A Review of Economic Models Used to Assess the Impact of Canceling Pesticide Registrations

(A Search for Chicken Little)

by

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EXECUTIVE SUMMARY

Pesticides have contributed significantly to food production world-wide. Yet in the past ten years, severe restrictions have been placed on their use in United States. Indeed, some pesticides have been removed entirely from the market. Injuries to agricultural workers and to the environment have been the main factors stimulating this new governmental intervention.

Cancellation of a pesticide's registration impacts many different groups. Producers, consumers and manufacturers can be direct or indirect losers and gainers, while agricultural workers and the ecosystem have been direct beneficiaries.

Although there are alternatives to registration cancellation, all of them may impose increased costs or administrative restrictions. The effects of third party pesticide illness or injury are reflected as additional costs that reduce the net income of agricultural producers who apply a pesticide which causes injury to innocent parties.

Transaction costs, the cost of searching for information, bargaining and contract enforcement are very high in the case of pesticide injury compensation. This reflects the fact that pesticides are public goods once they have been applied. The costs of their adverse impacts on the environment, consumers or workers are usually borne by the public at large as opposed to chemical manufacturers or agricultural producers.

Existing economic models that describe the costs of canceling the registration of a particular pesticide can be divided into two groups. A model utilizing a partial budget analysis provides only limited information to policy makers. This is because such a model measures only changes in a commodity price that result from imputed reductions in market supply which are, in turn, attributed to decreases in product supply that result from eliminating use of a pesticide. The partial budget model ignores possible adjustments of supply and demand which could be made by both producers and consumers as both supplies and prices of farm commodities change with cancellation.

Partial equilibrium models provide some of this missing information but may overstate the impact of cancellation by not fully taking into account information about the impact of crop alternatives for growers and alternative substitute foods for consumers. For example, consumers may readily substitute a less expensive product when they perceive that the price of a preferred product has become too high, thus limiting price increases induced by crop shortages.

Several studies conducted on behalf of the California Environmental Protection Agency (Cal-EPA) have relied on these same economic models to determine the imputed impacts of cancellation of other important agricultural chemicals, such as methyl bromide. Thus, the same incomplete economic models continue to be relied upon to inform policy decisions.

A sector equilibrium model is suggested to more adequately deal with the above deficiencies. However, this model should also take into account the distortions caused by the simplifying assumptions underlying less comprehensive models. This would include tendencies of price to vary less than otherwise assumed due to market structure (size concentration among producers, or oligopoly), economies of scale, interdependence of producing regions, vertical integration and coordination and the coarseness of publicly available data.

The predictions of published economic models in the context of cancellation of a specific pesticide are examined in detail in this paper. It is our purpose to carefully examine both the predictions of the economic models in this specific case and, as well, to analyze the general validity of the models.

Ethyl parathion was canceled in late 1991 and, at that time, reports were published describing imputed crop yield losses, increases in producer costs and others economic effects that were predicted to result from the removal of this chemical from the marketplace. Adequate information is now available to examine the validity of these predictions.

A review of the economic models used in the cancellation decision for ethyl parathion in California resulted in the following findings:

- Total annual parathion use in California was decreasing slightly before cancellation.

- An ex post analysis of statewide acreage, yields and production of almonds, plums and prunes found there was no significant difference in these variables before and after cancellation.

- In reviewing the lettuce study conducted for U.S. EPA, statistically we found, using field level data, no difference between yields before and after cancellation even though a 25 percent yield decrease was predicted for 50 percent of lettuce acreage along the Central Coast of California in the EPA study.

- California Department of Pesticide Regulation published reports significantly overstate, by some 64%, the actual acreage of lettuce treated with ethyl parathion in 1990. However, the total amount of the chemical applied to lettuce in 1990 appears to be accurate.

- Subjective estimates of yield losses, even by experts, are not an adequate substitute for empirical data based on rigorous field tests.

- A literature review found a wide range of demand and supply elasticities for lettuce, both on an annual and a seasonal basis. This response of price to changes in supply is important because the amount of the increase of lettuce price when the supply is reduced has a strong influence on who would gain and who would lose due to a cancellation.

- The greater the number of production alternatives available to agricultural producers, the lesser the loss in farm income due to a cancellation. The greater the number of close food substitutes, the lesser the loss in consumer welfare.

- California agricultural workers apparently incurred a lower pesticide acute illness rate per 1,000 applications after 1986, when stringent controls were placed on the use of parathion. This suggests that administrative regulations were relatively effective.

- Ignoring the pesticide illnesses that go unreported will bias any pesticide policy towards the status quo.

- Valuing worker illness and environmental damage and including these injuries within a sector equilibrium model would directly show changes in their welfare status (full social accounting), and reduce the bias towards the status quo found in less comprehensive models.

- Accuracy and credibility of assessment models can be improved by taking advantage of the rapidly decreasing cost of computations, thus utilizing finer data to better simulate real world behavior.

Overall, this review finds that published economic models used in assessing the impacts of the cancellation of ethyl parathion tended to significantly overstate adverse impacts agricultural producers and consumers. They also completely ignore adverse negative impacts on agricultural workers and the environment. It is suggested that improvements in the models are needed before they can be regarded as reliable information in the public policy decision-making process.

