REPORT

The Economic Importance of Organophosphates in California Agriculture

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October, 2002

This study was funded by the California Department of Food and Agriculture. The opinions expressed are those of the authors.

1. Introduction

Pesticides are important production inputs for many agricultural commodities, and decisions concerning their use necessitate balancing tradeoffs between their economic benefits and the protection of the environment and human health. The passage of the Food Quality Protection Act (FQPA) by Congress represents a significant change in pesticide policy that could have large impacts on both pesticide users and the rest of society. The FQPA focuses on protecting children and other segments of the population from the aggregate effects of pesticides with common mechanisms of toxicity. New safety standards target the organophosphate (OP) and carbamate insecticide classes of pesticides and could restrict or cancel several pesticide uses. This study estimates the welfare loss to California producers and consumers resulting from a total ban of all OP pesticides.

Much of the discussion and controversy surrounding FQPA implementation has focused on the technical challenges facing the Environmental Protection Agency (EPA) as new risk criteria are established.[1] Far less emphasis has been placed on the quantification of the potential economic impact of the Act under plausible implementation scenarios. Such economic analysis of pesticide policy is important because the FQPA calls for the EPA to evaluate whether certain pesticide uses "are necessary to avoid a significant disruption in domestic production of an adequate, wholesome, and economical food supply" (Public Law 104-170). Economic theory suggests that in the short run stricter tolerances or outright cancellations of pesticides may decrease the cost-effectiveness of pest control through decreases in crop yield due to crop damage from pests or increased costs for substitute pest control strategies (Silberberg). This causes a reduction in the supply of crops that previously relied on OP pesticides; the only question is the magnitude of the changes.

Some of the first estimations of the impacts of FQPA implementation assume a total ban of both the OP and carbamate classes of pesticides.[2] Two studies funded by the American Farm Bureau Federation found significant impacts on society from FQPA

[1]Byrd provides an interesting account of the events that led to the passage of the FQPA, and of the challenges that its passage poses for the EPA.

implementation. A study by Taylor and Smith predicts decreases of $17 billion in countrywide economic output, and the loss of 209,000 jobs, while Gray and Hammitt state "it is difficult to imagine that the benefits of a ban could offset the 10 to 1,000 annual premature fatalities predicted from the income losses that would be caused by elimination of OP/carbamate use." Although significant uncertainty exists concerning the final level of pesticide restrictions, through discussion with EPA it is clear that all OP and carbamate pesticides will not be cancelled (Widawski). Any study that uses the underlying assumption of a total ban of these two important classes of pesticides will overstate the costs of FQPA implementation.

We take a more moderate approach than previous studies and conduct our analysis as though all OP pesticides were cancelled, while carbamates remain a viable alternative. To keep the scope of our analysis within reasonable limits, we focused on the impacts from the cancellation of all OP insecticide use on 15 important California commodities.

Table 1: Net Exports and Value of Production, 1994-1998

Commodity	California Production	Other U.S. Production	Net Exports	Total Value of Sales
	tons	tons	tons	$1,000
Alfalfa	6,716,118	68,915,195	231,375	7,373,645
Almonds	313,509	0	20,758	1,006,276
Broccoli	797,462	21,567	0	410,890
Carrots	1,337,377	1,621,808	-1,557	508,970
Cotton	650,922	3,419,190	1,668,955	6,438,748
Grapes	5,923,642	243,669	-74,898	2,356,908
Lettuce, Head	2,162,647	1,297,994	0	1,158,631
Lettuce, Leaf	394,820	56,378	0	278,542
Oranges	2,472,940	11,120,179	543,672	1,705,899
Peach & Nectarines	1,212,796	117,125	43,356	483,926
Strawberries	538,541	49,413	30,630	830,017
Tomatoes, Fresh	532,825	986,875	0	970,600
Tomatoes, Processed	10,800,564	86,740	0	686,524
Walnuts	261,207	0	52,628	319,967

Source: CA Agricultural County Commissioners and USDA (2001).

These commodities were chosen from over 100 other California commodities because of their economic importance to the state. Table 1 lists the 15 commodities along with the California production in tons, total production in the rest of

[2]See, for example, Giannessi (1997b), Gray and Hammitt, and Taylor and Smith.

the United States, the net volume exported (defined as exports minus imports), and the total value of production in the United States. California is an important production region for many of the nation's fruit, vegetable, and nut crops, and many of these crops rely extensively on OP insecticides (see Table 2).

Table 2: Percent of CA Commodity Acres Treated with Organophosphates in 1999

Commodity	Chlorpyrifos	Diazinon	Oxydemeton Methyl	Malathion	Dimethoate	Methamidophos
Alfalfa	28.50	0.00	1.00	17.10	24.40	5.60
Almonds	21.60	11.30	0.00	0.00	0.00	0.00
Broccoli	33.40	10.10	50.40	1.10	35.80	1.60
Carrots	0.00	9.60	0.00	3.50	0.00	0.00
Cotton	21.60	0.00	0.50	1.00	5.80	2.00
Grapes	4.19	1.00	0.00	0.00	1.70	0.00
Lettuce, Head	0.00	36.30	31.30	5.90	32.30	0.00
Lettuce, Leaf	0.00	42.00	0.03	5.10	28.70	0.00
Oranges	24.40	0.00	0.00	3.47	5.70	0.00
Peach & Nectarines	21.10	19.80	0.00	0.00	0.00	0.00
Strawberries	16.90	6.90	0.00	35.20	0.00	0.00
Tomatoes, Fresh	0.00	1.60	0.00	0.50	22.20	13.80
Tomatoes, Processed	0.00	7.60	0.00	0.00	44.10	6.90
Walnuts	34.50	2.20	0.43	2.90	0.00	0.00

Commodity	Azinphos Methyl	Acephate	Methidathion	Phosmet	Methyl Parathion	Fenamiphos
Alfalfa	0.00	0.00	0.30	4.10	0.10	0.00
Almonds	10.80	0.00	6.80	8.20	0.00	0.00
Broccoli	0.10	0.13	0.00	0.00	0.00	0.00
Carrots	0.00	0.00	0.00	0.00	0.00	0.00
Cotton	0.00	3.30	0.00	0.00	0.20	0.00
Grapes	0.00	0.00	0.00	2.20	0.46	3.90
Lettuce, Head	0.00	49.32	0.00	0.00	0.00	0.00
Lettuce, Leaf	0.00	0.36	0.00	0.00	0.00	0.00
Oranges	0.00	0.00	6.10	0.00	0.00	2.20
Peach & Nectarines	1.20	0.00	9.40	25.30	18.20	1.60
Strawberries	1.00	0.00	0.00	0.00	0.00	0.00
Tomatoes, Fresh	0.90	0.00	0.00	0.00	0.00	0.00
Tomatoes, Processed	0.00	0.00	0.00	0.00	0.00	0.00
Walnuts	9.90	0.00	3.30	15.10	15.70	0.00

Source: Calculated from 1999 field-level data obtained from California's Department of Pesticide Regulation.

We also attempt to disaggregate the overall impacts on California agriculture by examining the regional effects of a ban. Table 3 presents production levels of these commodities by California regions. The sources are different from those in Table 1 and, therefore, the production values cannot be directly compared.

Table 3: Average Cumulative Acreage and Value of 15 Commodities by California Regions, 1994-1998

Region	Acres	Value of Sales ($1,000)
North-Central Coast	331,263	1,611,818
South Coast	141,554	718,683
Sacramento Valley	452,107	751,222
Northern San Joaquin Valley	693,702	1,361,298
Southern San Joaquin Valley	2,430,502	5,018,443
Desert	370,891	700,737
Mountain	146,342	111,282
California Total	4,566,361	10,273,483

Source: California Agricultural County Commissioners.

The second section of the report provides an economic perspective on the role of pesticide regulation in society and provides a further discussion of the FQPA. Section 3 discusses the history of OP pesticides and describes the current role they play today in California's agricultural production processes. Section 4 explores the potential qualitative effects from the cancellation of all OP pesticide uses. We examine the potential effects on Integrated Pest Management (IPM), the overall level of pesticide use resulting from FQPA implementation, and the economic effects on producers and consumers. Section 5 explains the methodology of the report, discusses the problems of implementing the methodology, and provides a description of our results. We conclude with a discussion of policy implications and what the results mean for California agriculture.

