leading producer of a large number of crops in the U.S., and had significant market share for several more. However, the practices for some of the largest crops, including corn, soybeans, wheat, barley, and peanuts, may not be truly representative as California was not a leading producer of these commodities. More data tends to be available for applications on fruits and vegetables than on other types of crops. Second, this measure assumes that the quantity applied in a single application corresponds to the amount a worker would be exposed to in a day.

As the California data has the pounds per treatment, I do not have to rely on using acres per farm. Also, since I have some information on formulation and method of application, I can use the unit exposures in calculating average daily dose in Equation 2 and define separate exposure measures for applicators and mixers/loaders.

For all of these data sources, I calculate an MOE as explained in Equation 3. The chronic No Observed Adverse Effect Level (NOAEL) is from the EPA’s Health

Effects Division of the Office of Pesticide Programs, and is measured in milligrams/kilogram-day. The number of observations available are limited by the extent of overlap between the California application data and the reregistration data: fewer than 1000 for applicator MOE, and about 650 for mixer/loader MOE.

Additional Measures of Occupational Hazard

Margins of exposure (MOEs) form the foundation of the EPA’s assessment of occupational risk. In addition to MOEs, there are additional aspects of occupational hazard worth investigating: first, occupational cancer risk, and second, levels of inhalation and dermal toxicity.

Cancer risk variables consist of the projected exposure of an applicator or mixer/loader multiplied by the q*. For example, the applicator cancer risk could be expressed as:

$$ApplicatorCancerRisk = MeanApplicatorExposure_{ijm} * q^{*} \tag{6}$$

A similar calculation can be made for mixer/loaders. Unfortunately, q* data is sparse; it is only available for about a quarter of pesticide uses in the dataset.

Pesticides are also classified as to their dermal and inhalation toxicity based on research on laboratory animals. Both have the same classification system: one for highly toxic, two for moderately toxic, three for slightly toxic, and four for non-toxic.

Table 26: Summary of occupational risk measures by reregistration decision

	Cancelled			Reregistered		
Variable	*N*	*Mean*	*Median*	*N*	*Mean*	*Median*
Mixer/Loader MOE	103	16.028	0.006	547	13.620	0.018
Applicator MOE	143	36.961	0.452	827	64.618	1.740
Handler MOE (Reported Application Rate)	96	0.276	0.013	515	1.013	0.036
Mixer/Loader Cancer (CA data)	32	45.195	0.019	240	226.703	0.503
Applicator Cancer (CA data)	56	3.323	0.005	329	14.818	0.011
Handler Cancer (Reported Application Rate)	41	3.049	0.108	204	2.356	0.355

Higher MOE reflects a higher level of safety; higher cancer measures reflect lower levels of safety. Handler MOE is an approximation of the MOE calculated by the EPA, using national data on application rates, but without information on formulation or application method. Mixer/loader MOE and Applicator MOE are calculated using reported pesticide applications in California, including formulation and application method data.

Table 27 summarizes active ingredients by level of dermal toxicity and amount of required PPE for mixer/loaders; Table 28 does the same for applicators.[18] The pattern of PPE requirements suggests that the EPA uses PPE in response to dermal toxicity levels for mixer/loaders; 75% of highly toxic active ingredients require more PPE than gloves, whereas only 53% of nontoxic pesticides do. The nontoxic category also has the highest proportion of active ingredients requiring no specialized PPE (26%). For applicators, higher proportions of pesticides require PPE beyond gloves when toxicity is higher; however the differences are less pronounced than for mixer/loaders. Half of highly toxic pesticides require no PPE for applicators.

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[18] As PPE and dermal toxicity do not vary by pesticide use in the data, these tables are based only on active ingredients. Using all observations in the dataset would effectively weight the reported proportions in ways that may not represent the EPA's actions.

It may be the case that additional engineering controls, such as enclosed cabs, are mitigating risk to the point that PPE is not necessary: Table 29 suggests that this is true. For pesticides of either high dermal or high inhalation toxicity, the EPA requires engineering controls over 90% of the time.

Most of the mitigation measures discussed here (PPE, engineering controls, and respirators) only vary in the data by active ingredient[19], making them less useful for the regression models described later in the chapter. The descriptive statistics do suggest, however, that PPE, engineering controls, and respirators are important to occupational risk mitigation. Models explaining reregistration decisions should therefore be interpreted with caution; it is possible that higher risk uses that were reregistered have significant PPE and equipment requirements.

Table 27: Total pesticides and percent of pesticides by dermal toxicity ratings and mixer/loader personal protective equipment

Dermal Toxicity	*No PPE*	*Gloves Only*	*Gloves + Additional PPE*	*Total*
Highly Toxic	2	1	9	12
Moderately Toxic	3	2	11	16
Slightly Toxic	8	16	28	52
Nontoxic	5	4	10	19
Total	18	23	58	99

Dermal toxicity and PPE data vary only by active ingredient, so only one observation per active ingredient is included. Pesticides which had all uses cancelled are excluded, as PPE is only observed for reregistered pesticides. Additional PPE may include aprons, protective footwear, or coveralls, but does not refer to engineering controls or respirators.

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[19] In reality, respirator, engineering controls, and PPE requirements vary mostly by method of application. Method of application does not map easily to the data.

Table 28: Total pesticides by dermal toxicity ratings and applicator personal protective equipment

Dermal Toxicity	*No PPE*	*Gloves Only*	*Gloves + Additional PPE*	*Total*
Highly Toxic	6	1	5	12
Moderately Toxic	5	4	7	16
Slightly Toxic	14	18	20	52
Nontoxic	7	5	7	19
Total	32	28	39	99

Dermal toxicity and PPE data vary only by active ingredient, so only one observation per active ingredient is included. Pesticides which had all uses cancelled are excluded, as PPE is only observed for reregistered pesticides. Additional PPE may include aprons, protective footwear, headgear, or coveralls, but does not refer to engineering controls or respirators.

Table 29: Total pesticides by engineering controls and dermal and inhalation toxicity ratings

	Toxicity Rating	*No Engineering Controls*	*Engineering Controls*	*Total*
Inhalation Toxicity	Highly Toxic	1	9	10
	Moderately Toxic	4	12	16
	Slightly Toxic	23	24	47
	Nontoxic	10	15	25
	Total	38	60	98
Dermal Toxicity	Highly Toxic	1	11	12
	Moderately Toxic	1	15	16
	Slightly Toxic	27	25	52
	Nontoxic	9	10	19
	Total	38	61	99

Dermal toxicity, inhalation toxicity, and engineering controls data vary only by active ingredient, so only one observation per active ingredient is included. Pesticides which had all uses cancelled are excluded, as engineering controls is only observed for reregistered pesticides. Engineering controls include a mandate for mechanical controls for at least one use. These controls may include closed mixing and loading systems (including water-soluble packaging), enclosed cockpits and enclosed cabs, but not respirators or PPE.

Table 30: Total pesticides by inhalation toxicity and respirator requirements

Inhalation Toxicity	*No Respirator*	*Respirator*	*Total*
Highly Toxic	6	4	10
Moderately Toxic	8	8	16
Slightly Toxic	34	13	47
Nontoxic	18	7	25
Total	66	32	98

Pesticides which had all uses cancelled are excluded, as respirator requirements are only observed for reregistered pesticides. To be categorized as “respirator” there must be a respirator requirement for at least one use of the active ingredient.

Since farm workers entering a field after application are not expected to use special equipment or wear PPE, the EPA relies on reentry intervals, or possibly maximum application rates, to protect them. Longer reentry intervals mean that farm workers wait longer before entering a field after application, giving the pesticide longer to break down and reducing exposure. Lower maximum application rates reduce exposure by decreasing the amount of pesticide used. Table 31 summarizes reentry intervals and maximum application rates by level of dermal toxicity. Pesticides with high dermal toxicity have mean reentry intervals of about four days, whereas pesticides with moderate dermal toxicity have REIs of about nine days. These seem much more protective than the REIs for pesticides with slight dermal toxicity (1.5 days) and no dermal toxicity (0.9 days).

Maximum application rates do not have such a clear pattern across levels of dermal toxicity. Rates for highly toxic and nontoxic pesticides are about the same (2.1 pounds per acre) while moderately toxic and slightly toxic are 1.2 lbs/acre and 3.7 lbs/acre, respectively. Whereas the cost of a higher reentry interval may be determined by the production practices of an individual crop (and might be independent of the toxicity of the pesticide), more toxic pesticides might not require high rates of application to be effective. Lower application rates for more toxic pesticides could be driven either by risk concerns or by the properties of the pesticides themselves.

Table 31: Mean reentry interval and maximum application rate by level of dermal toxicity

	REI		***Maximum Application Rate***	
Dermal Toxicity	*N*	*Mean (days)*	*N*	*Mean rate*
Highly Toxic	161	4.2	163	2.1
Moderately Toxic	250	9.0	242	1.2
Slightly Toxic	1273	1.5	1226	3.7
Nontoxic	247	0.9	230	2.1
Total	1931	2.6	1861	3.1

Longer reentry intervals are more protective, as there is more time between application and field entry.

Grower Considerations

Grower interest would be best captured by a projection of economic losses to growers following a cancellation or other regulatory change to a pesticide use. The EPA calculated losses occasionally, but not often enough or systematically enough to be useful in this analysis. Therefore, I use variables that should be correlated with whether a change would have an effect.

If a substitute exists for a cancelled or more stringently regulated pesticide, then the burden of the cancellation on growers should be less. I count how many substitutes a pesticide has available for the same use and of the same type. This assumes that any new herbicide applied to corn could substitute for an existing herbicide applied to corn. This is often not true, as there is variation in the target weeds of herbicides, even just for a single crop. This variable also captures nothing about the relative effectiveness of pesticides (or how the effectiveness could vary based on the pest and other circumstances.)

Even if there are substitute pesticides available, it could be that they are far more expensive than the one being regulated. Even though growers may be able to maintain yields after a cancellation, it might be at a much higher cost. I attempt to capture this through a ratio of the price of the pesticide to the maximum price of "substitute" pesticides.

$$\text{RelativePrice} = \frac{P_{ijh}}{\max{(P_{jh})}} \qquad (7)$$

If the pesticide has the highest per acre price compared to other pesticides of the same type *h* applied to crop *j,* Relative price is unity. Relative price is limited to the number of observations available from the ERS data: about 700.