Table of Contents

List of Tables

List of Figures

A REVIEW OF ECONOMIC MODELS USED TO ASSESS THE IMPACT OF CANCELING PESTICIDE REGISTRATIONS
(A Search for Chicken Little)

CHARLES V. MOORE[1] AND DON VILLAREJO[2]

INTRODUCTION

In the past fifty years, pesticides have become an important input to the agricultural production process. Worldwide agriculture is a multi-billion dollar industry. There is little question that pesticides have contributed to the long-term upward trend in agricultural crop yields which has, at the very least, postponed the specter of widespread malnutrition and famine predicted by Reverend Thomas Malthus.

The success of pesticide use raises two important questions: One, why, if this agricultural input is so productive (Headly (1968) and Archibald (1984) found a return per dollar invested in pesticides ranging from $2.50 to $4.00), does it need to be so closely regulated? Keep in mind that pesticides as an input to the production process do not increase yields as would fertilizer and water but rather pesticides protect yields generated by the other inputs. Pesticides go through a long and increasingly expensive process of registration and use reporting (Sarhan et al. (1976)); and two, on what basis would the regulating agency decide to cancel or modify a registration? **An evaluation of the economic models used as one source of information in this reevaluation process is the objective of this report.**

The first section of this report addresses the question of why pesticides use requires any regulation at all. This analysis will include defining the major groups who benefit and/or incur injury from pesticide use. Second, the economic models used to assess the impact of pesticide cancellation are outlined. Third, a brief overview of the relevant portions of welfare economics is presented. After this review, an idealized economic impact model is posited including critical variables and a discussion of the model's explicit and implicit underlying assumptions. Finally, a case study of the economic effects of the cancellation of ethyl parathion use in California is discussed followed by an examination of the policy implications of both the review and the case study.

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Why Pesticides Need Regulation

Technical externalities are defined in the literature as the impact on third parties of the activities conducted by someone else. Pesticides pass through a market chain from manufacturer to the grower and sometimes to the food consumer. Because they can cause injury or death - although unintended - to one or more groups, they produce negative technical externalities. Unlike most pollutants which are a by-product of a manufacturing process, pesticides are an input to a production process. Pesticide externalities usually occur at the time the pesticide is applied. As a result, pesticide injuries generally occur to farm field workers, applicators and wildlife in the area. Persistent (long-lived) pesticides may leave a residue which can be become widely distributed in the environment and in the food chain. This can cause additional injury to a broader segment of the human and wildlife population over extended periods of time.

Pesticides thus take on some characteristics of a public good. Portions of the pesticide become attached to non-target organisms and may cause injury to humans and other species in the environment. Once it enters the biosphere, the pesticide is no longer a private property where access can be limited; rather, it becomes a collectively consumed public property, albeit one with a negative value. To reduce or to minimize the negative attributes of pesticides in the environment and thus protect the public from these "negative public goods", state and federal agencies have been directed by the various legislatures to develop standards for the use of these toxic chemicals.

Pesticide regulation is not new; quality standards and other precautions were legislated early in this century to protect both buyers and users of Paris green and cyanide. Pesticide regulation both at the state and federal level became intense following the advent of the highly toxic organophosphate-based pesticides and the concomitant increase in human injuries and deaths attributed to their use. Due to the large number of pesticides available on the market and the government agencies' limited resources, the regulatory focus was placed on restricting the more toxic chemicals. These restrictions limited pesticide application to specified pests on specified crops and required that only trained, certified applicators using approved equipment could apply these products. For some of these pesticides, this reduced the number of injuries and deaths but not to a socially acceptable level. Thus, pesticide regulatory agencies (Biological and Economic Assessment of Ethyl Parathion, ARS, PDQI, PAL (Sept. 12, 1989)) were forced to reevaluate their registration procedures and look at the contribution of an individual pesticide and compare this with the benefits and costs to all of society not just its efficacy and efficiency in controlling target pests.

Economic theory asserts that a market is not efficient unless all costs and benefits "to whomsoever they may accrue" are reflected in the costs incurred by the user of any commodity. That is, efficiency criteria requires the cost of all externalities (injuries) to be reflected back to the pesticide user. To internalize or calculate these externalities, policy makers must take into account the market and non-market effects on injured parties

Decision making in Government agencies is not always perfect, i.e., there can be government failure as well. With respect to injurious chemicals, agencies have at times restricted the use of substances which were in fact benign and have released chemicals which turned out under more careful examination to be quite detrimental. For example, the chemical DBCP inadvertently was given a clean bill of health but was later found to cause sterility in human males, a fact that was evidently known or suspected all along (NIOSH, 1978).

including the costs of operating the institutions implementing the policy (EPA).