This report was an interdisciplinary effort, a combination of entomologists' expert knowledge of pest control and economic modeling. The economic model is largely based on the model provided by the National Research Council (NRC) in the report, *The Future Role of Pesticides in US Agriculture*. The crucial step was determining which action producers would take after a ban of OP pesticides. To ascertain this, we commissioned a report from University of California Cooperative Extension (UCCE) pest management specialists (see Appendix A for the full report). The UCCE specialists described the role OP pesticides have in current agricultural practices and projected pest management programs producers would adopt under a ban. They also provided an estimate of cost and crop yield changes from the adoption of the new pest control practices, which provided the basis for the welfare calculations.

Results of the economic analysis suggest that the total loss to producers and consumers in California from banning all OP use will be approximately $203 million. This should only be considered an order of magnitude estimate of the effects, and represents only about 2% of the total revenue generated by the 15 crops in California. While the overall effects seem small, they may be more intense in some segments than others. The crops most directly affected are broccoli, oranges, almonds, and alfalfa. The losses are larger because there are less suitable alternative pest control strategies currently available to producers. For instance, the losses in broccoli are driven by the lack of an alternative insecticide to treat cabbage maggot. On the other hand, it seems clear that carrots have the least to lose from the elimination of OP insecticides since so few of these chemicals are used. Total welfare effects on the producers of all crops are estimated as ranging from less than 0.01% of total 1999 crop value for carrots to 3.4% of 1999 value for alfalfa.

It is important to understand that these impacts were calculated using a static equilibrium approach, while the actual implementation and resulting effects are a dynamic process. For instance, the changes were calculated assuming that all producers are the same and that they all adopt the best alternative OP-free pest management programs at the same time. Clearly the real world is a bit more complex. First, producers are a diverse group, and this heterogeneity may lead to differences in the speed of adoption of any "best" OP-free pest strategy (Carlson and Wetzstein). This gradual adoption in the short run may be due to differences in the information available and to differences in the ability of each producer to efficiently adapt to new pest management strategies. Some producers may be slower to learn and adopt the most efficient and cost-effective OP-free programs. Therefore, it is expected that economic losses will be greatest immediately after OP use is restricted and lower as more growers adopt more effective non-OP strategies.

Also, this report only considers today's available knowledge and abilities concerning pest control. Changes in the future could reduce the impacts of FQPA implementation. For example, we conducted our analysis as though only current pest control alternatives continue to be available. In fact, it is well known that regulation spurs innovation. Restrictions on the use of OP pesticides will encourage chemical companies to create new pesticides to substitute for OPs. In the long run, the effects may be smaller than those predicted here if new pesticides are successfully created and introduced. The regulation will spur innovations to ease the impact of the policy change.

2. Pesticide Regulation and the Food Quality Protection Act

This section provides an economic perspective on pesticide regulation and discusses specific provisions of FQPA. From an economic viewpoint, the goal of pesticide policy should be to maximize the net social benefits of pesticide use (NRC, 2000). Economists have developed methodologies to compare the overall social benefits of agricultural management practices and to select policies that result in the best allocation of resources.[3] Social benefits derived in monetary terms consist of the sum of net benefits to consumers, growers, and the environment.[4] Pesticide use is optimal if the gain from the incremental change in use is equal to the social cost (Carlson and Weitzstein). It is clear that optimal use levels cannot be attained without governmental intervention since the user costs of pesticides do not include the cost of possible ecological and human health effects. Therefore, economics suggests that without intervention, there is incentive for pesticides to be overused and applied with technologies that cause excessive damage. Lawmakers have the challenge of designing a policy mechanism that results in the efficient level of pesticide use.

The Costs and Benefits of Pesticide Use

Pesticide use confers costs and benefits to society, affecting both producers and consumers.[5] The most touted pesticide benefits are their ability to increase crop yield by preventing spoilage and pest damage to crops. These yield-increasing effects help reduce the amount of land and water resources necessary for agriculture. Without the use of these pesticides, valuable bio-resources may need to be converted to farming activities in

[3]See, for example, Just, Hueth, and Schmitz.
[4]Of course, one of the main challenges is to monetize environmental costs and benefits.
[5]See, for example, NRC 2000; OECD; Zilberman et al.; Lichtenberg, Parker, and Zilberman; Parker and Zilberman; and Babcock and Zilberman.

order to maintain production levels. Zilberman et al. demonstrate that pesticides also benefit consumers by reducing the price of certain fruits and vegetables, which makes them affordable to low-income consumers. This is an important observation since reductions in pesticide use could indirectly have a negative health effect by reducing the consumption of fruits and vegetables that contain many valuable micronutrients (Ames and Gold).

Pesticides vary in their ability to control pests, as well as their side effects on the rest of society. Much of the debate over pesticide use centers on these costs, rather than the benefits to society. NRC separates the harmful side effects of pesticide use into three groups: (1) environmental quality, (2) consumer health, and (3) worker safety. Effective pesticide policies try to minimize the risks of adverse effects while maintaining economic well-being. This includes testing pesticides for their possible effects on the nervous, reproductive, and immune systems of humans, and possible exposure to agricultural workers. Pesticides also affect nontarget soil microbes, wildlife, and other organisms.

There has been significant progress in modeling the processes that quantitatively assess the risk from pesticide use (Bogen, NRC, 1993). Risk is measured by the likelihood of harm to vulnerable humans or wildlife and is generated through the (1) application of chemicals and their residues, (2) fate and transport of the residues over space, (3) the exposure to chemicals or their byproducts, and (4) vulnerability to exposure of toxic substances. Risk from chemical use may be reduced through activities that alter these processes.

The benefits and risks of pesticides vary significantly with different types of uses; the challenge is to find and implement those uses that maximize net benefits. Of course, one easy way to lessen the risks of pesticides is to reduce the quantity used. However, there are more elegant alternative strategies to reduce risk while preventing the loss of all benefits. For instance, protective clothing for applicators lessens chemical exposure levels, while keeping pesticide use levels relatively unchanged. Other examples of risk reduction are through the adoption of precise pesticides and application technologies. Newer and more precise pesticides have fewer side effects, and application technologies reduce residue drift. Also, switching to IPM strategies that monitor pest populations prior to application can reduce pesticide applications and thereby levels of exposure.

The economic literature suggests two policy mechanisms to obtain the efficient level of pesticide use: financial incentives and direct control.[6] Performance standards are the most common example of direct control policies, while financial incentives include taxes/subsidies and tradable use permits. These policies can all generate the efficient outcome, but have different distribution effects. For instance, producers generally oppose taxes on pesticides, as it raises the costs of production.[7]

There are some examples of countries that have successfully used pesticide taxation, especially in Scandinavia (OECD). Taxes work because they bridge the gap between private marginal cost and social marginal cost. However, the extra cost imposed on society from pesticide use varies with the pesticide, location of use, and distance from population centers. These differences imply that the taxes should vary by region and commodity. However, enforcement of such an in-the-field tax requires exact monitoring of pesticide use. Monitoring of this sort is expensive and difficult to implement, which significantly reduces the appeal of taxes as a regulatory tool. Uniform taxes are easier to implement (for instance, as a sales tax), but are less efficient because they do not account for the variation in the social costs of pesticides. Nevertheless, it is the challenge of pesticide regulation to develop efficient policies that optimize pesticide use under political-economic constraints.

The United States has chosen to use a command-and-control pesticide policy; the EPA is in charge of implementing a rigorous pesticide registration process. All pesticides used commercially are required to obtain approval for every major application (OECD). The regulatory agencies continue to monitor and evaluate the performance and impact of chemicals after they are approved. If there is new scientific evidence of a chemical's undesirable side effects, the government may consider a chemical ban. Over time, there may be modifications in pesticide regulation as monitoring technologies and scientific knowledge improves. This registration process has allowed for a trend of increased precision in pesticide regulation. Pesticides can be regulated such that inefficient uses (whose costs are greater than their benefits) are prohibited, while allowing other

[6]See, for example, Baumol and Oates.
[7]See Buchanan and Tullock for a further discussion of taxes.

beneficial uses. These partial bans cancel use on less beneficial crops and tolerate use on crops with high benefits, until appropriate substitutes are made available. [8]

Some of the literature also suggests that intellectual property rights and patent laws may affect the timing of pesticide regulation (Carlson and Wetzstein). Companies may prefer to ban chemicals after the 17-year exclusive production rights have expired. Since they no longer have exclusive control over older chemical production, a ban may shift use to newly developed pesticides, which are still under protection. The cancellation agreements with the major methyl parathion manufacturers Cheminova and Elf Atochem are consistent with this theory. The EPA and these registrants agreed to cancel methyl parathion uses on foods that are significant to the diets of infants and children and agreed to cancel use on crops that require hand harvesting.