Major Pesticide Registrants and Pesticide Revenues

Pesticide registrants pursue reregistration to protect the profits earned from the marketing of pesticides. One measure of the importance of a particular pesticide use to a registrant is the amount of revenue it generates. I approximate this revenue by constructing an Expenditures variable, the product of the prices and pounds of pesticides reported in the USDA-ERS dataset of pesticide usage. Because data is not available on every pesticide and crop combination for every year, I select the most recent data available at least two years prior to the publication of the RED. This allows for a long process of economic assessment and publication, and may not be unreasonable as the EPA would also have been using similar data.

Using expenditures as a proxy for revenue requires some notable assumptions: first, that revenue and expenditures are the same (what growers report spending is equal to, or at least proportional to, what registrants receive). The second assumption is that the expenditures in the USDA-ERS database are representative of expenditures for pesticide uses generally. Data tend to be collected only for larger crops and more widely used pesticides, so there is some chance that available values of the explanatory variable may restrict the observations systematically, and that some characteristic of pesticide uses that determines their exclusion from the USDA-ERS data is also correlated with the error term.

Constructing a variable for profits was unfortunately not feasible. I do not know production costs. The costs associated with pursuing reregistration of a pesticide use, though significant, proved too difficult to obtain. Registrants were required to pay reregistration fees to the EPA, fund studies to meet the EPA's data requirements, and bear associated internal administrative costs. Information on all of these types of costs is not readily available. The few data points I did find (reregistration fees and examples of study costs) were so few and so limited in scope as to be unusable in estimating models.

Another proxy for the value of a pesticide to a registrant would have been its patent protection. Identifying which patents were still in effect proved challenging: each registrant has a library of highly technical patents; as a layperson, sifting through them was not practical. It is of some comfort that the pesticides studied here are decades old, and have perhaps exhausted the benefits of patent protection.

Consolidation in the pesticide industry has resulted in a few registrants with large market shares. In each RED, the EPA identifies the 'technical registrant' who pursues reregistration for the active ingredient.[20] I have identified the pesticides registered by six major firms, and use dummy variables to identify each of these firms in the data: Du Pont, Bayer, BASF, Syngenta, Monsanto, and Dow.[21]

Overview of Empirical Models

Relationship between Occupational Hazards and Regulatory Outcomes

I examine the effect of occupational risk variables on whether a pesticide use is reregistered using a probit model similar to that in Chapter 4. Reregistration outcome, *y*, takes a value of one when a use is reregistered and a value of zero when it is cancelled for each active ingredient *i* and crop *j*. Occupational risk (MOE) is *w*. Variables representing the interests of growers, such as relative prices of pesticides and availability of substitutes, are *G*. Registrant interest and sway in the decision process is *R*, which includes pesticide expenditures and dummy variables for individual registrants. In all models, I assume the error term is normally distributed and correlated within the observations for each active ingredient.

$$\mathrm{P}(y_{ij} = 1) = P(\theta_0 + \theta_1 w_{ij} + G\theta_G + R\theta_R + \omega_{ij} \geq 0) \quad (8)$$

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[20] In most cases, there was just one technical registrant listed in the RED. The identity of the registrant is still assigned to a major company if the company is listed in the RED, even if the registration is shared.

[21] Though multiple companies may market the same active ingredient, these dummies identify the technical registrant at the time that the RED was published.

The other outcome variable of interest when considering occupational risk is the reentry interval (REI), or number of days after application the EPA permits workers to enter the field. The REI varies widely between pesticide uses, but is censored at 0.5 days. I therefore use a Tobit model to allow for a latent variable, d^*.

$$\mathrm{d_{ij}} = \begin{cases} \mathrm{d_{ij}^*} \text{ if } \mathrm{d_{ij}^*} \geq 0.5 \\ 0.5 \text{ if } \mathrm{d_{ij}^*} < 0.5 \end{cases} \qquad (9)$$

I estimate the following model, using the same covariates as in the probit model above.

$$\mathrm{d_{ij}^*} = \sigma_0 + \sigma_1 w_{ij} + G\sigma_2 + R\sigma_3 + \varphi_{ij} \qquad (10)$$

As REI is only observed for reregistered uses, this model is estimated conditional on $y_{ij} = 1$.

Results

Reregistration Decisions and Occupational Risks

To find whether occupational risks have bearing on pesticide reregistration decisions, I construct three different risk variables. The first, Log of Handler MOE, is a general measure of occupational risk not specific to the function of the pesticide handler, and is limited by the availability of application rates from the USDA-ERS data. Higher values of MOE reflect a higher level of safety.[22]

Table 32 includes effects of handler MOE on reregistration decisions. The positive coefficient on log of handler MOE suggests that pesticides safer to handlers are more likely to be reregistered. This coefficient is not, however, significant, even

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[22] This differs from the dietary risk variables in Chapter 4, where higher values correspond to higher risk. These definitions reflect the EPA's constructions of risk measures. Marginal effects.

after including a larger sample in Model 2 or after the inclusion of expenditures or dietary risk.

Table 32: Reregistration decisions and pesticide handler MOE

	(1)	(2)	(3)	(4)
Log of Handler MOE (actual application rate)	0.0085	0.0088	0.0124	0.0021
	(0.0136)	(0.0142)	(0.0135)	(0.0130)
ERS data missing		-0.0445		
		(0.0626)		
Log of pesticide expenditures			0.0350***	
			(0.00896)	
Log of population risk				-0.0136**
				(0.00638)
Constant	1.1383***	1.1383***	1.4595***	1.0057***
	(0.3380)	(0.3375)	(0.3988)	(0.3658)
Observations	611	1997	611	464

Robust standard errors clustered by active ingredient. Higher MOE corresponds to a lower level of risk.*** p<0.01, ** p<0.05, * p<0.1 Outcome variable takes a value of one if reregistered, zero if cancelled.

The addition of grower and registrant covariates in Table 33 changes neither the sign nor the significance of handler MOE. The availability of additional substitute pesticides is positively associated with reregistration, though the coefficient is not significant. Higher values of the Log of price variable indicate a relatively more expensive pesticide. In Model 2, more expensive pesticides are less likely to be reregistered. If the reregistration process favored less expensive pesticides, it could indicate the EPA put some weight on grower concerns.

Model 3 includes registrant variables. Higher expenditures on pesticides, which should correlate to registrant revenues, result in a significantly higher probability of reregistration. This higher probability of reregistration should be driven in part by the fact that registrants would only have incentive to support economically valuable pesticides through the reregistration process. It also may reflect registrants' persistence in getting pesticide uses reregistered. To see if some registrants appeared to hold more sway over the EPA's decisions, I include dummies for five of the major pesticide firms. Monsanto was 100% successful in reregistering the pesticide uses in this dataset, and is therefore excluded from the model.

Table 33: Reregistration decisions and handler MOE with grower and registrant covariates

	(1)	(2)	(3)
Log of Handler MOE (actual application rate)	0.0112	0.00979	0.0105
	(0.0115)	(0.0123)	(0.0100)
Log of pesticide expenditures			0.0332***
			(0.00805)
Du Pont			-0.181
			(0.227)
Bayer			-0.286*
			(0.165)
Syngenta			0.00626
			(0.0844)
BASF			-0.0509
			(0.0997)
Dow			0.0202
			(0.0846)
Substitute	0.00443		
	(0.00548)		
Log of price per acre/max price per acre		-0.0522*	
		(0.0295)	
Constant	0.9018*	0.8662**	1.7263***
	(0.5532)	(0.3864)	(0.2641)
Observations	611	611	611

Marginal effects. Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1
Outcome variable takes a value of one if reregistered, zero if cancelled. All uses for Monsanto were reregistered, so the Monsanto dummy is excluded.

Table 34 presents results for variables specific to applicators, using data from the California Department of Pesticide Regulation. Applicator MOE has a positive coefficient, indicating that safer pesticide uses would be more likely to be reregistered, but this coefficient is insignificant. The coefficient on applicator MOE is similar in Model 2 after increasing the sample, still insignificant, and the coefficient on the dummy for missing data is also insignificant.

The EPA defined MOE below 100 as being of concern, and above 100 as not being of concern. The data here do not map to the EPA's scale, making it impractical to test MOE>100 and MOE <100. Instead, I examine whether the EPA treated quartiles of applicator MOE differently from one another. There is some reason to believe that they did. Quartile 1, the highest risk quartile, is excluded from the models. Quartiles 2-4 have positive coefficients, suggesting that the EPA cancelled more 'riskier' uses than 'safer' uses.

California is a leading producer of many crops, but may not have representative data for corn, barley, peanuts, soybeans, oats, and wheat, important crops of which it is not a major producer. In Model 4 I exclude these crops, as the exposure measures may not be representative of application practices. This exclusion makes little difference in the quartile coefficients.

Table 34: Reregistration decisions and applicator MOE

	(1)	(2)	(3)	(4)
Applicator MOE Quartile 2			0.0773*	0.0772*
			(0.0447)	(0.0446)
Applicator MOE Quartile 3			0.0810*	0.0802
			(0.0492)	(0.0506)
Applicator MOE Quartile 4			0.0736	0.0699
			(0.0827)	(0.0846)
Log of Applicator MOE (CA data)	0.00977	0.0115		
	(0.0107)	(0.0130)		
CA Applicator Missing		-0.0641		
		(0.0517)		
Constant	1.0526***	1.0526***	0.7786***	0.7854***
	(0.1960)	(0.1955)	(0.2208)	(0.2259)
Observations	969	2722	969	919

Robust standard errors clustered by active ingredient. *** $p<0.01$, ** $p<0.05$, * $p<0.1$
Marginal effects. The lowest quartile is omitted, which represented the highest risk. Model 4 excludes corn, barley, peanuts, soybeans, oats, and wheat, as California was not a leading producer of these crops. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

In Table 35 I report results for applicator MOE with registrant and grower variables. Though the coefficients on the safest quartiles (Quartile 3 and Quartile 4) remain positive, the estimates are sensitive to the inclusion of additional variables, and possibly to the subset of observations available for particular models.