Distributional impacts of pesticide use are not uniform; some groups are beneficiaries and some are negatively impacted. The first group of direct beneficiaries is the pesticide manufacturers who have invested significant amounts of capital in developing, testing and marketing the pesticide. In the long run, their expectations are to receive at least a market rate of return on their investment. The second group of direct beneficiaries is the growers who have a derived demand for a pesticide which is based on the productivity of the pesticide in ensuring the protection of the marketability (volume and aesthetics) of the crop. The higher the value of the crop, the more willing the grower is to invest in additional pesticide application. This risk avoidance behavior may explain in part the tendency of growers to overuse pesticides and their reluctance to adopt Integrated Pest Management (IPM) (see Carlson (1970)). A subset of the direct beneficiaries is the absentee landlord whose rental income is dependent on the productivity and profitability of the crops grown on rented land.

The final and largest group of direct beneficiaries are the consumers. They purchase the treated commodity and, due to increased productivity in the farming sector, benefit from continuously decreasing farm level food costs when measured in constant dollars. Geographically, this group can be divided into a domestic and a foreign market.

Indirect beneficiaries are difficult to specify and it is even harder to measure the level of their benefits. Most secondary benefits are in the form of employment, first, in the agricultural area for harvesting labor and second, labor for packing, processing, transport and marketing a volume of a commodity greater than would be produced in the absence of pesticides. On the other hand, expanded herbicide use has reduced field labor demand for certain tasks (weeding).

Negatively impacted groups (pesticide receptors) are smaller and also difficult to find in order to measure the level of costs incurred. Farm workers, due to their presence in the field after pesticide applications to either cultivate or harvest a crop, have the highest potential for injury. Although medical doctors are required to report cases of illness they believe to have been related to pesticide exposure, there is evidence of significant under-reporting of chronic illnesses caused by persistent pesticide exposure. In addition, there is a strong aversion among farm workers to visit an official or governmental agency, since the fraction of undocumented field workers in California agriculture may be as high as 40 percent in certain localities. As a result of these factors, it is likely that injuries associated with pesticide exposure are grossly under-reported.

Chemical firm workers and commercial pesticide applicators are a second group of receptors. While monthly tests of cholinesterase levels are required for chemical firm production workers and pesticide applicators, these tests are not mandatory for field workers or packing house workers.

The first level of reporting of pesticide injuries is the "Doctors First Report of Pesticide Injury" and is mandatory in California. However, this law is not always strictly enforced and, even so, subacute pesticide poisoning due to prolonged low-level exposure, (chronic) seldom requires a visit to a doctor's office or a hospital (Howitt, 1975).

Using parathion injuries in California as an example, Table 1, shows that the major groups at risk are farm workers exposed to pesticide drift and residues, and people employed in pesticide application. The makeup of pesticide injuries reported by doctors has changed over recent years. For example, two-thirds of the 28 Doctors First Reports of Injury by Parathion in 1985 were classified as definitely due to parathion. In 1986, the total number of reported injuries dropped to 24 in California but interestingly, 70 percent of these were classified as only possibly due to parathion. Other than 1988 when only 12 total injuries were reported, total annual injuries were fairly constant until 1991, the final year before cancellation, when only six cases were reported and all but one of these was classified as only possibly due to parathion. A well-researched estimate of the currently unreported pesticide illnesses must be made if sound pesticide policy is to be developed.

Governmental agencies at times work at cross purposes due to their agency's legislated mandates. For example, while there is one group of agencies whose objective is setting a minimum health and safety standard for certain occupational categories, such as farm workers, there is another group of agencies whose major objective is to locate and deport undocumented workers. Thus, in the area of public health where immunization and treatment for communicable diseases benefits the entire population, the fear of making contact with any government agency by undocumented workers and their families increases the risk to all families.

The second major receptor of pesticide externalities is the ecosystem. Damage to the environment by pesticides was greatly reduced but far from eliminated after the cancellation of DDT and other derivatives of chlorinated hydrocarbons. These chemicals, which tended to be persistent, were found extensively throughout the food chain. While the current generation of organophosphates are not as persistent, a large number of bird kills have been reported after grain fields were sprayed (ARS, et. al (1989) and California Department of Fish and Game (1995)). Because damages to the ecosystem and the food

Table 1

Doctors First Reports, Ethyl Parathion Injury, California, 1985-91

Activity	1985			1986			1987			1988		
	Def.	Prob.	Poss.	Def.	Prob.	Poss.	Def.	Prob.	Poss.	Def.	Prob.	Poss.
Mixer/Loader	2	0	0	1	3	1	0	1	0	0	1	5
Applicator	3	4	2	2	0	0	0	0	4	0	0	3
Coincidental Exp.	9	0	1	0	0	4	3	2	9	0	0	1
Field Residue	5	0	0	1	0	0	0	2	0	0	1	0
Occupational	0	1	0	0	0	12	0	0	0	0	0	1
Flagger	0	1	0	0	0	0	0	0	0	0	0	0
Sub-total	19	6	3	4	3	17	3	5	13	0	2	10

Activity	1989			1990			1991		
	Def.	Prob.	Poss.	Def.	Prob.	Poss.	Def.	Prob.	Poss.
Mixer/Loader	0	0	2	1	1	2	0	0	0
Applicator	3	1	4	1	0	7	0	0	3
Coincidental Exp.	1	0	2	0	4	2	1	0	3
Field Residue	0	0	8	0	0	1	0	0	1
Occupational	0	1	0	0	0	0	0	0	0
Flagger	0	0	0	0	2	0	0	0	0
Sub-total	4	2	16	2	7	12	1	0	7
Grand Total							67	46	96