The Food Quality Protection Act

The FQPA was unanimously passed by Congress in 1996 and hailed as a landmark piece of pesticide legislation. It amended the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Federal Food, Drug, and Cosmetic Act (FFDCA), and focused on new ways to determine the health effects of pesticides. It is the result of a newfound understanding that pesticides can have cumulative effects on people, and the policy should be designed to protect the most vulnerable segments of the population.

The FQPA is different from past legislation by acknowledging there is a diversity of impacts among pesticides' effects on people. The publication of the National Research Council report, *Pesticides in the Diets of Infants and Children,* showed that pesticide residues have disproportionate effects on children. First, children eat and drink more as a percentage of their body weight than adults. They also consume fewer types of food; these dietary differences account for a large part of the exposure difference between adults and children. The committee also found that pesticides have qualitatively different impacts on children because children are growing at such a rapid pace. The knowledge of the dangers of children being exposed to chemicals in foods has triggered the modification of regulations represented by FQPA. For instance, the 10X provision of the

[8]See Yarkin et al. for further discussion.

FQPA is an extra 10-fold safety margin for pesticides that are shown to have harmful effects to children and women during pregnancy.

The FQPA has also resolved the “Delaney Paradox” created by the Delaney Clause of FFDCA. Prior to FQPA, the Delaney Clause prohibited the use of any carcinogenic pesticide that became more concentrated in processed foods than the tolerance for the fresh form. This had the purpose of protecting consumer health, yet it had the paradoxical effect of promoting other noncarcinogenic pesticides that created other (possibly more serious) health risks for consumers. FQPA standardizes the tolerances for pesticide residues in all types of food and looks at all types of health risks.

The EPA must now ensure that all tolerances are “safe,” defined as “a reasonable certainty that no harm will result from aggregate exposure to the pesticide” (EPA). This cumulative provision has forced the EPA to take into consideration all potential risks of pesticide exposure, which can come in many forms. Historically, pesticide exposure was regulated through single pathways through food, water, or dermal exposure. Now, the EPA must account for the aggregate exposure resulting from all pathways, including cumulative exposure to multiple pesticides through a common mechanism of toxicity. This means that even though pesticides may be sufficiently differentiated that they are used on different crops to control different pests, they can have similar health effects on people. The result is that in some instances pesticide tolerances for seemingly different insecticides must be regulated together based on their cumulative effects.

In a study conducted for EPA, the International Life Sciences Institute concluded, “the six organophosphate insecticides considered [in their analysis] should be considered to act via a common mechanism of toxicity.” This outcome, although deemed a “preliminary finding,” makes it clear that OP insecticides will be regulated jointly under the presumption of a common mechanism of toxicity. Indeed, the OP class of pesticides is in the Tolerance Reassessment Priority Group 1, and is the first to undergo a cumulative risk assessment by the EPA.

3. Organophosphate Pesticides[9]

Organophosphate insecticides were developed shortly after World War II and over the subsequent 20 years became the most widely used class of insecticides replacing chlorinated hydrocarbons such as DDT. In 1995, OP insecticides accounted for an estimated 34% of worldwide insecticide sales (Casida and Quistad). The discovery of OP insecticides roughly coincided with the development of another group of pesticides, the methyl carbamate (MC) insecticides. OP and MC insecticides had two large advantages over past insecticides. First, they were easy to manipulate in order to obtain toxicity in insects while remaining relatively benign to mammals. Furthermore, OP and MC insecticides were found to be much less persistent in the environment than other pesticides like chlorinated hydrocarbons.

OP insecticides are highly effective insect control agents because of their ability to depress the levels of cholinesterase enzymes in the blood and nervous system of insects. Although high levels of exposure to any OP insecticide would undoubtedly result in serious harm to humans, existing evidence suggests that dietary exposure for U.S. consumers is significantly below critical risk thresholds. For example, Voss, Neumann, and Kobel show that reference doses (or acceptable daily allowances) for OP insecticides are much lower in the United States than the standards set by the World Health Organization. It has been suggested that while dietary exposure to a particular OP may be low, the cumulative effects of simultaneous exposure to multiple OP insecticides could cause some segments of the U.S. population to exceed acceptable daily allowances (Byrd). Reducing the potential of these aggregate effects is specifically addressed in the FQPA and is one of the reasons the EPA has chosen OP pesticides for the first cumulative risk assessment.

When FQPA was passed in 1996, 49 OP pesticides were registered for use in pest control throughout the country. When the EPA released the Revised OP Cumulative Risk Assessment in 2002, already 14 pesticides had been canceled or proposed for cancellation, and 28 others have had considerable risk mitigation measures taken through partial use bans (EPA). A few of the better-known cases include restrictions placed on the

[9]Much of the background presented in this section was obtained from articles by Casida and Quistad and

popular OP pesticides methyl parathion, chlorpyrifos, diazinon, and azinphos methyl. Methyl parathion is considered to be one of the most toxic and widely used OP insecticides, and in August, 1999, its use was cancelled on many fruits and vegetable crops that constitute a large portion of childrens' diets (EPA, 1999a). Azinphos methyl was also regulated in August, 1999, but the restrictions imposed were not as severe as those for methyl parathion (EPA, 1999b), and since then the EPA has opened negotiations with azinphos-methyl registrants to relax these restrictions for many of its uses. In January, 2001, diazinon's use was banned for one-third of existing agricultural crops (EPA, 2001). The June, 2000, restrictions imposed on chlorpyrifos were widely contested by apple, grape, and tomato producers who projected the restrictions to have a significant impact on production and were upset that these effects were not considered by the EPA in the regulatory process (Benbrook; EPA, 2000). The FQPA itself gives little or no guidance on how to set restrictions and, given the disagreement about what standards should be used, the EPA is currently facing legal action from parties on both sides of the debate. Given the volume of evaluations still to be undertaken and the existing uncertainty about the standards to be used, environmental groups, growers, and pesticide manufacturers will continue to contest restriction decisions (Shierow and Benbrook).

OP pesticides are used on many crops in the United States, with corn and cotton accounting for the majority of total OP insecticide use. Giannessi (1997b) reports that over 50% of all OP insecticides were applied to these two crops, with no other major commodity using OP insecticides for more than 5% of total pesticide use. Cotton and corn are widely grown crops, with intensive use of pesticides per acre, which may make it necessary to restrict OP insecticide use on minor crops. Pesticide use may be quite intensive on such crops as fruits, vegetables, and specialty crops in order to protect the high-value crops from pest damage. Because consumers eat many fruits and vegetables fresh from the producer, these crops may also expose consumers to increased pesticide risk. These specialty crops can be grown on small plots of land next to population centers, which also presents a greater exposure risk to nearby residential areas. It may also be difficult for chemical producers to maintain registrations on fruit and vegetable production in California because of the high costs of the registration process. Clearly not

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Voss, Neumann, and Kobel.

all OP insecticides will be banned, but given the uncertainty in the degree of regulation, studying the effects of a complete ban of OP pesticides provides a good benchmark for the possible effects on the state of California.

4. Qualitative Effects of the Organophosphate Pesticide Ban

The objective of effective pesticide policy is to protect the environment and human health from the harmful effects of pesticide use, while maintaining the economic well-being of producers and consumers. Regulators may draft a policy focusing on one of these aspects, but should understand that it will have other consequences as well. These aspects of pesticide policy are intertwined; we cannot independently regulate the effects of pesticide use on one, without affecting the others. The FQPA is an example of pesticide policy whose regulatory focus is reducing the human health effects of pesticides. However, its implementation will also have economic and environmental effects. This section uses a theoretical approach to assess the qualitative nature of the impacts from a complete ban of OP pesticides.

If producers are no longer able to use OP pesticides, there are a number of pest control alternatives available including MC, neonicotinoid, pyrethroid, various insect growth regulators and reduced risk insecticides, biological controls, pheromones, and genetically engineered crops. The impact of a ban on OP pesticides depends wholly on which alternative measure producers choose to implement and their relative benefits and limitations. For instance, MC and pyrethroid insecticides may not be as effective and/or as economical as the OP insecticides for which they would substitute. These insecticides have also been shown to cause adverse ecological effects on nontarget organisms. In addition, MC and pyrethroid are due for tolerance reassessment by the EPA, making their future availability uncertain. Other insecticides like the class of IGR insecticides can only be used during a very limited spectrum of pest activity. Furthermore, although new modes of action are continually being researched, it is becoming increasingly difficult to develop new chemicals, due to technological and regulatory constraints. For example, Casida and Quistad report that the average number of synthetic compounds created in order to develop one production-worthy pesticide has increased from 2,000 chemicals 40 or 50 years ago to 20,000 or more today.