Table 35: Reregistration decisions and applicator MOE with grower and registrant covariates

	(1)	(2)	(3)	(4)
Applicator MOE Quartile 2	0.0764	-0.00803	0.0701	-0.0416
	(0.0486)	(0.0548)	(0.0474)	(0.0529)
Applicator MOE Quartile 3	0.0795	0.0429	0.0775	0.0125
	(0.0510)	(0.0597)	(0.0512)	(0.0650)
Applicator MOE Quartile 4	0.0715	0.0548	0.0722	0.0689
	(0.0732)	(0.0795)	(0.0829)	(0.0565)
Log of pesticide expenditures				0.0362***
				(0.0121)
Du Pont				-0.183
				(0.232)
Bayer				-0.361**
				(0.177)
Syngenta				-0.0483
				(0.118)
BASF				-0.118
				(0.131)
Substitute	-0.000488			
	(0.00429)			
Log of price per acre/max price per acre		-0.0481	-0.0406	
		(0.0338)	(0.0325)	
ERS data missing			0.0658	
			(0.0573)	
Constant	0.8131**	0.6455**	0.5292*	1.599***
	(0.3832)	(0.2776)	(0.2712)	(0.2981)
Observations	969	354	969	354

Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1
All uses for Monsanto were reregistered, so the Monsanto dummy is excluded. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

Mixer/loader MOE

Mixer/loaders perform different tasks than applicators, with different implications for exposure. The EPA assumes that mixer/loaders handle the same quantities of active ingredient as applicators in given scenarios, but mixer/loader exposure depends more on formulation of active ingredients, whereas applicator exposure hinges on application method. The risk variables for these two groups are therefore distinct.

Like applicator MOE, however, mixer/loader MOE is insignificant (Model 1 of Table 36). Adding a dummy variable for missing observations does not change this. I cannot identify which of my observations have MOE smaller than 100 on the EPA's scale, but I can examine whether different quartiles of risk have differing effects of reregistration decisions. Quartile 1, the highest risk, is excluded from Models 3 and 4. All the remaining quartiles have positive coefficients, implying that safer pesticide uses for mixer/loaders were more likely to be reregistered. Quartiles 2 and 3 are 10% more likely to be reregistered than Quartile 1. The estimates are robust to removing unrepresentative crops from the sample in Model 4.

Table 36: Reregistration decisions and mixer/loader MOE

	(1)	(2)	(3)	(4)
Mixer/Loader MOE Quartile 2			0.104**	0.107**
			(0.0513)	(0.0519)
Mixer/Loader MOE Quartile 3			0.109**	0.0973*
			(0.0550)	(0.0584)
Mixer/Loader MOE Quartile 4			0.0663	0.0605
			(0.0915)	(0.0965)
Log of Mixer/Loader MOE (CA data)	0.00358	0.00399		
	(0.0135)	(0.0150)		
CA Mixer/Loader Missing		-0.0548		
		(0.0758)		
Constant	1.0655***	1.0655***	0.6890***	0.7047***
	(0.3647)	(0.3632)	(0.2374)	(0.2477)
Observations	649	2722	649	617

Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1
Marginal effects. Quartile 1 is omitted, which represents the highest risk group. Model 4 excludes corn, barley, peanuts, soybeans, oats, and wheat. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

The number of substitute pesticides available, as in previous models, is not a significant predictor of reregistration success. It also does not materially affect the coefficients on the quartiles of mixer/loader MOE. Again, relatively higher priced pesticides are less likely to be reregistered in Model 2. The change in the quartile coefficients between Model 1 and Model 2 seems likely to be the result of the reduced number of observations available. Model 4 has the same issue.

Table 37: Reregistration decisions and mixer/loader MOE with covariates

	(1)	(2)	(3)	(4)
Mixer/Loader MOE Quartile 2	0.103**	0.0189	0.0976*	0.0277
	(0.0520)	(0.0516)	(0.0528)	(0.0499)
Mixer/Loader MOE Quartile 3	0.105*	0.0531	0.0994*	0.0526
	(0.0563)	(0.0634)	(0.0562)	(0.0611)
Mixer/Loader MOE Quartile 4	0.0590	-0.0104	0.0645	0.0432
	(0.0904)	(0.113)	(0.0934)	(0.0654)
Log of pesticide expenditures				0.0287**
				(0.0116)
Du Pont				-0.283
				(0.304)
Bayer				-0.284*
				(0.160)
Syngenta				-0.0528
				(0.120)
BASF				-0.141
				(0.161)
Substitute	-0.00149			
	(0.00347)			
Log of price per acre/max price per acre		-0.0608*	-0.0589	
		(0.0367)	(0.0360)	
ERS data missing			0.0731	
			(0.0640)	
Constant	0.7921**	0.6059**	0.4010	1.4723***
	(0.3645)	(0.2855)	(0.2701)	(0.3698)
Observations	649	258	649	258

Robust standard errors clustered by active ingredient. . *** p<0.01, ** p<0.05, * p<0.1
All uses for Monsanto and Dow were reregistered, so their dummies are excluded. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

Including both mixer MOE and applicator MOE in the same model decreases the number of observations available for estimation. It is possible, however, that there is a difference in the treatment of mixer/loader and applicator risk. In Model 1 of Table 38, mixer/loader MOE and applicator MOE actually have different signs: safer values of applicator MOE result in more reregistrations, whereas safer values of mixer MOE result in more cancellations (though this coefficient is insignificant). It is possible that the EPA is more protective of applicators than of mixers and loaders, but it is also possible that mixer/loader risk was simply mitigated in other ways. Engineering controls such as closed mixing and loading systems substantially reduce risk for mixers and loaders, but not for applicators. Unfortunately, changes in these requirements are not easily observed at the use level, and are not included in the models.

Model 2 includes the measure of population dietary risk from Chapter 4. Measures of MOE are somewhat correlated with dietary risk (correlations are about 0.35). The inclusion of dietary risk does not change the sign of either applicator or mixer/loader MOE, but appears to increase the magnitude of both of them. In this case, however, the MOE coefficients are sensitive to the reduction in observations that results from the inclusion of dietary risk, rather than the inclusion of dietary risk itself (results not shown).

Effects of MOE on reregistration decisions for insecticides (Model 3) and fruits and vegetables (Model 5) are not remarkably different than for the full sample. Coefficients on MOE change little with the inclusion of crop group dummies (Model 4).

Table 38: Reregistration decisions and occupational MOE, alternative specifications

	(1)	(2)	(3) Insecticides only	(4)	(5) Fruits and vegetables only
Log of Applicator MOE	0.0338*	0.0504**	0.0231	0.0310	0.0381*
	(0.0192)	(0.0247)	(0.0209)	(0.0189)	(0.0231)
Log of Mixer MOE	-0.0216	-0.0387	-0.0006	-0.0209	-0.0286
	(0.0221)	(0.0268)	(0.0166)	(0.0215)	(0.0252)
Log of Population Risk		-0.0054			
		(0.0064)			
Constant	0.6730	0.3276	1.0141***	0.4743	0.5407
	(0.4591)	(0.5526)	(0.3969)	(0.5548)	(0.4833)
Crop group effects	No	No	No	Yes	No
Observations	645	430	363	642	454

Robust standard errors clustered by active ingredient. Marginal effects. *** p<0.01, ** p<0.05, * p<0.1 Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled. Fruits and vegetables include berry, citrus, pome, stone fruit, cucurbit, brassica, fruiting vegetables, tuber, bulb, and leafy crop groups.

Mixer/Loader and Applicator MOE and Expenditures

Table 39 gives effects of applicator and mixer/loader MOE on reregistration decision by quartile of expenditure. Because higher MOE values represent a less risk, positive coefficients indicate protective action by the EPA. For the first two models with mixer/loader MOE, the coefficients are not significant save for the highest quartile of expenditure, which is negative. The EPA was less responsive to MOE for the highest quartile of expenditure, which is consistent with the EPA trading off occupational hazard with the economic value of the pesticide. Applicator MOE in the highest quartile of pesticide expenditure in Models 3 and 4 also has a negative coefficient; however, in Model 5 the coefficient on applicator MOE in Quartile 4 is positive. This coefficient is sensitive to the number of available observations (results not shown).

Table 39: Reregistration Decision and Applicator and Mixer MOE by Quartile of Expenditure

	(1)	(2)	(3)	(4)	(5)
Exp. Quartile 1*Log of Mixer MOE	0.0099	0.0077			0.0042
	(0.0083)	(0.0084)			(0.0102)
Exp. Quartile 2*Log of Mixer MOE	0.0061	0.0043			-0.0004
	(0.0065)	(0.0066)			(0.0097)
Exp. Quartile 3*Log of Mixer MOE	-0.0011	-0.0034			-0.0019
	(0.0077)	(0.0079)			(0.0087)
Exp. Quartile 4*Log of Mixer MOE	-0.105***	-0.104***			-0.125***
	(0.0360)	(0.0340)			(0.0390)
Exp. Quartile 1*Log of Applicator MOE			0.0282**	0.0256**	0.0129
			(0.0133)	(0.0128)	(0.0139)
Exp. Quartile 2*Log of Applicator MOE			0.0203**	0.0172	0.0126
			(0.0103)	(0.0111)	(0.0118)
Exp. Quartile 3*Log of Applicator MOE			-0.0039	-0.0075	0.0006
			(0.0139)	(0.0150)	(0.0115)
Exp. Quartile 4*Log of Applicator MOE			-0.0207**	-0.0253**	0.0511***
			(0.0097)	(0.0118)	(0.0190)
Constant	0.9874***	0.5930	1.0529***	0.6700**	0.9580***
	(0.2242)	(0.3773)	(0.1918)	(0.2988)	(0.2295)
Crop group effects	No	Yes	No	Yes	No
Observations	649	646	969	960	649

Robust standard errors clustered by active ingredient. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled. Number of observations differ due to number of missing values and also because crop group dummies perfectly predict the outcome in some cases (and these observations are dropped). *** p<0.01, ** p<0.05, * p<0.1 Marginal effects.

Mixer/loader Cancer Effects

None of the three measures of cancer risk has a significant association with pesticide reregistration (Table 40) and all coefficients are very small. Though it is possible that cancer risk was not a major factor in the EPA's decisions, it seems likely that the few observations available for handler exposure and cancer risk are simply not representative of all decisions, or that measurement error is too much of a factor.