Source: State of California, Department of Pesticide Regulation, Worker Health and Safety Branch; agency classification key is Def.=Definite, Prob.=Probable, Poss.=Possible.

chain do not pass through a market place, it is difficult to place a financial cost on their loss, although there are some tools available which have been used to value non-market goods (see Contingent Valuation, Mitchell and Carson (1989)). This technique has been used most extensively in the area of environmental quality. The willingness of some consumers to pay a premium for certified organic foods gives analysts an indication that a portion of the population place a positive value on pesticide-free commodities.

The indirect impact of pesticide externalities on society comes in the form of distortions in the relative prices of resources and consumer commodities. That is, if a significant cost is not recognized in the net income of the firms producing third-party injuries, resources in excess of that which is socially optimal will be allocated to that firm. In other words, due to the failure of the market to send a price signal which internalizes the externality, a socially unacceptable level of injuries will occur. In addition, an excess of the pesticide will be applied and the commodity on which it is applied will therefore be produced in excess relative to other commodities which could have been produced using those same resources.

Price distortions or less than optimal resource allocations set up a major conflict in a democratic society. On one hand, producers currently using the pesticide in question and consumers who purchase the output of these producers have strong incentives to maintain the status quo. On the other hand, producers who do not benefit from the use of the target pesticide would gain if their competitors were denied the pesticide, while applicators, farm workers and environmentalists who no longer would be injured, all want the pesticide to be banned. Thus, two political coalitions are created, each with opposing objectives.

Alternatives to Pesticide Cancellation

Most industrialized countries have a policy of attaching liability to any hazardous material by making the user of a pesticide liable for any damages caused by its use. The U. S. Government and the State of California have several alternatives from which to choose to internalize third-party costs. (1) The government may require employers to have Workers Compensation Insurance to cover medical costs of any worker taken ill from exposure to pesticides, such as in California. Insurance premiums will, in turn, reflect the probability of injury and the associated medical bills – assuming the rating system and the market are accurate and efficient. However, Workers Compensation Insurance may not adequately address the problem. This issue was clearly demonstrated in a 1973 survey of farm workers in two California counties where 69.8 percent of the 1,416 workers interviewed reported they "had never heard of workman's compensation" and only 7.9 percent answered the question correctly (Howitt, 1975). (2) As noted earlier, governmental agencies may restrict the crops on which a particular pesticide can be used. (3) The California or the U.S. Environmental Protection Agency may place restrictions on the dosage and timing of pesticide applications with respect to workers entering the field or harvesting (re-entry and pre-harvest intervals). (4) The use of protective clothing and safety equipment may be required. (5) the regulating body may require certain pesticides to be applied only by trained and licensed applicators.

Twenty years ago several questions were raised regarding administratively set policy with respect to the internalization of pesticide injuries among farm workers (Howitt (1975)). It is pertinent to raise those same questions today in order to gauge the success of pesticide policy. First, "Standards and enforcement are not without cost to the agricultural industry and consumers. What are these costs?". Second, "Currently, farm workers are eligible to claim medical costs from occupational injury through Workers Compensation Insurance. Does the Workers Compensation insurance adequately internalize the costs of pesticide injuries to the workers?". Third, "What are the costs of pesticide injuries to the workers?". Finally, "Are the current legislated standards adequate? Is enforcement of the standards effective?" Following a further examination of the development of pesticide policy, we will reexamine these questions.

Economics of Pesticide Policy

There is a rich literature describing the economics of internalizing externalities. In its simplest form its logic is as follows. First, if the receptors of pesticide externalities (injury) were given clear property rights to a clean, safe work environment, a market between pesticide users and pesticide receptors could be created; and through bargaining, an economically optimal level of externalities could be determined. This approach runs into difficulty because oftentimes the costs of operating this market in property rights to a clean work environment are very high. Economists call these transactions costs.

Transactions costs can be grouped into three categories: First, the cost of searching for and collecting information about the actual level of and cost of injury to the receptor on the one side, both in medical costs and lost income; and the level of benefits to the pesticide user in being allowed to use the pesticide on the other. We know that the higher the desired degree of precision we have for these estimates of benefits and costs, the higher will be the cost of searching for and collecting this information. If one party, due to information uncertainty or high cost, believes they can not be made better off by trading in this market, then the market will fail to operate.

Bargaining costs are the second group included under the broad term transactions costs. In our hypothetical market for the rights to a clean environment, the total cost of bargaining between the two sides increases as the precision of the information gathered in the first step decreases. That is, precise information equally distributed between the two parties should allow them to quickly consummate a bargain. However, if the information has a high variability (parties are not highly confident in the estimates), or if only one party has all of the information, no bargain will be struck. The market will fail to operate.