In this section we focus on how an OP ban could impact California: (1) the impact on IPM, (2) the impact on overall pesticide use, and (3) the economic well-being on producers and others. IPM programs utilize effective pest control techniques in an ecological sound manner to prevent economic damage (Stern et al.). Currently, OP pesticides play important roles within many IPM programs. The adoption of IPM programs is a stated national goal of the U.S. Department of Agriculture. In fact, the promotion of IPM practices is required by section 303 of the FQPA, and the National IPM Initiative has the goal of implementing IPM on 75% of the nation's cropland. With this goal in mind, it is important to understand how a ban of OP pesticides will affect producers' propensity to adopt IPM programs.

In order to reduce the harmful environmental effects of pesticides, a policy should reduce the amount of toxic pesticides in use. We try to predict how the adoption of alternative pest control strategies in response to a ban of all OP insecticides will affect the overall level of pesticide use. A ban of OP pesticides would have a direct and immediate impact on producers; they will have to switch to alternative pest control measures. A ban will prohibit producers from using OP pesticides and force them to switch to less effective and/or more costly pest control strategies. Price increases will also reduce total consumer surplus, further reducing the total welfare of society. In this section we try to formulate a picture of the effects from a ban of OP pesticides on producers and other aspects of the economy.

Throughout this discussion, it is important to remember the dynamic nature of the pesticides available to producers. As such, the institution of a new policy cannot be seen as a transition from one static equilibrium to another. Chemical companies are always trying to forecast the future needs of growers and to develop the appropriate pesticides to meet these needs. For instance, pesticide producers are in a continual race to develop new chemicals to replace older pesticides as insects develop resistance to pesticides. As pests develop resistance to the older, broad-spectrum insecticides, chemical companies are increasingly responding by creating new pesticides that are targeted at specific pests (NRC, 2000). These new pesticides may increase producer cost if producers use a greater number of pesticides because of the pest specificity of the newer insecticides. However, the newer pesticides have fewer detrimental side effects on the environment and other living organisms due to their targeting nature. Examples of recently introduced chemicals are Dow AgroSciences' spinosad, tebufenozide and methoxyfenozide from Rohm and Haas, diflubenzuron by Uniroyal, Sygenta's fenoxycarb, and Valent's pyriproxifen.

IPM Practices and Organophosphate Insecticides

IPM is a pest control system that utilizes all available pest control techniques (chemical, biological, and cultural) in an environmentally compatible manner to prevent economic damage. When OP pesticides are used, IPM promotes their targeted use to minimize the harmful effects on the environment, human health, beneficial insects, and other nontarget species. This section discusses the role of OP insecticides in California IPM strategies and the potential effects of an OP pesticide ban. In particular, the focus is on the relationship between OP insecticides and IPM, since promoting the adoption of IPM practices is an important policy goal in California. Currently, OP pesticides play an important role in three characteristics of an IPM program: (1) providing the rapid response necessary for a quick knockdown of pest populations, (2) promoting beneficial insect populations relative to MC and pyrethroid alternatives, and (3) helping to maintain low pest resistance. The effects of OP restrictions on these characteristics are discussed in detail below.

Rapid Response

An important element of a successful IPM program is monitoring pest populations to determine the pest population level and appropriate timing of control measures. At times, pest populations may be low enough that pesticides are not necessary, or less toxic products and smaller doses may be appropriate. For example, when pest populations are low, peach and nectarine growers can use pheromone-mating disruption to control Oriental fruit moth (see Appendix A). However, producers need the ability to rapidly suppress large pest populations if an outbreak occurs. Having a highly effective pesticide available provides a type of insurance by allowing the producer to use a "softer" control strategy, with the knowledge that the highly effective insecticide is available should it be needed to combat large populations. Currently, OP pesticides play the role of a rapid response insecticide in many IPM programs. If OP pesticides are no longer available, producers will have to find alternative pesticides to act as the backup. If no rapid response alternative is available, producers may not implement an IPM strategy calling for a "soft" strategy. In most cases, however, sufficient alternatives exist, and IPM adoption should not be largely affected.

Beneficial Insects

Beneficial insects and mites are an important component of IPM since they reduce the need for chemical pesticides. Some OP pesticides are less harmful to beneficial insects and mites than their alternatives. Without OP pesticides, producers may switch to alternatives like pyrethroid and MC insecticides, which are more damaging to beneficial insects and mites for almost all of the crops examined (see, for example, alfalfa, almonds, and broccoli in Appendix A). While pyrethroids are less toxic to humans than many OP insecticides, they are more broadly toxic to natural enemies and persist for longer periods in the environment. This means that increased use of pyrethroid and MC insecticides could lead to increases in populations of spider mites, scale insects, and other pests that might otherwise be controlled by beneficial insects. This will, in turn, lead to a greater use of miticides and other control measures in order to control these outbreaks.

Resistance Management

An important characteristic of any effective pest management program is maintaining pesticide effectiveness. This is best achieved through low pest resistance to the pesticides available to growers. There are two main issues related to pesticide resistance management from an OP ban. The first is that pest resistance is negatively correlated between some OP chemicals and other pesticides. Insects are able to build up resistance to one pesticide, but in doing so reduce their resistance to an OP pesticide. That is, the use of one pesticide makes another chemical more effective for later use (Dunley and Welter).

Another way to maintain low pest resistance to chemicals is to use pesticides with different modes of toxicity (Roush and Tabashnik). Banning OP pesticides would reduce the number of options available to producers to control pests. Without OP pesticides, producers will rely more heavily on other pesticides, which may in turn increase the speed at which pests develop resistance to these alternatives. For example, pyrethroids are an alternative to OP insecticides for pest control in many of the crops (broccoli, carrots, tomatoes, peaches, strawberries, almonds, and walnuts) and in many cases are considered the primary alternative (see Appendix A). However, pests can and have developed resistance to pyrethroid insecticides. Therefore, it is critical that growers have a diverse range of alternative pesticides available to them in order to address the possible implications of increasing resistance (Carlson and Weitzstein). Cancellation of OP insecticide use reduces the chemicals available and may lead to increasing pest resistance on many crops throughout California.

It must be noted that pests have already developed resistance to OP pesticides, in some cases quite extensively. For example, the codling moth has developed about a 10-fold resistance to azinphosmethyl in pears and apples in California and a much higher level in South Africa (Dunley and Welter). Producers must find alternatives to these pesticides regardless of a ban on OP pesticides. In reality, we cannot attribute all the costs of finding and implementing alternatives to OP pesticides to a ban. In some cases, the switch to more costly pest management schemes may happen anyway.

Organophosphate Cancellation and Overall Pesticide Use

One way to gauge the impact of the policy change on the environment is to examine the overall level of pesticide use. The overall pesticide use level will depend on which alternatives current OP pesticide users choose to implement. A priori, we cannot unambiguously state what will happen to the overall level of pesticide use if a ban were to take place; there are factors that would tend to both increase and decrease pesticide use.

Factors that Increase Pesticide Use

If OP insecticides are not available to growers, there are at least three reasons why the overall use of pesticides may increase. First, alternative pesticides may not be as effective as OP insecticides. If the alternative pesticide is less effective at controlling a pest species, a greater number of applications may be required. For example, methomyl and pyrethroids are less effective as methamidophos in controlling stinkbugs in tomatoes (see Appendix A). Therefore, use of these non-OP alternatives may require the combination of two or more insecticides, compared with one for methamidophos. Pest resistance only compounds the problem of alternative effectiveness. As pesticide resistance increases, growers often react in the short run by increasing the quantity of the pesticide used. This increase in resistance to alternatives may require an additional increase in the number and intensity of applications.

Secondly, pesticide use could increase if non-OP alternatives control fewer pest species. Without the broadly effective OP pesticides, the grower may need to use a greater number of pesticides to control the same pests. An example is the use of acephate in head lettuce, which controls both aphids and cabbage loppers (see Appendix A). Without acephate, some growers may have to use two or more chemicals to control the same pests previously controlled by one. It is important to note that this increase in the number and quantity of pesticides does not necessarily mean an increase in the dangers of pesticide use. The new pesticides may be more targeted to pest species, with the result of fewer detrimental side effects. The more important aspect of this increase in chemical use is the <u>increased cost</u> for producers.