Table 40: Reregistration decisions and occupational cancer risk

	(1)	(2)	(3)
Handler cancer risk (reported application rates)	-0.0016		
	(0.0085)		
Log of applicator cancer risk		-0.00043	
		(0.0145)	
Log of mixer cancer risk			0.0145
			(0.0179)
Constant	0.9014***	1.0472***	1.3394***
	(0.1931)	(0.2671)	(0.3273)
Observations	490	385	272

Robust standard errors clustered by active ingredient. Marginal effects. *** p<0.01, ** p<0.05, * p<0.1 Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

Re-entry Intervals and Handler MOE

In addition to concerns about risks to pesticide handlers, the EPA should also take into account the safety of other workers who may encounter pesticides in the field. To protect these workers, the EPA restricts entry to the field after pesticide application. In Table 41 I use two versions of handler MOE to see if occupational safety was a factor in setting REIs. The first uses actual application rate data from ERS. This offers some insight based on actual usage patterns, but has relatively few data points. The second uses maximum application rates set by the EPA as part of the reregistration process, which should more closely track some "maximum" level of exposure. Since reentry intervals are not reliably available for cancelled pesticide uses, I restrict the data to those uses that survived the reregistration process. The EPA's lowest (and apparently, default) REI appears to be 0.5 days. As nearly half the data is censored at 0.5 days, I use a Tobit model.

MOEs were constructed for pesticide handlers, so their assumptions do not apply perfectly to other farm workers. In particular, the assumption that handlers might apply pesticides to an entire farm's acreage does not seem to be appropriate for tasks such as weeding or picking. Because I do not have a flawless measure of risk for agricultural workers who are not handlers, I examine several variables approximating occupational risk.

Higher (safer) levels of handler MOE have lower reentry intervals in Table 41 for both types of application rate data. A one percent increase in handler MOE predicts a reduction in REI of 1.6 days. Coefficients are robust to expenditures. Though the dummy for missing data in Model 2 is significant (and indicates that the missing pesticide uses have REIs seven days longer), the coefficient on handler MOE changes little with the larger sample. In addition, handler risk using maximum application rates is not so restricted in its observations, and has a similar coefficient in Model 4.

Table 41: Reentry intervals and handler MOE

	(1)	(2)	(3)	(4)
Log of Handler MOE (actual application rate)	-1.640**	-1.597**	-1.695**	
	(0.801)	(0.770)	(0.830)	
ERS data missing		6.940**		
		(3.289)		
Log of pesticide expenditures			-0.307	
			(0.258)	
Log of Handler MOE (using maximum application rates)				-1.498**
				(0.688)
Constant	-8.296*	-7.925*	-8.782*	-6.544*
	(4.388)	(4.125)	(4.669)	(3.487)
Sigma	10.94**	10.51***	10.93**	10.35***
	(4.313)	(4.052)	(4.307)	(3.954)
Observations	476	1451	476	1385

Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1
Reentry interval measured in days. Tobit model used, as nearly half of the reentry intervals are 12 hours. Conditional on reregistration.

As handler MOE using maximum application rates has a similar coefficient to risk using reported rates (and has more observations) I use the former in Table 42. Substitute is marginally significant in Model 1, though the sign is difficult to explain. Pesticide uses with more substitutes have longer reentry intervals. If the EPA is responding to grower interests, it would seem more likely that uses with fewer substitutes would have longer intervals, as there would be no alternatives when there are time-sensitive tasks to complete in the field. Relative price of the pesticide has no significant effect.

Registrant dummies also have no significant effect, nor do expenditures. Quite possibly REI is not an important regulatory decision for registrants in most cases.

Table 42: Reentry interval and handler MOE with covariates

	(1)	(2)	(3)
Log of Handler MOE (using maximum application rates)	-1.420**	-1.531**	-1.763*
	(0.712)	(0.729)	(0.924)
Log of pesticide expenditures			-0.295
			(0.275)
Du Pont			2.927
			(3.108)
Bayer			-3.640
			(6.323)
Syngenta			-6.819
			(7.181)
BASF			-1.071
			(4.179)
Dow			-2.490
			(4.534)
Monsanto			-5.158
			(5.177)
Substitute	0.272*		
	(0.160)		
Log of price per acre/max price per acre		2.402	
		(1.661)	
Constant	-12.25**	-4.722	-8.653*
	(6.059)	(3.179)	(4.464)
Sigma	11.03**	10.71***	11.00***
	(4.367)	(4.081)	(4.189)
Observations	469	469	469

Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1
Reentry interval measured in days. Tobit model used, as nearly half of the reentry intervals are 12 hours. Conditional on reregistration.

As with the handler MOE variables discussed above, applicator MOE is an imperfect stand-in for risks to other farm workers. However, these MOE variables were constructed assuming that applicators would not wear protective equipment, which farm workers also do not. As applicator MOE is increasing in safety, safer pesticide uses have significantly shorter REIs. This is a similar result to that found with handler MOE measures, but is significant at only the 10% level.

Table 43: Reentry intervals and applicator MOE

	(1)	(2)	(3)	(4)
Log of Applicator MOE (CA data)	-0.944*	-0.935**	-1.047*	-0.975*
	(0.484)	(0.470)	(0.539)	(0.503)
CA Applicator Missing		-2.271		
		(1.418)		
Log of pesticide expenditures			-0.0749	
			(0.179)	
Constant	-0.159	-0.0790	-2.411	-1.393
	(1.348)	(1.242)	(1.734)	(1.397)
Sigma	10.28**	10.05***	10.73***	10.41***
	(4.104)	(3.805)	(4.121)	(3.968)
Observations	772	1931	541	1772

Robust standard errors clustered by active ingredient. *** $p<0.01$, ** $p<0.05$, * $p<0.1$
Reentry interval measured in days. Tobit model used, as nearly half of the reentry intervals are 12 hours. Model 4 excludes corn, barley, peanuts, soybeans, oats, and wheat. Conditional on reregistration.

The coefficient on applicator MOE does not change much with the inclusion of grower and registrant variables. Having more substitute pesticides available makes reentry intervals rise (the opposite result of that in Table 42) whereas relative price of the pesticide to its substitutes has no significant effect. None of the registrant dummies or pesticide expenditures has a significant effect, either.

Table 44: Reentry interval and applicator MOE with grower and registrant covariates

	(1)	(2)	(3)
Log of Applicator MOE (CA data)	-0.820*	-0.987**	-1.129*
	(0.435)	(0.493)	(0.583)
Log of pesticide expenditures			-0.0474
			(0.190)
Du Pont			2.398
			(2.421)
Bayer			-0.369
			(3.860)
Syngenta			-6.498
			(7.212)
BASF			0.508
			(3.514)
Dow			-1.426
			(3.699)
Monsanto			-8.404*
			(5.019)
Substitute	0.242**		
	(0.110)		
Log of price per acre/max price per acre		2.001	
		(1.425)	
Constant	-4.062*	0.668	-1.808
	(2.342)	(1.896)	(2.235)
Sigma	9.986***	10.44***	10.64***
	(3.789)	(3.893)	(3.988)
Observations	1931	541	541

Robust standard errors clustered by active ingredient. *** $p<0.01$, ** $p<0.05$, * $p<0.1$
Reentry interval measured in days. Tobit model used, as nearly half of the reentry intervals are 12 hours. Conditional on reregistration.

Re-entry Intervals and Mixer/Loader MOE

The final option for assessing the relationship between REI and occupational risk is to use mixer/loader MOE. Like applicator MOE, it does not assume that protective clothing is worn. In Table 45, mixer/loader MOE has a significant and negative effect on REI, meaning that safer pesticide uses are more likely to receive less restrictive reentry intervals. A one percent change in mixer/loader MOE predicts a reduction in REI of about 1.2 days. This result is robust to the inclusion of expenditures, a dummy for missing observations, and the exclusion of possibly unrepresentative crops.

Table 45: Reentry intervals and mixer/loader MOE

	(1)	(2)	(3)	(4)
Log of Mixer/Loader MOE (CA data)	-1.212**	-1.187**	-1.339 *	-1.243 **
	(0.589)	(0.563)	(0.736)	(0.613)
CA Mixer/Loader Missing		3.212		
		(2.186)		
Log of pesticide expenditures			-0.057	
			(0.410)	
Constant	-5.536	-5.252*	-8.057	-5.768
	(3.438)	(3.138)	(4.855)	(3.579)
Sigma	10.50**	10.01***	13.45***	10.72***
	(4.203)	(3.800)	(5.602)	(4.336)
Observations	516	1931	206	489

Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1
Reentry interval measured in days. Tobit model used, as nearly half of the reentry intervals are 12 hours. Conditional on reregistration.

Grower and registrant covariates (Table 46) have similar coefficients to those reported with applicator MOE in Table 44. Having an additional substitute pesticide available increases the reentry interval by a few hours, while relative price and registrant dummies are insignificant.

Table 46: Reentry interval and mixer/loader MOE with grower and registrant covariates

	(1)	(2)	(3)
Log of Mixer/Loader MOE (CA data)	-0.665**	-0.832*	-0.980*
	(0.326)	(0.450)	(0.535)
Log of pesticide expenditures			0.107
			(0.209)
Du Pont			2.952
			(2.443)
Bayer			-0.0623
			(3.762)
Syngenta			-7.358
			(7.218)
BASF			0.377
			(3.546)
Dow			-2.099
			(3.770)
Monsanto			-7.140
			(4.471)
Substitute	0.195**		
	(0.0962)		
Log of price per acre/max price per acre		1.922	
		(1.375)	
Constant	-4.429*	-0.705	-3.159
	(2.464)	(2.022)	(2.381)
Sigma	10.01***	10.35***	10.50***
	(3.808)	(3.780)	(3.836)
Observations	1931	541	541

Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1
Tobit model used, as nearly half of the reentry intervals are 12 hours. REI censored at 0.5 days.
Conditional on reregistration.

In Table 47, I model the effects of both applicator MOE and mixer/loader MOE on the reentry interval. Applicator MOE is not significant across models, including the models for fruits and vegetables only and insecticides only. Mixer/loader MOE is negative, implying that safer levels of MOE will have lower, more protective reentry intervals, though these results are not significant across models and groups. The insecticide model has the biggest coefficient on mixer/loader

MOE, suggesting a decrease in reentry interval of about 1.5 days for a 10% increase in MOE.