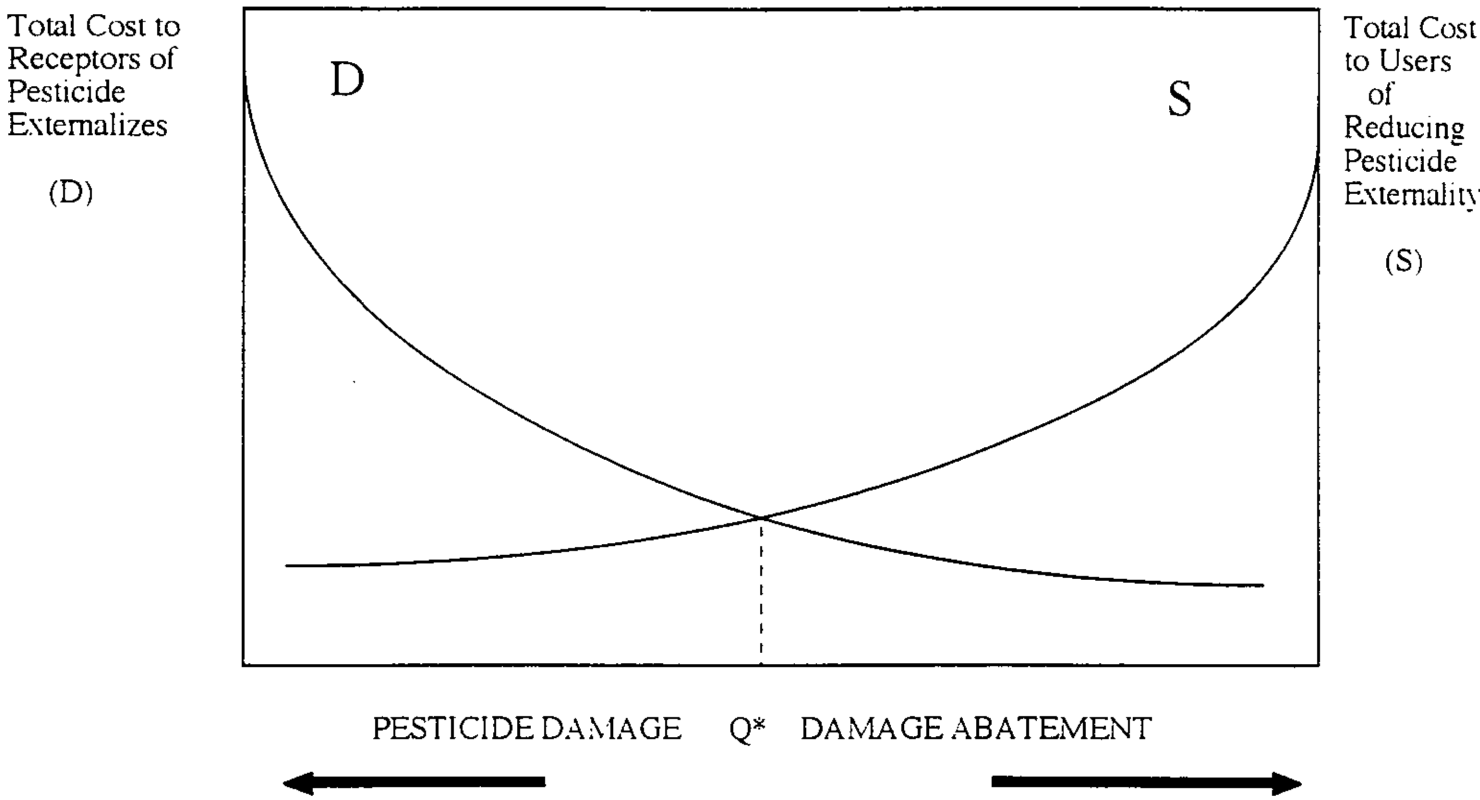
The third category of transactions costs is monitoring and enforcement costs. Property rights have no value if there is no way to protect and enforce those rights. For a market to operate, there must be a third party to monitor and enforce the terms of the bargain.

Where economic regulation is applied to commodity markets, monitoring and enforcement are easily carried out by observing the process and the quantities passing through the markets. However, the market for externalities, by definition, has no prices; thus we can only monitor the quantities of pesticides used and the injuries and damages reported.

Figure 1

OPTIMUM PESTICIDE USE UNDER BARGAINING

(NO TRANSACTIONS COSTS)



Ideally, as suggested by Coase (1960), if we had sufficient information about the injury and benefit function from pesticides, we could draw the graph shown in Figure 1. This graph shows that as the level of pesticide abatement increases — moving from left to right on curve D — receptors' (workers and the environment) injuries will decrease, whereas the total cost to pesticide users of reducing these damages (including pest control benefits foregone and enforcement costs) increases — moving from left to right on curve S. Because these two curves intersect, it would be possible through bargaining (assuming no transactions cost and a uniform distribution of information), to reach an optimum level of pesticide use given these trade-offs between the users' benefits and the receptors' costs. Clearly defined and perfected property rights to a clean environment would confer significantly greater bargaining power to those groups who are now unwilling receptors of these third-party damages.