Thirdly, some alternative strategies to OP insecticide are more harmful to beneficial insects. Fewer beneficial insects could cause an increase in pesticide use as producers apply pesticides to do the job that the predatory insects once did. For example, if growers switch to pyrethroids, they will frequently be required to apply an additional miticide to control the spider mites that would otherwise have been controlled by their natural enemies.

Factors that Decrease Pesticide Use

In some instances, a ban of OP pesticides could decrease the total amount of pesticides used. This section identifies factors that can reduce pesticide use from the cancellation of OP insecticides. First, growers may increase the use of cultural pest control practices or use nontoxic alternatives that are currently not used because of high expense and low efficacy. For instance, not being able to use chlorpyrifos or diazinon at the planting stage may mean that growers increasingly turn to transplanting crops from greenhouses or increase the density of planting and thin the crop out later (see, for example, grapes in Appendix A). Secondly, the higher cost of alternative treatments increases the incentives for growers to use fewer pesticides. For instance, producers might increasingly turn to pest monitoring systems to determine if and when applications are needed. This is true for both chemicals used in response to pest populations and those used as a preventative.

Of course, the overall quantity of pesticides is not a perfect measure of environmental impacts. For instance, fewer pesticides may be used after the ban, although these pesticides may be more toxic than OP pesticides; or the new pesticides may have fewer side effects, which will result in fewer negative environmental impacts even if more pesticides are used. In order to determine the environmental impact of a ban on OP pesticides, empirical data on the actual producer adoption strategies are needed.

Economic Effects

The total economic effects from a ban of OP pesticides will depend on the final market equilibrium price and quantity. Economic theory suggests that if a ban of OP pesticides is to have any effect in the short run, it will cause a reduction of the market supply curve (Lichtenberg, Parker, and Zilberman). For any given price, growers will produce a lower quantity than before the ban. The supply effects will be small if producers have close substitutes to OP pesticides and greater when producers are forced to stop using pesticides that have no close substitute. In any case, a shift of the supply curve will likely result in a reduced market output and higher price charged to consumers.

In cases where producers are currently using OP pesticides, a ban can be seen as prohibiting producers' first choice pest control measure. If OP pesticides are no longer available, producers will adopt a "second best" pest control scheme. Profit-maximizing producers will choose a production quantity such that the marginal cost of the last unit produced is equal to the price producers receive in the market. Since the "second best" alternatives will either be less effective, more costly, or both, the per-unit cost of production will increase, which will in turn cause growers to reduce production. In some cases, OP pesticides have close substitutes; and producers can transition to slightly higher cost pesticides, in which case the supply effects will be small. However, there may be cases where no viable OP substitute exists because it is either too expensive or ineffective. In these cases, the second-best strategy may be to accept crop damage caused by pest outbreaks, which will have a larger effect on the supply curve. The magnitude of these supply responses will depend on the exact alternatives adopted.

Increases in production costs may be due to producers being forced to use greater quantities of less-effective pesticides, a greater number of pest-specific pesticides, or simply because alternative pesticides are more expensive. These higher costs per unit of effectiveness may encourage producers to reduce their use of pesticides through the use of nonpesticide alternatives. In some cases, the cost of pest management may rise sufficiently that producers accept yield losses instead of paying for the alternative form of pest management. For instance, broccoli producers currently have no viable alternative pesticide to control cabbage maggot. If OP pesticides are banned, producers will be forced to accept yield losses as cabbage maggots destroy some of the crop.

Since an effective pesticide policy is a balancing act between the economic welfare of producers and the harmful side effects of pesticide use on the environment and human health, it is important to understand how a new policy focusing on health hazards will affect the environment and producer economic well-being. For instance, it seems clear that a ban of OP pesticides will cause a shift in the supply curve of commodities that currently use OP pesticides. However, empirical data are necessary to determine the nature and magnitude of other effects. The total quantity of pesticides used after a ban of OP pesticides could go up or down. Also, it is unclear whether IPM participation is likely to increase, decrease, or stay the same. The ban could have other effects too, such as increased prices of commodities, and even (indirectly) negative health effects.

5. Economic Methodology and Model Results

Methodology[10]

In order to assess the welfare effects of a ban of OP pesticides, this report followed the model suggested by the National Research Council. Their model suggests to (1) identify the in-the-field responses available to producers if the policy were to go into effect, (2) assess the impacts of these alternative actions, (3) determine actual producer choice of alternatives, (4) aggregate the effects of this alternative to obtain the total supply effect, (5) find the equilibrium price and quantity in the market using supply and demand, and (6) calculate the total welfare effects in the market. If uncertainty exists

[10]For a more in-depth description of the NRC model, see Chapter 5 of *The Future Role of Pesticides in US Agriculture* by the National Research Council.

concerning some of the parameters, this calculation process may be repeated several times in order to obtain a distribution of welfare effects. This model can best be seen as a flow chart in Figure 1 below.

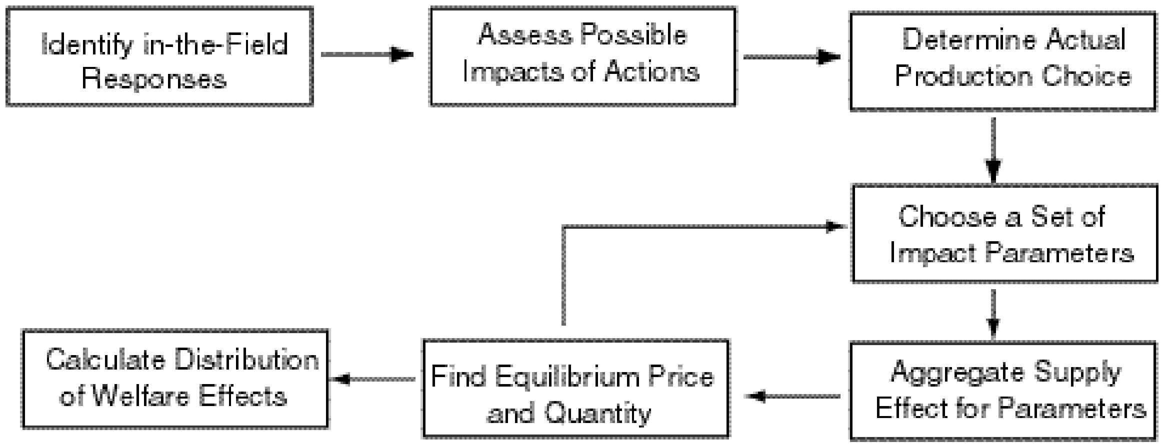

Figure 1

Applying this model to our study involved the following:

- We surveyed University Extension specialists in order to identify the "best" alternative pest control measures that producers could implement if OP pesticides were banned. Examples of alternative pest management strategies include the use of non-OP pesticides, increased use of IPM's, or other biological/cultural forms of crop protection. The surveyed opinions of these pest management specialists also included probable effects from implementing these alternative measures, such as increased production costs or reduced crop yields. The effects of the alternative measures are uncertain, so the surveys solicited a minimum and maximum possible effect. Appendix A provides a summary of the survey results.
- We used a Monte Carlo method to choose from the set of possible effects, and these effects were aggregated across the state.
- We used supply and demand elasticity parameters to calculate the appropriate price and quantity effect of the ban.

- We used these new equilibria to calculate a distribution of the possible changes in welfare due to a ban on OP insecticides. Appendix B provides a further mathematical presentation of the economic model used in this analysis to calculate economic impacts.

Methodology Implementation Problems

This methodology is appealing for its simplicity and intuition; however, its implementation in the real world caused problems. The most difficult part of the methodology was finding data on the available OP pesticide alternatives, determining which alternative pest management strategy producers would actually choose to implement, and studying the quantitative effects of implementing these alternatives.

Our approach was to commission University Extension specialists to study the alternatives available to producers in the absence of OP pesticides. These specialists' opinions are crucial because their knowledge links the academic literature with the realities of the field. They have access to the current state of technology in the field and know which technologies will soon be available to producers. These experts in their field were asked to provide their opinions on the "best" non-OP alternative pest management strategies and then estimate the resulting effects on production yields. Appendix A provides the written summaries provided by UC pest management specialists. Because of the complex issues involved in designing these programs, they were asked to abstract from cost considerations and not consider pest resistance. The summary in Appendix A describes the key pests that were identified for each commodity and lists the OP insecticides that are used for their control. Information is also provided as to the availability of non-OP alternatives and the effectiveness of the alternatives adopted in the absence of OP insecticides.