Table 47: Reentry Interval and Applicator and Mixer MOE, alternative models

	(1)	(2)	(3) Fruits and Vegetables only	(4) Insecticides only
Log of Applicator MOE	-0.568	-0.623	-0.594	-0.515
	(0.448)	(0.435)	(0.513)	(0.482)
Log of Mixer MOE	-0.749*	-0.806*	-0.721	-1.029**
	(0.408)	(0.426)	(0.479)	(0.443)
Constant	-3.578	-8.369**	-3.719	-2.760
	(2.504)	(3.365)	(2.749)	(2.167)
Crop group effects	No	Yes	No	No
Sigma	10.51**	10.10***	11.41**	11.66**
	(4.192)	(3.791)	(4.731)	(4.718)
Observations	513	513	358	287

Robust standard errors clustered by active ingredient. Marginal effects.
*** p<0.01, ** p<0.05, * p<0.1 Reentry interval measured in days. Tobit model used, as nearly half of the reentry intervals are 12 hours. Fruits and vegetables include berry, citrus, pome, stone fruit, cucurbit, brassica, fruiting vegetables, tuber, bulb, and leafy crop groups.

Coefficients on MOE are generally negative in Table 48, suggesting that the EPA reduced reentry intervals in response to higher levels of occupational hazard at all levels of pesticide expenditure. Though some of these effects are significant in the middle quartiles of expenditure, they are never significantly different than zero at the highest level of expenditure.

Table 48: Reentry interval and mixer/loader and applicator MOE by level of expenditure

	(1)	(2)	(3)	(4)	(5)
Exp. Quartile 1*Log of Mixer MOE	-0.732	-0.676			-0.264
	(0.643)	(0.524)			(0.461)
Exp. Quartile 2*Log of Mixer MOE	-0.639*	-0.575*			-0.116
	(0.326)	(0.330)			(0.283)
Exp. Quartile 3*Log of Mixer MOE	-0.426	-0.488*			0.374
	(0.275)	(0.272)			(0.390)
Exp. Quartile 4*Log of Mixer MOE	-0.527	-0.601			-0.0130
	(0.582)	(0.527)			(0.443)
Exp. Quartile 1*Log of Applicator MOE			-1.390	-1.323*	-1.273**
			(0.862)	(0.743)	(0.623)
Exp. Quartile 2*Log of Applicator MOE			-1.245**	-1.362**	-1.122*
			(0.570)	(0.607)	(0.591)
Exp. Quartile 3*Log of Applicator MOE			-0.650**	-0.792**	-1.436
			(0.321)	(0.359)	(0.917)
Exp. Quartile 4*Log of Applicator MOE			-0.756	-0.819	-1.033
			(0.578)	(0.537)	(0.739)
Constant	-1.248	-4.605	-0.476	-2.466	-0.539
	(1.988)	(2.932)	(1.439)	(2.553)	(1.717)
Crop group effects	No	Yes	No	Yes	No
Sigma	11.00**	10.64***	10.51**	10.22***	10.92**
	(4.378)	(3.962)	(4.231)	(3.886)	(4.340)
Observations	516	516	772	772	516

Robust standard errors clustered by active ingredient. Reentry interval measured in days. Tobit model used, as nearly half of the reentry intervals are 12 hours. *** p<0.01, ** p<0.05, * p<0.1 Marginal effects.

Reentry Interval and Cancer Risk

Higher levels of cancer risks are associated with higher (and more protective) REIs across measures of occupational risk, though these effects are largely insignificant. A one percent increase in handler cancer risk corresponds to an increase in REI of almost a day, though the effects for other cancer measures are considerably smaller. As with all the cancer risk variables presented here that rely on q*, relatively few observations are available, limiting the interpretation of coefficients.

Table 49: Reentry interval and cancer risk

	(1)	(2)	(2)	(3)
Handler cancer risk (using reported application rates)	0.9241*			
	(0.6576)			
Handler cancer risk (using maximum application rates)		0.6905		
		(0.4728)		
Log of applicator cancer risk			0.332	
			(0.271)	
Log of mixer cancer risk				0.117
				(0.175)
Constant	-12.788*	-9.4562	0.699	-0.762
	(9.1668)	(6.3905)	(1.359)	(1.230)
Sigma	13.86**	5.288**	4.846***	3.731***
	(2.056)	(1.700)	(1.415)	(1.343)
Observations	162	558	322	238

Robust standard errors clustered by active ingredient. Reentry interval measured in days, and censored at 0.5 days. Conditional on reregistration.
*** p<0.01, ** p<0.05, * p<0.1

Conclusion

Using several measures of MOE, I examined whether occupational health concerns predicted pesticide cancellation or reentry restrictions. Though the data and assumptions behind the MOE measures were different, the results for Handler MOE, Applicator MOE, and Mixer/Loader MOE were similar. Linear measures of MOE do not have significant coefficients. Due to data limitations, I could not identify the EPA's threshold of concern in the data, and test if uses with MOEs above that level were treated differently than uses with MOEs below that level. Analysis of quartiles of MOEs suggests that higher levels of risk correspond to more cancellations.

It appears that the EPA did mitigate occupational risk through other means, however. MOEs were at least marginally significant predictors of REI, with higher risk MOEs corresponding to more restrictive REI.

Cancer risk had few significant coefficients, possibly due to the limited availability of cancer data. Higher cancer risk is associated with longer REI, though these results are at best marginally significant.

Registrant dummies had mostly insignificant coefficients for REI models. For reregistration decisions, most dummies were also insignificant, save for Bayer. Bayer fared considerably worse in the reregistration process.

The relative price of a pesticide to other pesticides of the same type used on the same time was a slightly significant predictor of reregistration. Relatively cheap pesticides were less likely to be cancelled, which is consistent with the EPA protecting grower interests. Number of substitute pesticides of a particular type and use is a significant predictor of REI. More available substitutes are associated with more restrictive REIs, also consistent with the protection of grower interests.

Personal protective equipment, respirators, and engineering controls are additional requirements the EPA can set on pesticide use to mitigate risk. Generally, there are a higher proportion of these requirements when pesticides are of higher toxicity.

Chapter 6: Additional Factors Influencing Pesticide Decisions

Introduction

In addition to occupational and dietary risk factors and the particular registrant and grower concerns explored in Chapter 5, there are numerous other factors that could have influenced pesticide reregistration decisions. Registrants' interest and motives may have been driven by whether there were substitute pesticides in their development pipeline. Media coverage of individual pesticides could have attracted public attention and influenced regulatory decisions. The EPA could have paid special attention to smaller crops, which, it was feared, would suffer disproportionate cancellations under reregistration due to registrants' unwillingness to support them.

Empirical strategy

Reregistration Outcome

Similar to Chapter 4 and Chapter 5, I employ a probit model predicting whether a particular use was successfully reregistered (in which case it takes a value of one) or cancelled (taking a value of zero). All models have errors clustered by active ingredient.

Tolerance Changes

In an ordered probit model similar to that described in Chapter 4, I use an outcome variable that captures the direction of the tolerance change. Positive coefficients imply more relaxed tolerance levels, whereas negative coefficients imply more protective tolerance levels. Since tolerance changes are recorded only when a pesticide is reregistered, cancelled uses are excluded from these models. All models have errors clustered by active ingredient.

Data Description

Reregistration Decisions, Tolerance Changes, and Reentry Intervals (REIs)

I use the outcome variables described in more detail in Chapter 4 and Chapter 5: *decision* (whether the pesticide use was reregistered) and *tolerance change* (whether the tolerance for the residue of the pesticide on a particular crop was relaxed, strengthened, or remained the same).

Media Variables

There are three measures of media coverage of pesticides. A Lexis-Nexis search of each pesticide name (and its variants, when appropriate) yielded listings of articles from three national news outlets: *USA Today, The New York Times*, and *The Washington Post*. For each outlet, I created a count of the number of articles appearing on a particular pesticide over the five years prior to the publication of the pesticide reregistration decision (RED).[23] These allow for both count variables (*USA Today articles, New York Times articles,* and *Washington Post articles*) as well as dummy variables for any media mention within a source (*USA Today dummy, New York Times dummy,* and *Washington Post dummy*), and a dummy for any mention in any source (*Any article).* Permethrin had the most mentions, with 21 in the *Post* prior

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[23] I made no distinction between articles that discussed pesticides in a negative light, those that discussed them in a more positive light, or those that were mentioned in passing (though anecdotally, several of them were negative in tone). It is perhaps more accurate to characterize these variables as measuring the extent to which a particular pesticide might have penetrated the public consciousness, rather than the extent of public controversy.

to its RED. The *Post* had the most articles on pesticides of the media outlets, with 1.20 articles per pesticide compared to 0.81 for the *Times* and 0.26 for *USA Today*. One-third of pesticides had at least one article prior to the publication of their REDs. Looking at these averages across the whole sample (with several observations per pesticide) gives a different picture. The *Post* had 2.25 articles per pesticide compared to 1.99 for the *Times* and 0.33 for *USA Today*. Over half the observations in the full dataset have at least one article published.

Table 50: Summary statistics for variables included in pipeline active ingredient, media mention, and minor use models

Variable name	*Units*	*N*	*Mean*	*s.d.*	*Median*
Reregistration decision	Binary	2722	0.81	0.39	
Tolerance change (% change in tolerance from 1994 to 2009)	Percent	1163	0.334	3.368	0
ERS data missing	Binary	2722	0.74	0.44	
Du Pont	Binary	2722	0.11	0.32	
Bayer	Binary	2722	0.13	0.34	
BASF	Binary	2722	0.06	0.23	
Dow	Binary	2722	0.09	0.29	
Syngenta	Binary	2722	0.06	0.23	
Monsanto	Binary	2722	0.06	0.23	
Expenditures	Millions of dollars	708	3.61	16.42	0.288
Washington Post articles	Number of articles	2720	2.26	4.02	0
USA Today articles	Number of articles	2720	0.33	1.08	0
New York Times articles	Number of articles	2720	1.99	3.53	0
Any article	Binary	2722	0.55	0.50	
Minor	binary	2722	0.72	0.45	
Average acres planted	Thousands of acres	2035	5694.17	17528.12	147.24
Population risk		1342	4.09	30.38	
Pipeline active ingredient	binary	2722	0.06	0.24	

Du Pont, Bayer, BASF, Dow, Syngenta, Monsanto, *Washington Post* articles, *USA Today* articles, *New York Times* articles, and Any article vary only by active ingredient. Minor and Average acres planted vary only by crop.