The major impediment to this approach is the magnitude of the transactions costs mentioned above. If the level of transactions costs, (information searching, bargaining and enforcement) exceed the level of benefits to the receptors, the market will fail to operate and no externalities will be internalized. If the market fails because information is very "fuzzy" -- that is, it has a high variance -- the only recourse is to apply administrative regulations and standards such as requiring *workers compensation insurance*, and all of the health and safety standards already discussed. However, the economic optimum bargaining outcome will depend on the initial allocation or distribution of property rights.

Economists (Pegou (1960) and Randall (1981)) have suggested that the same optimum level of externalities damages and benefits foregone can be achieved by assessing a tax directly on the pesticide at the point of sale. By sufficiently increasing the cost of the pesticide to the user, pesticide use could be reduced to a point just equal to the optimum level (market solution) described in Figure 1. From a practical sense it has been found that the demand for pesticides is so insensitive to changes in their market price that a tax, like that suggested by Pegou, would have to be extremely high to achieve the goal of reducing pesticide use to the optimum level (McIntosh and Williams (1992) estimated a price elasticity of demand for pesticides of -0.112, implying a 100 percent increase in pesticide prices would only reduce pesticide use 11 percent). Therefore, the pesticide tax solution is probably is not a fruitful path or policy to take.

Brief Overview of Welfare Economics

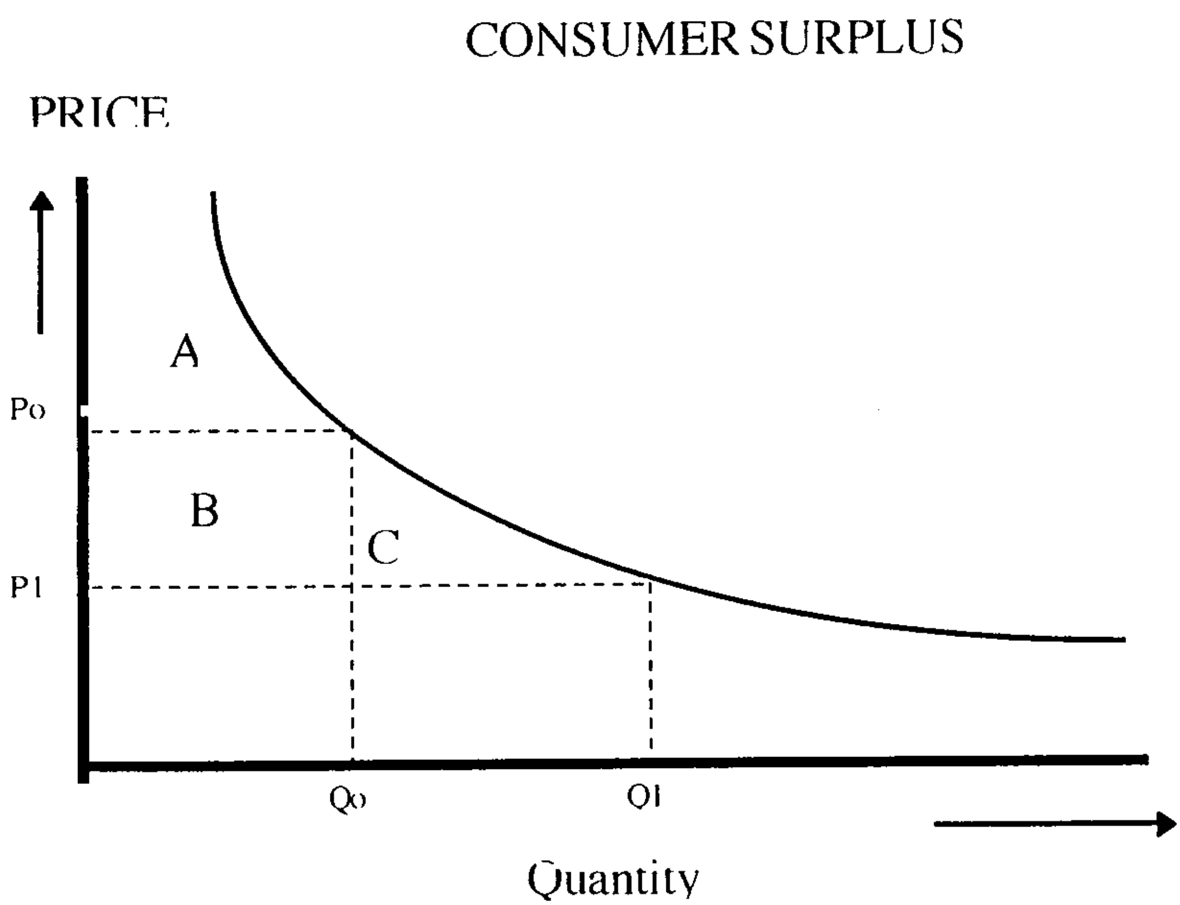
Economists have developed tools not only to measure economic efficiency but also to measure the change in the distribution of benefits and costs to assist policy makers. While economists are comfortable in discussing maximizing economic efficiency, they are generally reluctant to make recommendations where there are significant changes in the welfare of different groups of participants. Economists find it impossible to state that a dollar of benefit accruing to one group or individual is more highly valued than that same dollar going to another group. In policy analysis, economists usually stop after presenting the distributional changes due to a policy change leaving the value judgments to legislatures and other elected representatives — this is especially true when policy changes may cause an increase in injury and mortality rates.