Economic theory suggests that full information, combined with profit maximization, will lead all producers to immediately switch over and use the best available alternative technology. In this idealized world, we only need to calculate "the best" alternative technology (profit maximizing), and with this knowledge we can fully determine the effects of the policy. We recognize that the theory is an oversimplification and must be taken into account in the welfare analysis. Indeed, the technology diffusion literature suggests that information about the best available alternatives may, in fact, spread slowly among heterogeneous producers, and over time these producers will slowly changeover to the "best" alternative.[11] Therefore, it is expected that losses would be highest immediately following the restrictions and decrease later as more growers adapt and more effectively utilize non-OP alternatives.

The technology diffusion literature suggests that the technology diffusion process is slow for three reasons: risk, heterogeneity among adoptees, and transaction costs. The first is that the transition to a new technology has a large risk premium, which slows its spread. That is, it is possible that the benefits are greater than costs, but change does not occur. There is also a vast heterogeneity among growers and farm locations that may slow the diffusion process. Some farming systems are quite rigid and the adoption of new technology can create high transactions costs. The transition is generally a long process, taking anywhere between 3 and 20 years, and some technologies may never gain full adoption.

Carey and Zilberman also suggest that a shock to the system will increase the speed at which the new technology is adopted. Surely, a regulatory ban of OP pesticides qualifies as a shock to the producer system, but one must recognize that the adoption of the currently available cutting-edge technologies will be relatively slow. In the meantime, new technologies may be created which are better alternatives to OP pesticides, which will further change which alternatives are adopted and at what speed. This slow adjustment process and the corresponding lag in technology adoption must be accounted for in the welfare analysis.

In order to account for this real-world adoption process, one might like to ask producers, in the form of focus groups, how they would respond if the policy in question were to be implemented. These focus groups could provide an on-the-ground perspective from those most directly affected by the policy change and augment the specialists' opinions. This approach was tried and later abandoned for two reasons. First, producers may not learn about their alternatives until they find themselves in the once-hypothetical situation. Without this information, the focus groups would not be able to accurately predict producer responses. Secondly, and the primary reason this approach was

[11]See, for example, Sunding and Zilberman (2001) or Carey and Zilberman (2002).

abandoned, is the moral hazard danger. Producers and others understand that their responses can affect the eventual policy outcome, and this knowledge creates an incentive to overestimate their costs. One way to address moral hazard is to have routine focus group meetings that continuously provide opinions on the changes, and whose members will be confronted with their earlier responses. This increases the incentive to give truthful responses to the questions posed.

An alternative approach to supplementing the specialists' findings is to use an econometric model to predict the producer responses to a policy. The use of past observations of the types of technology available and actual producer responses would remove the problem of moral hazard. Ideally, gathering information on the best alternative technologies would be a continuous process where actual behavior is used to econometrically estimate adoption parameters and provide us with a better understanding of the responses on the farm level over time. Increasingly, California is gaining access to this important information through state programs that are gathering pesticide decision data at the farm level. We encourage further research along these lines by combining this decision-making information with other available farm data. The results of the research can provide the foundation for the estimation of adoption parameters, which will greatly enhance future studies like this one.

Given the constraints of this report, our work represents the results of the first approach. We commissioned a survey of extension advisors and specialists to determine the effects of alternative pest control strategies after a total ban of OP insecticides. The resulting calculations provide welfare changes for a single year and represent the predicted welfare changes occurring immediately after OP use is restricted. In actuality, the heterogeneity of producers means that they will adopt different pest management programs immediately after regulation and, over time, slowly move to what is considered to be the "best" non-OP alternative. Therefore, it is expected that losses would be highest immediately following restrictions and decrease, as more growers are able to adopt and more effectively utilize non-OP alternatives.

The Economic Model

The economic model developed uses three parameters to summarize the production-related consequences of the cancellation of OP insecticides. These parameters are the per-acre yield changes and the per-acre cost changes as provided by the UC specialists, as well as the fraction of total acres that use OP insecticides. These parameters are chosen because they directly determine the production consequences to growers and, hence, indirectly affect the availability and the price of commodities available to consumers. It is important to consider the fraction of acres using OP insecticides because their use varies by region and crop, and it would be a gross overestimation as to the importance of OP insecticides if the yield and cost effects were assigned to all of the state's production acres.

Changes in these three parameters lead to changes in total economic welfare in the economy, for both producers and consumers. Total economic welfare is defined as the sum of consumer welfare, which is a measure of the difference between the benefit derived from consumption and the cost of consumption, and producer surplus, which is a measure of producer profits. The economic impact of the cancellation of OP insecticide use is calculated as the difference between economic welfare with and without the use of OP insecticides. To calculate the changes in producer and consumer surplus that would occur under cancellation of OP insecticides, a model of market activity must be developed to determine how such an absence would alter the existing market equilibrium (Lichtenberg, Parker, and Zilberman; Sunding).

All of the results presented in the following section depend on the estimates provided by UC specialists as well as supply and demand elasticities for each crop. Estimates of each of these parameters are somewhat uncertain; therefore, to capture this uncertainty in this study, a Monte Carlo analysis is conducted by specifying a distribution for each of these estimates in our model. A discrete distribution for each parameter is specified that assigns a $\frac{1}{4}$ probability to low and high outcomes, and a $\frac{1}{2}$ probability to a medium or average outcomes. With distributions for each parameter specified, we then calculate welfare changes repeatedly, each time drawing randomly from the relevant distributions. With a large number of repeated draws (we used 1,000), information on the range of potential effects can be obtained.

Summaries of the yield and cost range estimates given from the UC specialists are provided in Table 5. The yield effect estimates of the UC specialists are zero in most cases, the exception being broccoli in coastal regions that will suffer losses due to a lack of a non-OP alternative to control cabbage maggot.

Table 5: Yield and Cost Change Estimates of UC Specialists

Crop	Yield Change low	Yield Change high	Cost Change* low	Cost Change* high
Alfalfa	0%	0%	$27	$70
Almonds	0%	0%	$72	$206
Broccoli**	10%	30%	$65	$87
Carrots	0%	0%	$0.11	$0.69
Cotton	0%	0%	$56	$56
Grapes	0%	0%	$32	$163
Lettuce, Head	0%	0%	$64	$107
Lettuce, Leaf	0%	0%	$87	$129
Oranges	0%	0%	$119	$256
Peaches & Nectarines	0%	0%	$24	$82
Strawberries	0%	0%	$141	$189
Tomatoes, Fresh	0%	0%	$9	$44
Tomatoes, Processed	0%	0%	$16	$16
Walnuts	0%	0%	$56	$135

* Cost per acre

*** Yield changes in coastal region only*

Results

This section discusses the empirical results obtained from the model introduced in the previous section. The economic impacts from this analysis provide the expected changes in economic welfare occurring immediately after OP restrictions are imposed. It is important to remember the issues involving differences in the ability of producers to learn and adopt new non-OP insecticide pest management strategies. This learning process could result in larger economic impacts occurring immediately after regulation, followed by gradual movement over time to lower impacts as producers are able to effectively and efficiently adopt the "best" OP-free pest management strategies suggested by UC specialists.

The results are provided by crop for the state as a whole and by regions within the state. The regions within the state are defined by counties and are provided in Table 6.

Table 6: Counties by Regions

Region	Counties
North and Central Coast	Alameda, Contra Costa, Del Norte, Humboldt, Lake, Marin, Mendocino, Monterey, Napa, San Benito, San Mateo, Santa Clara, Santa Cruz, Sonoma
South Coast	Los Angeles, Orange, San Diego, San Luis Obispo, Santa Barbara, Ventura
Sacramento Valley	Butte, Colusa, Glenn, Placer, Sacramento, Solano, Sutter, Tehama, Yolo, Yuba
Northern San Joaquin Valley	Merced, San Joaquin, Stanislaus
Southern San Joaquin Valley	Fresno, Kern, Kings, Madera, Tulare
Desert	Imperial, Inyo, Riverside, San Bernardino

Table 7 provides the average parameter values by crop for percentage of acres treated with OP insecticides as well as the average values for supply, demand, and net export elasticities. The acres treated with OP insecticides are high in peaches, nectarines, and broccoli while the use of OP insecticides is very limited in alfalfa and carrot production.