Anticipated Active Ingredients

Major pesticide registrants have a pipeline of new active ingredients. It is possible that some registrants did not pursue the reregistration of certain uses, knowing that they would produce a new product (presumably more profitable, due to its patent protection) to substitute for it.

A list of newer active ingredients came from the EPA's website.[24] These active ingredients were categorized as to their type (whether they were herbicides, insecticides, or fungicides). To get a list of relevant pesticide uses, I consulted the Code of Federal Regulations (40 CFR 180) to find which uses of the pesticides had current tolerances. A current tolerance, in most cases, indicates an active registration for the named crop.[25] In cases where crop groups, rather than individual crops, were listed, I expanded the data to include the relevant crops. For example, when the EPA lists a "pome fruit" tolerance, I assume that pears and apples both have registrations.

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[24] The list of new registrations was accessed in 2009, and a comparable list does not appear to exist on the EPA's site at this time.

[25] In few cases, the CFR lists tolerances when there are no domestic registrations, so that there is a standard for imported food that may have been treated with the pesticide. It is possible, therefore, that some of these tolerances do not indicate a registration of the use, though I assume that they do.

Table 51: List of newer pesticide registrations with primary registrant, year of registration, and type

New Active Ingredient	*Registration year*	*Registrant*	*Type*
AZOXYSTROBIN	1997	Syngenta	Fungicide
CARFENTRAZONE-ETHYL	1998	FMC	Herbicide
CLORANSULAM-METHYL	1997	Dow	Herbicide
DIFLUFENZOPYR	1999	BASF	Herbicide
FIPRONIL	1996	Bayer	Insecticide
FLUFENACET	1998	Bayer	Herbicide
FLUMIOXAZIN	2001	Valent	Herbicide
FORAMSULFURON	2002	Bayer	Herbicide
GAMMA-CYHALOTHRIN	2004	Pytech	Insecticide
INDOXACARB	2000	DuPont	Insecticide
ISOXAFLUTOLE	1998	Bayer	Herbicide
MESOTRIONE	2001	Syngenta	Herbicide
PYRACLOSTROBIN	2002	BASF	Fungicide
S-METOLACHLOR	1997	Syngenta	Herbicide
SPINOSYN A	1997	Elanco	Insecticide
SULFENTRAZONE	1997	FMC	Herbicide
THIAMETHOXAM	2000	Syngenta	Insecticide
TRALKOXYDIM	1998	Syngenta	Herbicide
TRICLOPYR	2002	Dow	Herbicide
TRIFLUSULFURON-METHYL	1996	DuPont	Herbicide

Active ingredient list was sourced from EPA's website in 2009, but does not appear to be on their site in this form any longer. Only active ingredients first registered after 1996 (when FQPA was passed) are included.

I then match the new active ingredients to the active ingredients subject to reregistration by crop and type. In cases where a new active ingredient with the same crop use and type became registered during the reregistration period, I assign a value of one to the 'pipeline' variable.[26] Those uses without a match were assigned zero.

Minor uses

At the time of FQPA, one of the concerns of growers and legislators was whether smaller crops would have their uses supported. Managing the reregistration process

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[26] This assumption is discussed in Chapter 5.

and providing the necessary data (which can include crop-specific studies) may not be worthwhile to registrants of uses that are not very profitable. The EPA was to give special consideration to minor uses, and the hardships that their cancellations could cause growers. The Interregional Research Project #4 (IR-4), a cooperation of state experiment stations and federal agencies, supported the reregistrations and data collection of some minor crops.[27] The EPA defined about 30 crops as “major” crops, leaving the remaining crops categorized as “minor” (EPA's Minor Use Team and Public Health Steering Committee n.d.). I construct a dummy for these “minor” crops.

In addition, I use data on acres planted from the USDA as a continuous measure of crop size.

Additional Covariates

The measure of dietary risk, Log of population risk, is described in more detail in Chapter 4. It is a ratio of a “safe” level of pesticide exposure to estimated exposure. Higher values represent a higher level of safety.

Log of pesticide expenditures and Expenditures missing are also discussed in Chapter 4. Expenditures are price per acre multiplied by pounds per acre by active ingredient and crop. When expenditures are missing, they are recoded to zero and a second variable, expenditures missing, indicates this recoding.

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[27] A more detailed discussion of IR-4’s role is part of the *Encylopedia of Agrochemicals*, and is available online at
http://ir4.rutgers.edu/NewsItems/Encyclopedia%20of%20Agrochemicalsentirety.pdf

Results

Media Influence

Major news outlets appear to have a limited effect on the EPA's pesticide decisions. Table 52 gives results for probit models predicting reregistration decisions for pesticide uses; dummy variables for each news outlet publishing an article on a particular pesticide do not have significant coefficients. These three dummies are correlated with each other, though running separate models for each outlet also does not result in significant coefficients (results not shown). These dummies are also jointly insignificant.

Model 3 uses a count of articles for each outlet within five years before the RED. The count for *USA Today* is significant at the 10% level, and suggests that more media coverage resulted in less chance of reregistration. *USA Today* had fewer articles mentioning pesticides than the other news outlets, so it is possible that the few articles it did carry were more relevant to pesticide safety.

Model 4 tests a dummy (Any article) that measures whether any outlet reported on the pesticide, and is also insignificant.

I cannot rule out the possibility that news outlets report on more risky pesticide uses, which would have been cancelled by the EPA regardless of coverage. Pesticide uses had almost the same likelihood of having a news article mentioning the active ingredient if they were cancelled (54%) as if they were reregistered (55%). The number of articles with mentions is also not statistically different between reregistered and cancelled pesticide uses. None of the news outlet dummies is significant, nor do they all have the same sign. Furthermore, the inclusion of the dietary risk variable in Model 2 changes neither the significance nor the sign of these dummies, indicating that the news outlet coverage is not just a signal of risk.

Table 52: Reregistration outcomes and media mentions

	(1)	(2)	(3)	(4)
Log population risk		-0.0137*		
		(0.00826)		
Washington Post dummy	0.0423	0.127		
	(0.121)	(0.115)		
USA Today dummy	-0.0876	-0.0207		
	(0.171)	(0.156)		
New York Times dummy	-0.0075	-0.162		
	(0.123)	(0.133)		
Washington Post articles			0.0212	
			(0.0132)	
USA Today articles			-0.101*	
			(0.0532)	
New York Times articles			0.0079	
			(0.0083)	
Any article				0.0072
				(0.0832)
Constant	0.8658***	0.8809***	0.8210***	0.8705***
	(0.1872)	(0.2805)	(0.1823)	(0.1898)
Observations	2722	1342	2720	2722

Robust standard errors clustered by active ingredient. . *** p<0.01, ** p<0.05, * p<0.1
Marginal effects. Outcome variable is zero if tolerances were reduced, one if they were unchanged, and two if they were increased.

Since the public's concern about pesticides may be driven by population exposure, particularly dietary risk, I also investigate the relationship between tolerance changes and news articles in Table 53. Only *Post* articles are significantly predictive of tolerance changes. A mention in a *Post* article is more likely to result in a reduction of tolerance (a more stringent requirement).

Table 53: Tolerance changes and media mentions (ordered probit)

	(1)	(2)	(3)	(4)
Washington Post dummy	-0.336	-0.278		
	(0.311)	(0.301)		
USA Today dummy	0.00808	0.00755		
	(0.307)	(0.291)		
New York Times dummy	0.0249	-0.0244		
	(0.312)	(0.294)		
Log population risk		-0.0569^{***}		
		(0.0170)		
Washington Post articles			-0.0508^{**}	
			(0.0188)	
USA Today articles			0.0180	
			(0.110)	
New York Times articles			0.0252	
			(0.0217)	
Any article				-0.294
				(0.170)
cut1				
Constant	-1.251^{***}	-1.087^{***}	-1.166^{***}	-1.255^{***}
	(0.131)	(0.147)	(0.159)	(0.133)
cut2				
Constant	1.202^{***}	1.385^{***}	1.290^{***}	1.196^{***}
	(0.137)	(0.168)	(0.123)	(0.135)
Observations	1163	1117	1163	1163

Standard errors in parentheses. Conditional on reregistration. Outcome variable is zero if tolerance was reduced, one if it was unchanged, and two if it was increased.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Treatment of Minor Uses in the Reregistration Process

There is little evidence that minor uses were cancelled disproportionately. Minor crops had a slightly higher reregistration rate than major crops (81.5% vs. 80.3%). The regression results in Table 54 do not suggest a strong association between minor crops and probability of reregistration; the largest coefficient, in Model 2, appears to be the result of including pesticide expenditures as a covariate and the reduction in sample size. Indeed, the coefficient on Expenditures missing in Model 3 suggests that the important factor is that expenditure data is available more often for large crops than for minor crops. Crops with less acreage could generally have higher concentrations of pesticides, making dietary risk more relevant. Controlling for dietary risk in Model 4, however, has little effect on the Minor use coefficient.

Table 54: Reregistration decisions and minor use crops

	(1)	(2)	(3)	(4)
Minor use	0.0122	0.0649*	0.0446	0.0266
	(0.0310)	(0.0352)	(0.0314)	(0.0259)
Log of pesticide expenditures		0.0422***	0.0441***	
		(0.00984)	(0.0111)	
Expenditures missing			-0.0977**	
			(0.0425)	
Log of population risk				-0.0137
				(0.00925)
Constant	0.8529***	1.1116***	1.1400***	0.7583***
	(0.1341)	(0.1589)	(0.1616)	(0.1670)
Observations	2722	708	2722	1342

Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1
Marginal effects. Minor crops exclude almonds, apples, barley, snap beans, canola, corn, sweet corn, popcorn, cotton, grapes, oats, oranges, peanuts, pecans, potatoes, rice, rye, soybeans, sugarbeets, sugarcane, sunflower, tomatoes, and wheat. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

Though the EPA’s mandate on which crops were minor crops was very clear, it seems appropriate to extend the analysis to a continuous measure of crop acreage. Table 55 presents results using log of average acres planted. As acreage increases, probability of reregistration decreases, though this result is not significant. Including a squared term allows for the possibility that very large crops are treated differently than large ones; these coefficients (not presented here) are also insignificant, as are coefficients on log of acres planted and quartiles of acres planted (also not presented here).