When measuring "improvements" or changes in the well-being of groups, it is important to specify the starting point. In the case of pesticide policy there is a debate as to which is the "correct" starting point, the group's welfare prior to the introduction of pesticides or that point in time when pesticides are already in use and a change in policy which would cancel the registration of that pesticide is being analyzed. Bromley (1994) has succinctly presented the case where, if there are significant third-party externalities present, the base line for measuring changes should be that one generated by an efficient market where the total social cost of the pesticide is reflected in the costs of the user. That is, the starting point should be the state and distribution of benefits and costs after all externalities have been internalized as well as possible.

If one group has use of an input where a portion of the costs are carried by third parties (externalities), then the policy analysis will tend to be biased toward maintenance of the status quo. By using, as a starting point for policy analysis, a situation where externalities are not internalized, policy makers will necessarily develop pesticide policy which distorts relative prices, encourages excess production of commodities using the pesticide as an input and fosters unacceptable levels of injuries and damages.

Lichtenberg et al (1988) describe two major requirements of an economic policy assessment model. First, it must provide estimates of the efficiency impacts as measured by changes in the social surplus and second, it must provide estimates of the distributional impacts of the policy. Because both producers and consumers are distributed over space and other parameters, they must be grouped into homogeneous units and the impact of the policy assessed for each group.

FIGURE 2



The social surplus is the total benefit to society enjoyed by both producers and consumers. This can be subdivided into **producer surplus** and **consumer surplus.** In its simplest terms, producer surplus is the producer's (grower's) net return over and above their variable costs. Consumer surplus is usually defined as the area under the demand curve and above the price line in a supply/demand diagram and is a measure of consumer satisfaction or willingness to pay (Just, Schmitz and Hueth (1982)). In Figure 2, if the price at the farm gate increases from price P_1 to P_0 due to a reduced supply, i.e., from quantity Q_1 to Q_0 there will be decrease in consumer surplus shown as areas A + B + C to only area A; thus the reduction is equal to areas B+ C. That is, if the loss of the use of a pesticide caused a reduction in the market supply of the agricultural commodity, producer surplus would increase and consumer surplus would decrease and vice versa. Our economic system through efficient markets attempts to maximize the sum of the two. **It is important to note that most models use only costs and prices of goods and services which pass through a market. Costs of third-party injury or damages that have not been internalized are ignored.**

Economic Impact Models

The objective of an economic analysis is to estimate the impact on both producers and consumers of the results of a reduction in use of a pesticide or its outright cancellation. Economists attempt to simulate the commodity market by first calculating the change in the yield per acre and/or cost of production per acre and then estimating the change in consumer and producer surplus.

The economic impact models reviewed here fell into two broad categories: (1) partial budgets, and (2) partial equilibrium models. Within this latter category there were models that estimated only short-term impacts and those that also estimated longer-term impacts.

Partial budget models are typified by the American Farm Bureau Research Foundation funded study, "Economic Impacts of Reduced Pesticide Use on Fruits and Vegetables" conducted by a group of economists at College Station, Texas (see Knutson et al., (1994)). This study examined the impact of two levels of pesticide use reduction, 50 percent and 100 percent, for four pesticide groups, including herbicides, fungicides and insecticides. Crop budgets were developed for each scenario and horticulturists in each producing area were asked to estimate yield reductions for each combination.

Results indicated very large yield reductions, up to 78 percent under the zero pesticide use scenario and up to 48 percent under the 50 percent pesticide use scenario with commensurate increases in the average cost per unit of production. Due to different micro-climates and indigenous insects, the geographic impact varied significantly. By ignoring the ability of either producers or consumers to make any market adjustment to changing production conditions, the partial budget model presents the "worst-case scenario".

Partial equilibrium impact models can be described as computer simulation models that focus on the supply and demand parameters of a single commodity, although desegregated into multiple producing regions and seasonal consumption characteristics. Some models separate consumption into domestic demand and export demand. Since all producers in all regions may not use the pesticide being analyzed, growers are grouped separately to measure the impact on both users and non-users.

Partial equilibrium models are superior to the partial budget approach due to the more realistic market responses and information provided to policy makers. These models estimate changes in the total supply of the commodity, in prices and in producer and consumer surplus by homogeneous groups. Thus, the requirement that the model assess efficiency as well as distribution impacts is met at least under *ceteris paribus* conditions. Lichtenberg et al. (1988) point out the major deficiency in the partial budget model vs. the partial equilibrium model is that partial budgets fail to show the distributional impacts and efficiency changes of alternative policies. Models showing only short-run impacts tend to produce greater changes in producer and consumer surplus because of the sensitivity of prices to small changes in supply is relatively high (relatively inelastic) in the short run. That is, a small percentage decrease in supply, due to the loss of use of a pesticide, can create a large increase in the commodity market price which, in turn, increases net incomes for growers not affected by cancellation and a commensurate decrease in consumer surplus.