Table 7: Average Value of Parameters By Commodity, 1994-1999

Crop	Treated Acres	Elasticities: Supply	Elasticities: Domestic Demand	Elasticities: Net Trade
	percent			
Alfalfa	7.5	0.79	-0.20	-0.46
Almonds	49.7	0.23	-1.35	-0.46
Broccoli	75.3	0.81	-1.23	-0.44
Carrots	8.3	0.80	-1.04	-0.94
Cotton	48.4	0.80	-0.20	-0.46
Grapes	14.6	0.22	-0.56	-0.93
Lettuce, Head	55.3	0.80	-0.99	-0.45
Lettuce, Leaf	44.2	0.81	-1.05	-0.45
Oranges	28.3	0.23	-2.09	-0.45
Peaches & Nectarines	80.8	0.22	-1.45	-0.95
Strawberries	46.5	0.81	-1.24	-0.94
Tomatoes, Fresh	36.8	0.80	-0.83	-0.94
Tomatoes, Processed	39.1	0.80	-0.79	-0.94
Walnuts	62.5	0.22	-1.03	-0.46

Table 8 provides the results from the economic model calculating the percentage changes in crop prices and changes in the quantities of production in California and the rest of the United States. These are estimates of the effects expected to occur immediately after cancellation of all OP use. While the regulatory possibility of total OP cancellation is not likely, it is examined in order to obtain a dollar amount for the total value of OP insecticide use in California.

Table 8: Changes in Price and Quantity

Crop	Change in Price (percentage)	Change in Production* California	Change in Production* Rest of US	Change in Consumption*	Change in Net Exports*
Alfalfa	0.93	-184,845	48,743	-135,145	-957
Almond	0.48	-1,356	n/a	-1,311	-45
Broccoli	16.00	-111,285	2,083	-100,321	-8,881
Carrots	>0.01	-5	-3	-8	>-1
Cotton	1.69	-1,148	-19,214	-7,823	-12,540
Grapes	0.05	-999	-265	-1,231	-33
Lettuce, Head	0.36	-12,778	3,864	-8,641	-273
Lettuce, Leaf	0.46	-1,510	-148	-1,457	-200
Oranges	0.32	-40,517	-28,137	-67,848	-806
Peaches & Nectarines	0.32	-1,561	-2,016	-3,443	-133
Strawberries	0.26	-508	-743	-1,177	-74
Tomatoes, Fresh	0.03	-388	-223	-439	-172
Tomatoes, Processed	0.16	-10,849	114	-10,474	-261
Walnuts	0.58	-1,091	n/a	-956	-135

* Change in tons

The largest changes in price occur in broccoli production as price increases of 16% are expected. This higher price increase in broccoli is due to expected yield losses in coastal regions due to cabbage maggot damage. There are currently no registered alternatives to OP insecticides for this pest. The resulting changes in California and the rest of U. S. production associated with this price change is -111,285 tons and 2,083 tons, respectively. Price increases in all other commodities are more moderate given the 0% expected yield changes in these crops. All price changes for these crops are caused only by increases in the per acre production costs resulting from the switch to OP-free pest management programs. The highest price changes are for cotton and alfalfa, which face a more inelastic demand than vegetable, fruit, and nut crops. Note that production increases for some commodities in the rest of the United States, as these regions benefit from price increases but are not as dependent on OP insecticides and thus do not incur higher costs.

The calculated estimates of the resulting changes in producer and consumer welfare are provided in Table 9. The largest absolute changes in producer welfare occur in oranges, alfalfa, and almonds where losses represent 3.0%, 3.4%, and 2.3% of the 1999 production value, respectively. These losses are driven by the large decrease in quantities produced in alfalfa and oranges and by the high value of almonds. Losses are also high for broccoli where it is estimated that approximately $13.6 million could be lost representing 3.1% of the total 1999 value of this crop. This large loss is expected given the high percentage of broccoli acres currently using OP insecticides and the predicted yield losses in coastal regions. In total, it is estimated that California's producers will lose over $115 million, or 1.1% of the total 1999 value for these crops.

Table 9: Changes in Producer and Consumer Welfare

Crop	Producers* (California)	Percentage of CA Value	Consumers**	Total Loss*
Alfalfa	-26,868	-3.4%	-6,059	-32,927
Almonds	-24,049	-2.3%	-5,797	-29,846
Broccoli	-13,621	-3.1%	-54,091	-67,712
Carrots	-3	>-0.01%	-1	-4
Cotton	-1,520	-0.1%	-10,573	-12,093
Grapes	-2,221	-0.1%	-1,091	-3,312
Lettuce, Head	-5,797	-0.9%	-2,809	-8,606
Lettuce, Leaf	-858	-0.5%	-925	-1,783
Oranges	-27,113	-3.0%	-1,096	-28,209
Peaches & Nectarines	-3,045	-0.6%	-1,545	-4,590
Strawberries	-643	-0.1%	-1,433	-2,076
Tomatoes, Fresh	-254	-0.1%	-137	-391
Tomatoes, Processed	-1,298	-0.2%	-1,037	-2,335
Walnuts	-8,092	-2.4%	-1,619	-9,711
Total	-115,382	-1.1%	-88,213	-203,595

*Change in thousands of dollars.

**Consumer loss due to change in California production.

Consumers are also adversely affected. The consumer welfare changes in Table 9 are due to exclusive changes in California production. In this way, the total loss, calculated as the sum of losses in California producer welfare plus the losses in U.S. consumer welfare due to decreases in overall California production, is a measure of the total value to society of OP insecticides use in California. This total value is estimated as $203 million for the crops examined.

Table 10: Regional Effects on California Producers

Crop	North Coast*	South Coast*	Sac. Valley*	Northern San Joaquin*	Southern San Joaquin*	Desert*
Alfalfa	-	-	-2,549	-7,991	-13,510	-
Almonds	-	-	-3,023	-4,861	-9,979	-9,004
Broccoli	-12,479	-17,698	-	1,310	5,832	9,414
Carrots	<-1	<-1	-	-	1	-3
Cotton	-	-	-42	315	-1,734	-59
Grapes	-23	-6	3	3	-2,066	-132
Lettuce, Head	-2,712	-435	-	-	-1,344	-1,303
Lettuce, Leaf	-791	-28	-	-	-59	21
Oranges	-	-619	-	-	-26,494	-
Peaches & Nectarines	-	-	-406	-363	-2,276	-
Strawberries	-396	-246	-	-	-	-
Tomatoes, Fresh	-62	-117	-10	-76	3	8
Tomatoes, Processed	-	-	-1,056	-459	217	-
Walnuts	-723	-128	-2,343	-2,421	-2,478	-
Total	-17,186	-19,277	-9,426	-14,543	-53,887	-1,058

* Change in thousands of dollars

- Not grown in significant quantities in region.

Changes in producer welfare by region within the state are provided in Table 10. It can be seen that there are both positive and negative values in this table, which shows that while producers in some regions will lose (negative values) producers in other regions will gain. These gains are due to the fact that OP insecticides are not used as extensively in certain regions of the state and also because expected changes in production yield and costs can vary by region depending on types of pests and the size of pest populations. Totals for each region show that losses are the largest in the Southern San Joaquin Valley region. This is a consequence of the variety and abundance of production that occurs in this region. The total loss for the two Coastal regions is greatly influenced by the potentially large losses occurring in broccoli.

The Sensitivity of Results to Yield Losses

The results obtained in this analysis are based on the opinions of UC specialists that there will be resulting yield losses only for coastal broccoli production. The fact that there are no predicted yield losses for the rest of the crops influences the economic welfare results. As can be seen from the predicted yield losses in coastal broccoli, the inclusion of yield losses imposes significant consequences on economic welfare predictions and, therefore, it is important to investigate the sensitivity of these results to yield changes.

The importance of the learning and adoption effect has been discussed a few times in this report. Any transition to a new pest management program will require some amount of time to learn how to effectively and efficiently use the new program. In some situations, this time may be relatively short, while in other cases it may be longer. Therefore, some yield loss may be expected for those growers who have more difficulty in effectively implementing new OP-free programs. The specialists providing OP-free management programs for this report were unable to estimate the impacts of learning and adoption and thus may have overlooked some of this initial yield loss.

Another important reason in considering the potential of yield losses is the opinion that was expressed by growers, farm advisors, and pest control advisors (PCAs) concerning the regulation of OP insecticides. A series of focus group meetings we held with these individuals suggest that yield losses will be positive and in some cases a substantial problem. Therefore, it is important to acknowledge the possibility of some yield effect and demonstrate the sensitivity of the model to these yield losses. In order to demonstrate this sensitivity, the model has been run with the current cost changes and a 5% yield loss in all crops except broccoli. The use of 5% as an example seems reasonable given our discussions with growers and farm advisors in our focus groups. Calculating economic losses with yield loss will demonstrate how the results change if there is some initial yield loss in these crops as producers learn how to use new OP-free programs. These results are provided in Table 11.