Table 55: Reregistration decisions and average acres planted

	(1)	(2)	(3)	(4)
Log of average acres planted	-0.00005	-0.0140	-0.0079	-0.0027
	(0.0062)	(0.0094)	(0.0065)	(0.0062)
Log of pesticide expenditures		0.0428***	0.0444***	
		(0.0098)	(0.0108)	
Expenditures missing			-0.1065**	
			(0.0458)	
Log population risk				-0.0161**
				(0.0089)
Constant	0.8636***	1.6050***	1.3973***	0.8780***
	(0.2260)	(0.3803)	(0.2752)	(0.2637)
Observations	2035	684	2035	1174

Marginal effects. Robust standard errors clustered by active ingredient. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Coefficients for quartiles for average acres are also insignificant and are not reported here. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

Success of Registrants and Effect of New Active Ingredients in the Pipeline

To analyze the effect of individual pesticide registrants on the decision process, dummy variables for each of the major pesticide registrants are included in the models in Table 56. Not included in Table 56 is Monsanto, which had 100% success in registering pesticide uses included in the dataset. Of all the included registrants, only Dow has a significant coefficient—it was 14% more likely to have a successful pesticide reregistration. Dow is significant when controlling for dietary risk and pesticide expenditures, except when observations are limited by the inclusion of Log of pesticide expenditures. Though this result suggests that Dow held some sway with the EPA beyond what might be expected given pesticide expenditures and dietary risk, it must be interpreted with caution. The intrinsic characteristics and history of individual pesticides are not captured in these models, which could bias the results. In addition, each of these registrant dummies varies only by active ingredient, meaning that the results of one or two successful active ingredients (with many uses) can have a big effect.

If a registrant has a similar active ingredient in its development pipeline to the pesticide under review, it may not have incentive to pursue the reregistration. I test for this possibility in Table 56, Model 5. The variable Pipeline active ingredient indicates that a similar pesticide was introduced to the market during the reregistration process by the same registrant. It is not significant.

Table 56: Reregistration decisions, registrants, and new active ingredients

	(1)	(2)	(3)	(4)	(5)
Log of pesticide expenditures		0.0372***	0.0376***	0.0214**	0.0369***
		(0.00954)	(0.0114)	(0.0085)	(0.0113)
Log population risk				-0.0058	
				(0.0089)	
Du Pont	-0.0735	-0.0871	-0.0781	-0.216	-0.0865
	(0.201)	(0.203)	(0.202)	(0.247)	(0.206)
Dow	0.143***	0.0482	0.136***	0.129***	0.136***
	(0.0533)	(0.0836)	(0.0529)	(0.0428)	(0.0527)
Syngenta	0.0943	0.0289	0.0897	0.0458	0.0684
	(0.0699)	(0.0887)	(0.0673)	(0.0615)	(0.0771)
BASF	0.00515	0.0101	-0.0003	0.0226	-0.0114
	(0.118)	(0.0957)	(0.120)	(0.0932)	(0.123)
Bayer	-0.199	-0.128	-0.196	-0.256	-0.204
	(0.155)	(0.150)	(0.156)	(0.163)	(0.158)
Expenditures missing			-0.0628	-0.0390	-0.0564
			(0.0400)	(0.0330)	(0.0404)
Pipeline active ingredient					0.0727
					(0.0737)
Constant	0.960***	1.259***	1.227***	1.373***	1.202***
	(0.202)	(0.213)	(0.194)	(0.293)	(0.194)
Observations	2722	708	2722	1342	2722

Robust standard errors clustered by active ingredient. *** p<0.01, ** p<0.05, * p<0.1
Marginal effects. All Monsanto uses were reregistered. Monsanto predicts the outcome perfectly and is omitted from the model. Outcome variable is one if the pesticide use was reregistered, and zero if it was cancelled.

Table 57 displays the effects of registrant dummies on tolerance change. Since these models are conditional on pesticide reregistration, Monsanto's uses can be observed. Monsanto has the only significant coefficients of the registrants included, and the positive coefficient indicates that the tolerances on its pesticide uses tended to rise (become less restrictive).

Interestingly, the coefficient on log of population risk in Model 4 is only marginally significant. As discussed in Chapter 4, dietary risk was supposed to meet a "reasonable certainty of no harm" standard, which would not be affected by consideration of pesticide benefits. The coefficient on dietary risk is not robust to the inclusion of registrant dummies, however. There are several possibilities. One is that dietary risk is unevenly distributed among the registrants' portfolios of active ingredients, meaning that the variation between these portfolios is picking up the variation in dietary risk. A second possibility is that pesticide registrants are treated differently by the EPA, dietary risk notwithstanding.

Table 58 demonstrates that the pesticide portfolios of the registrants vary a great deal: Monsanto has both the lowest average risk and the highest expenditure values for its pesticides, due to the fact that the vast majority of Monsanto's uses in the dataset are of glyphosate.[28] Interaction terms between the registrant dummies and dietary risk are not significant, which also does not suggest that some registrants had preferential treatment regardless of risk. A Wald test does reject the null hypothesis that the interaction terms are jointly equal to zero, however.

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[28] Glyphosate is one of the most widely used pesticides, both in terms of pounds applied and number of crops for which its use is registered. It is also, according to Pete Caulkins, a pesticide of relatively low safety concern.

Table 57: Tolerance changes and pesticide registrants

	(1)	(2)	(3)	(4)	(5)
Du Pont	0.110	0.466	0.106	0.112	0.0590
	(0.317)	(0.281)	(0.312)	(0.299)	(0.454)
BASF	0.563	0.378	0.548	0.617	0.496
	(0.354)	(0.400)	(0.358)	(0.350)	(0.401)
Monsanto	0.785***	1.047***	0.782***	0.676***	1.066**
	(0.174)	(0.191)	(0.172)	(0.169)	(0.345)
Dow	0.212	0.130	0.207	0.0661	0.387
	(0.188)	(0.258)	(0.187)	(0.187)	(0.478)
Syngenta	-0.218	-0.0855	-0.222	-0.186	-0.494
	(0.425)	(0.380)	(0.426)	(0.412)	(0.453)
Bayer	-0.169	-0.197	-0.163	-0.0331	0.0301
	(0.220)	(0.213)	(0.222)	(0.285)	(0.274)
Log of pesticide expenditures		0.0111	0.0173	0.0106	0.000960
		(0.0339)	(0.0378)	(0.0379)	(0.0377)
Expenditures missing			-0.0886	-0.116	-0.0941
			(0.105)	(0.110)	(0.108)
Log population risk				-0.0547*	-0.0629
				(0.0219)	(0.0365)
Du Pont*Log Population Risk					-0.0199
					(0.0805)
BASF*Log Population Risk					-0.0856
					(0.0602)
Monsanto*Log Population Risk					0.0672
					(0.0448)
Dow*Log Population Risk					0.0643
					(0.0713)
Syngenta*Log Population Risk					-0.105
					(0.0854)
Bayer*Log Population Risk					0.0730
					(0.0396)
cut1					
Constant	-1.040***	-0.980***	-1.102***	-0.957***	-0.927***
	(0.208)	(0.203)	(0.223)	(0.233)	(0.274)
cut2					
Constant	1.464***	1.330***	1.404***	1.557***	1.616***
	(0.146)	(0.159)	(0.154)	(0.184)	(0.213)
Observations	1163	455	1163	1117	1117

Standard errors in parentheses. Conditional on reregistration. Outcome variable is zero if tolerance was reduced, one if it was unchanged, and two if it was increased. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 58: Population risk and pesticide expenditures by registrant

	Population Risk				Pesticide Expenditures			
Registrant	*N*	*mean*	*s.d.*	*median*	*N*	*mean*	*s.d.*	*Median*
BASF	90	2.123	5.315	0.435	70	2.953	10.047	0.408
Bayer	257	14.899	65.858	0.406	91	1.723	5.121	0.167
Dow	138	0.134	0.902	0.005	76	6.314	22.710	0.800
DuPont	151	0.393	1.429	0.040	85	2.778	10.418	0.345
Monsanto	61	0.008	0.018	0.002	31	13.052	39.671	1.301
Syngenta	79	2.493	7.494	0.051	49	1.686	3.438	0.243

In addition to their interest in influencing reregistration decisions and tolerance changes, registrants may have benefited from delaying reregistration decisions. In Table 59, I test whether the timing of the decision was sensitive to the expenditures on pesticides. As REDs included decisions for all uses of an active ingredient, the duration model is restricted to one observation per active ingredient, and time is recorded as the number of years from the first RED in the sample. The coefficient on total expenditure (the sum of expenditure over all the values of an active ingredient) is not significantly different than zero, nor is the coefficient on log of reference dose. I have no evidence, therefore, that the value of the pesticide affected the timing of the publication of the decision.

Table 59: Expenditure levels and time to RED publication

	(1)	(2)
Log of reference dose		-0.0476
		(0.0447)
Log of total expenditure (sum over crops)	0.0324	0.0381
	(0.0671)	(0.0671)
Observations	92	92

Cox proportional hazards model. Standard errors in parentheses. Duration is measured in years, where Year 0 is the first year a RED was published that appears in the dataset. Because REDs are specific to active ingredients, not to crops, data is collapsed to the active ingredient level, and total expenditure is the sum of expenditures over all crops for an active ingredient. Reference dose is a benchmark for the toxicity of the active ingredient. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Conclusion

Several factors that may have influenced the outcomes of reregistration do not appear to be important. News articles, which may approximate the level of public interest in particular pesticide, apparently had little bearing on the process. Coefficients on media variables are generally insignificant and in some ways inconsistent.

Whether registrants would support minor uses in the reregistration process was a concern at the time that FQPA was passed. I find no evidence that minor uses were cancelled more often or that the size of the crop (measured by acres planted) was a significant determinant of the EPA’s decisions.

Furthermore, having similar pesticides in the development pipeline had no significant effect on the reregistration of uses. Most registrant dummies also were insignificant, with the notable exception of Dow. Dow was more likely to have a use reregistered than the other registrants. Dow had uses that were relatively low risk and relatively high value, but the coefficient is still significant when population dietary risk and pesticide expenditures are included. Monsanto, which had 100% success in reregistration, was also 18% more likely to have its tolerances increased.

Chapter 7: Discussion and Conclusions

Summary of research findings

Do reregistration decisions appear to be protective of dietary risk to consumers?

Regulatory decisions for pesticide uses seem to be protective of consumers, but only in certain ways. There is weak evidence that the EPA cancelled pesticide uses in response to dietary risk: a 10% increase in dietary risk would increase the probability of cancellation by well under 1%, and these effects are only slightly significant.

Pesticide expenditures are a highly significant predictor of reregistration outcomes, but it does not appear that expenditure levels interfered with the EPA's assessment of dietary risk (which should have been evaluated independently). At the highest levels of expenditures, pesticide uses were more likely to be reregistered, but the EPA also was most responsive to dietary risk within that group.

The EPA did seem to reduce dietary exposure through restricting pesticide tolerances. Dietary risk has a highly significant and negative effect on tolerance changes; a 1% increase in dietary risk implies a 1.3% increase in the probability of having the tolerance reduced. The EPA's responsiveness to dietary risk in setting tolerances does not diminish at higher levels of expenditure.

Data for cancer risks was weak, and though coefficients on cancer variables indicate that higher risks were associated with more cancellation and stricter tolerances, these coefficients are not generally significant.

Are active ingredient and crop combinations with greater risks to children more likely to be cancelled?

There is limited evidence that the EPA was particularly protective of the health of infants in children during the reregistration process. Several measures of infant and child risk do not have significant coefficients. The exception is for child and infant risk measures above a threshold of concern: above a certain level of risk, child and infant risk does appear to increase the probability of cancellation by approximately 10%.

Do occupational hazards appear to be significant factors in reregistration outcomes?

Several measures of occupational hazard did not have consistently significant relationships with reregistration decisions. The effect of occupational hazard does vary by level of expenditure, however, with low levels of expenditure having higher probabilities of cancellation and high levels of expenditure having lower probabilities of cancellation. This result is consistent with the EPA trading off the economic benefit of a pesticide with the occupational risk.

For reregistered pesticide uses, occupational hazards do have a significant effect on the reentry interval, suggesting that the EPA was inclined to mitigate occupational hazard without cancellation.

Similar to the analysis of dietary risk, there were not significant relationships between cancer risk for workers and regulatory outcomes.

Are active ingredients more likely to be cancelled on small crops (measured in terms of acreage)?

In spite of concerns about pesticide availability for minor crops following reregistration, minor crops were not cancelled at a higher rate than high-acreage crops, and acreage is not a significant predictor of reregistration. To protect growers' interests, the EPA could have also taken into account the availability and price of substitutes, as a regulatory change to one pesticide would have less impact if there were cheap alternatives. However, the effects of substitute availability and price were not consistent across specifications.

Are some registrants more successful at reregistering pesticides than others?

The highly significant effect of pesticide expenditures on reregistration suggests that pesticide registrants were successful at reregistering high value active ingredients. Of the six major registrants, Dow and Monsanto were most likely to have their pesticide uses reregistered (Monsanto was successful for every use in the dataset.) Both companies had high-value and relatively low-risk pesticides under review, however, making it difficult to determine if their success was the result of their lobbying efforts or the result of the characteristics of their pesticide portfolios.

Is there evidence that uses were cancelled when registrants were about to bring substitutes onto the market?

If a registrant anticipated the introduction of a comparable pesticide in the future, it might have saved the expense and effort of reregistration and simply cancelled the pesticide. There is no evidence, however, that uses were cancelled in anticipation of bringing substitute pesticides to the market.

Did media coverage of pesticides appear to affect reregistration decisions?

Media coverage had no significant effect on reregistration decisions after controlling for dietary risk. Of the news outlets analyzed, may drive greater public awareness of pesticide toxicity, and in turn, create additional public pressure for regulation.

Researching the regulatory process

Many economic analyses attempt to predict the outcomes of public policies or measure how a single regulatory change affects agent behavior or benefits. These are valuable lines of research. This thesis, however, examines public policy from a less-viewed angle: does the regulatory process, at the agency level, produce the regulations that were intended in the original legislation?

This is an important link when attempting to understand the mechanisms and effects of public policy. To what extent can we trust that legislation will result in the intended outcomes, if we are not sure that it will result in the intended intermediate regulations? Is public trust in agencies to represent their interests well placed? This is a particularly salient question for pesticide regulation, as the public is continually exposed to pesticides, and in most cases relies on the government to ensure their safety.

The analysis of regulation presented here illustrates some possibilities for research on regulatory outcomes, but also some challenges. The more complex the regulations or process, the more we might learn from close examination—and the more costly that close examination becomes. Significant effort was required not just to understand the regulatory environment, but also to recreate the set of information the agency was using.

In the case of pesticide reregistration, the EPA's instructions from Congress on how to ensure the safety of pesticides were clear. The details of implementing this instruction, however, were complex: the EPA amassed large quantities of disparate data on pesticide effects and usage; its decisions attracted input from a variety of stakeholders, including registrants, growers, consumers, and environmental groups.

Determinants of the EPA's regulatory decisions on pesticides

The pesticide reregistration process was expensive. It took the EPA decades of work to publish reregistration decisions, and longer still to reregister individual pesticide products. Pesticide registrants spent significant resources to generate data to support reregistrations. The completion of reregistration does not mean the process is over: the EPA will continue to review pesticide products on a schedule.

The EPA did appear to respond to human health risks in making reregistration decisions. Though there was not a linear relationship between population dietary risk and reregistrations or applicator MOE and reregistrations, the data suggests that the EPA may have treated pesticide uses differently depending on whether they were below or above a threshold of concern. This is consistent with how the EPA was directed by Congress to address dietary risk as well as with how the EPA describes its own regulatory processes.

There is significant evidence that the EPA relied more on mitigation measures rather than on the cancellation of pesticide uses to reduce risk. This may be a positive thing: cancellation is a firm reduction in pesticide options, and has economic consequences for growers and registrants. An overabundance of caution could do harm.

On the other hand, there may be more questions about the enforceability of the mitigation measures chosen by the EPA. The EPA sets tolerances, but does not enforce them; the FDA is responsible for that. Large scale screening of commodities for pesticide residues is expensive and impractical.

Increasing PPE and other equipment for agricultural workers significantly reduces exposure if used correctly. It is a key assumption on the part of the EPA that workers will understand and comply with pesticide label requirements. Monitoring how pesticides are mixed, loaded, and applied is a considerable task.

Perhaps just as interesting as the factors that significantly influenced EPA’s decisions were the factors that did not. Anticipation of new active ingredients, media mentions of active ingredients, and individual registrants did not appear to have a big effect on the regulatory process. Pesticide expenditures were a highly significant determinant of reregistration, but seemed to operate independently of population dietary risk.

Appendix A: Data Sources

Variable	***Units***	***Source***
Reregistration outcome under FQPA	Binary	EPA Reregistration Eligibility Decisions (REDs)
Pesticide tolerances, 1994	parts per million	Code of Federal Regulations (40CFR180)
Pesticide tolerances, 2009	parts per million	Code of Federal Regulations (40CFR180)
Reentry Intervals	Days	EPA Reregistration Eligibility Decisions (REDs)
Price of AI	millions of nominal U.S. dollars/pound	NASS/Doane
Acres treated (acre-treatments)	Acres	NASS/Doane
Pounds of AI	Pounds	NASS/Doane
Carcinogenicity category		"Chemicals Evaluated for Carcinogenic Potential by the Office of Pesticide Programs" Sept. 2009
Lifetime cancer risk (q*)		EPA IRIS and REDs
Chronic No Observed Adverse Effect Level (cNOAEL)	mg/kg-day	EPA
Reference dose	Mg/kg-day	EPA Reregistration Eligibility Decisions (REDs), other EPA sources
Inhalation toxicity	Count	EPA Reregistration Eligibility Decisions (REDs), Courbois (2000), other EPA sources
Commodity consumption per capita	grams per day	Continuing Survey of Food Intakes by Individuals (CSFII) 1994-1996
Commodity consumption per capita, children	grams per day	CSFII
Commodity consumption per capita, infants	grams per day	CSFII

Variable	***Units***	***Source***
Commodities commonly consumed by infants		National Academy of Sciences, *Pesticides in the Diets of Infants and Children*, 1993
Commodities commonly consumed by children		National Academy of Sciences, *Pesticides in the Diets of Infants and Children*, 1993
Maximum application rate	pounds of active ingredient per acre	EPA Reregistration Eligibility Decisions (REDs)
Personal Protective Equipment, Applicators	indicators for no PPE, gloves required, and additional PPE required	EPA Reregistration Eligibility Decisions (REDs)
Personal Protective Equipment, Mixer/loaders	indicators for no PPE, gloves required, and additional PPE required	EPA Reregistration Eligibility Decisions (REDs)
Engineering controls required	Binary	EPA Reregistration Eligibility Decisions (REDs)
Respirators required	Binary	EPA Reregistration Eligibility Decisions (REDs)
Unit exposure	Mg/lb	PHED Surrogate Exposure Guide, 1998
Acres per farm	Acres	USDA-NASS 1992 Agricultural Census
Application rate	lbs/acre	USDA-ERS (NASS and Doane)
Formulation		California Department of Pesticide Regulation, 1994
Application method		California Department of Pesticide Regulation, 1994
Acres per application	Acres	California Department of Pesticide Regulation, 1994
Pounds per application	Pounds	California Department of Pesticide Regulation, 1994
Registrant dummies	Binary	EPA Reregistration Eligibility Decisions (REDs)
Counts of news articles (Washington Post, New York Times, USAToday)	Count	coded from Lexis-Nexis searches
Minor crop dummy	Binary	as specified in FQPA
Pipeline active ingredient	Binary	recent pesticide registrations as reported by EPA

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