Results from a 5% yield loss shows how producer welfare losses for each crop increase leading to a 113% increase for the State as a whole. Consumer losses also increase making total losses for the banning of OP insecticides in California rise from $203 million to $515 million, or increase 154%. These results are provided to demonstrate the sensitivity of the model to yield effects and address the possibility of some initial yield loss due to the time required to learn new OP-free management programs. It seems realistic to expect some initial yield loss as new OP-free programs are introduced, and then see yield loss decrease to zero as new OP-free programs are effectively and efficiently implemented.

Table 11: Sensitivity of Model to 5% Yield Loss

Crop	Producers* (California)	Percentage of CA Value	Consumers**	Total Loss*
Alfalfa	-55,048	-7.0%	-12,743	-67,791
Almonds	-39,148	-3.7%	-46,186	-85,334
Broccoli	-13,621	-3.1%	-54,091	-67,712
Carrots	-2,460	-1.5%	-1,341	-3,801
Cotton	-2,790	-0.2%	-37,858	-40,648
Grapes	-1,806	-0.1%	-37,105	-38,911
Lettuce, Head	-28,339	-4.2%	-27,221	-55,560
Lettuce, Leaf	-11,805	-6.3%	-8,841	-20,646
Oranges	-38,974	-4.4%	-4,085	-43,059
Peaches & Nectarines	-3,785	-1.0%	-24,510	-28,295
Strawberries	-17,084	-3.6%	21,218	4,134
Tomatoes, Fresh	-16,856	-7.4%	-7,916	-24,772
Tomatoes, Processed	-4,826	-1.0%	-16,313	-21,139
Walnuts	-8,824	-2.6%	-12,951	-21,775
Total	-245,366	-2.5%	-269,943	-515,309

* Change in thousands of dollars

**Consumer loss due to change in California production.

6. Conclusions and Policy Implications

The challenge in establishing pesticide policy is managing pesticide use to mitigate the harmful effects of pesticides to human health and the environment while maintaining increased agricultural productivity and welfare. The FQPA is based on the realization that some segments of the population are more vulnerable to the effects of pesticides than others. Specifically, the FQPA protects infants and young children who may currently be exposed to unsafe quantities of pesticide residues through stricter tolerances where appropriate. It also attempts to regulate the aggregation of pesticide residues through mandating cumulative risk assessments for pesticides that act through a common method of toxicity.

Organophosphate pesticides are the first priority for reassessment by the EPA under the implementation of the FQPA. This change in regulation of the popular OP pesticides will have effects on producers and consumers. Producers who are currently using pesticides that are banned in the future will be forced to find substitute pest control methods. It seems clear that the impacts of FQPA implementation rest on the effectiveness of these alternative control methods, which economic theory suggests that in many instances will be less effective and more costly. If FQPA results in the cancellation of pesticides that have no close substitute, we expect to see larger effects than if producers had suitable substitutes for the cancelled or restricted pesticides. It is uncertain what the ultimate regulatory scenario will be, but it seems clear that implementation will be broad and in some instances quite drastic. The exact magnitude of the impacts of FQPA will rest on which OP pesticides are more stringently regulated.

We conducted our analysis as though full FQPA implementation resulted in a complete ban of OP pesticides. Clearly, not all uses of OP pesticides will be prohibited, but this simplifying assumption eases the analysis and provides a benchmark to compare the true economic impacts of OP regulation. However, a ban does reflect the general trend of OP use in the field; pests have been exposed to OP pesticides long enough that they are developing resistance. Regardless of FQPA implementation, producers must find and adopt alternative pest control measures; this policy simply accelerates the inevitable.

The OP-free management programs provided by UC specialists suggest that costs will increase but most non-OP pest management strategies can prevent yield losses. Results of the economic analysis suggest that the total value to society of OP use in California is significant at approximately $203 million, but hardly devastating when it is noted that the average California production value of these commodities totals over $10 billion (see Table 2). However, not all groups will share this burden equally. As expected, the losses are greatest in those instances where currently used OP pesticides have no close substitutes. For example, the largest reason for the pronounced losses to broccoli producers in the coastal region is lack of an alternative insecticide to control cabbage maggot. The crops most economically affected by OP cancellation are broccoli, oranges, almonds, and alfalfa, while carrots have the least to lose from a ban since very few OPs are currently being used in production. The total effects on producers of these crops are estimated as ranging from less than 0.01% of total 1999 crop value (carrots) to 3.4% of total 1999 crop value (alfalfa).

When interpreting the economic results calculated in this study, it is important to consider the dynamic nature of policy implementation. Depending on future events, the actual impacts may be higher or lower. For instance, restrictions on currently used chemicals will increase the incentive for chemical companies to develop new pesticides. These new pesticides will be created to meet the needs of producers and will reduce the effects of the policy. Even without new pesticides, these results should be interpreted as reflecting the losses once all producers have learned to effectively implement OP-free programs. In reality, producers will adopt new pest control strategies over time, and impacts may start out significantly higher. Then, as producers learn about new methods, the impacts will lessen and move towards our estimates. For example, the productivity improvements available through computer use have been demonstrated time and time again, but adoption of computers is far less than 100%. In agriculture, the introduction of IPM and drip irrigation technologies were met with much lower than expected adoption levels even though the efficiency advantages of these technologies seem clear. These short-term impacts can be lessened through programs at the state level to educate producers about the alternatives available to them.

The timing of implementation is also important to the overall impact of the policy. The prevailing economic conditions facing crop producers will, in part, determine the severity of impacts from the new policy. It is important to note that net grower income is only a percentage of total revenues; therefore, in some instances the economic impact on grower welfare is greater than what this 0.01% to 3.4% range may suggest. Individual growers who face higher production costs or who are operating with a higher amount of debt can be severely affected by changes in total revenues of just a few percent. A study by the USDA using 1999 data finds that 26.8% of U.S. vegetable businesses and 29.1% of U.S. fruit businesses are considered to be in a nonfavorable financial situation

(USDA). A nonfavorable situation is defined for those firms facing high debt/asset ratios and earning problems. Therefore, over one-quarter of all fruit and vegetable producers may be especially sensitive to any losses in producer profits.

It should be reiterated here that the cancellation of OP insecticides may or may not reduce the overall use of chemical pesticides. As was discussed in section 4, there are many factors that influence pesticide use, and the removal of one type of chemical may open the door for increased use of an alternative. Thus, the implications on overall toxicity may be ambiguous. In addition, it is not clear how FQPA implementation will affect IPM adoption. OP pesticides play an important role in many IPM programs and, without them, producers will need to find suitable alternatives.

The economic impact of losing a pesticide is a function of the availability of suitable alternatives. Given this fact, it is important to remember that the value of OP insecticides was calculated here assuming the availability of all existing alternatives. If FQPA cancels the use of current alternatives to OP pesticides, the economic losses will be higher than our estimate. However, Roosen and Hennessy find that the impacts of a ban of only azinphos-methyl on apple production are much less than a ban of all OP pesticides. This means that since an across-the-board ban is not likely, the impacts may be significantly less than those predicted here.

These results provide an ex ante order of magnitude estimate of the welfare effects on California from a complete ban on OP pesticides. Future research should be conducted in order to compare our predicted impacts with the true welfare effects. The actual impacts will depend on which pesticides are restricted or canceled, which alternative pest control strategies producers adopt, and when these strategies are adopted. For instance, the carbamate class of pesticides is also due for reevaluation by the EPA, and this could affect which alternatives are available to producers. Special attention should be paid to those pest control strategies adopted that are not currently available and those created by chemical companies as a response to the policy. Future study should also concentrate on the timing of the actual adoption of alternative control methods, including pesticides that are not even available yet.

In conclusion, the FQPA is a new form of pesticide regulation and will impact the pest control strategies available to producers. This will result in welfare effects to both consumers and producers by affecting the market equilibrium price and quantity. Our study estimates nearly $200 million total welfare loss driven by a cancellation of all OP pesticides. It will raise production costs for producers, and in some cases cause reductions in yield. This will manifest itself in the market through higher prices and lower quantities purchased. It will have an impact, but will not devastate California agriculture. It will also create opportunities for pesticide manufacturers to introduce new pesticides to ease the transition. Furthermore, programs to educate producers about the alternative pest control strategies available to them will lessen the impact.

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