Lichtenberg, Parker and Zilberman (1988) have described a good example of this type of model. The researchers investigated the impact of the cancellation of ethyl parathion on tree crops. The short-term nature of the demand elasticity estimates were appropriate because the perennial crops analyzed -- almonds, plums and prunes -- have long development periods ranging from 5 to 7 years and their acreage and production can not be increased quickly. However, imputed values of short-run elasticities are based on assumptions about carryover inventory levels and their management that may not match real world behavior, in essence they are ignored.

Price elasticity is related to the slope of the demand curve, i.e., the percent change in quantity purchased divided by the corresponding percent change in price. In simpler terms, a steeply sloping demand curve (elasticity "e" near zero) indicates consumers will change their buying habits only very little in the face of increasing market prices. Thus, if supplies in the market are reduced due to a pesticide policy, prices will increase and total consumer expenditures can also increase. Depending on the amount of yield decrease and the elasticity (steepness) of the supply curve, some or all producers may actually benefit financially from the cancellation. See Table 3 for different estimates of supply and demand elasticities.

Growers of short production cycle crops such as fresh vegetables can make allowances for within-year changes in planted acres in response to market conditions. For example, broccoli requires just 90 days from planting to harvest in California's Central Coastal counties during the summer season. In these cases the partial equilibrium model should utilize long-run price elasticities of both supply and demand which are more responsive (elastic) than short-run estimates. More elastic supply and demand elasticities will result in less volatile changes in producer and consumer surplus. (For a good example of the use of long-run elasticity, see the study by Lichtenberg, Parker and Zilberman (1987) conducted for the U. S. Environmental Protection Agency of the impact of canceling parathion registration for lettuce.)

The U.S. fresh vegetable industry is without doubt the most dynamic and fast-changing industry in the agricultural sector. To supply the wants, tastes and preferences of millions of consumers for fresh, cosmetically attractive but highly perishable food on a daily basis requires planning and coordination efforts far beyond any other industry. Fresh vegetable production depends on micro-climates which change with the seasons. For example, lettuce production starts each calendar year in Florida and the southern desert areas of Arizona and California. The time from planting to harvest depends on temperature, moisture and day length (increasing or decreasing). Forward planning across climatic zones is crucial for a continuous flow of product to the market throughout the course of the entire year. Due to the very high risks involved and high capital requirements, the industry has tended to become more and more concentrated.

A variation of the short-run partial equilibrium model is used by the USDA in its Biological and Economic Assessment of Ethyl Parathion (ARS, PQDI, PAL, 1989). In this economic model, short-run price elasticity coefficients were used on the demand side but no supply response function was specified. Yield changes were used to represent shifts in an implied supply curve. No adjustment was allowed in acreage planted in response to price increases.

All models where cancellation of a pesticide engendered a loss in yield required input from biologists. Information on yield changes due to the loss or a reduction in the use of pesticides was elicited from biologists, horticulturists and entomologists. In some cases a single expert's opinion was used whereas, in the two national analyses, panels of experts were used to provide data for each state or region. These data were then aggregated for the entire country. In almost no case was the biological input based on formal field tests which could be statistically tested and verified. Although yields vary widely from year to year and from location to location, the final point estimate became an average of averages with no information on the variability of those estimates.

An Idealized Impact Model

Before any impact study is undertaken it is necessary to ask, "Are we asking the right question?" If this is a study in welfare economics, whose welfare should be measured? It would appear that all of the studies reviewed here ignored the one group that has the most at stake in this policy decision — those receptors who are currently being damaged or injured by the presence of certain restricted pesticides now being reviewed for possible cancellation. Externalities imposed on farm workers, pesticide applicator employees and the environment are the raison d'être for reviewing the re-registration or canceling the registration of a pesticide. When Lichtenberg et al. (1988) stated that estimates of the distribution effects must be provided, they could have added "including non-market externalities" (see also Antle and Wagnet (1995)).

George and King (1971, p. 2), in their classic study of consumer demand for food commodities in the United States, introduce their report by stating, "The effect of a change in the price of one commodity will influence the consumption of all commodities in the consumer's choice relationship" and by implication would influence planting decisions within the decision set of every producer. Therefore, an additional requirement, one that takes into account the interrelationships between close substitutes both on the demand side and the supply side should be added to the list proposed by Lichtenberg et al. (1988). Classifying this proposed idealized model as a Sector Equilibrium Model which solves for both supply and demand (endogenous) would characterize the scope of the model.

Variables to be Included in the Model

Demand elasticities, that is the measure of the sensitivity of consumers to changes in a commodity's price are basic to estimating impacts involving changes in the cost of production or a yield reduction due to the cancellation of a pesticide registration. For annual crops such as fresh vegetables, there are many close substitutes. For example, as a replacement for iceberg lettuce, consumers may substitute leaf lettuce, fresh spinach, fresh broccoli, cabbages of all varieties and the chard family as well. The more substitutes available to the consumer, the more sensitive purchases will be (elastic) to changes in prices. Thus excluding the additional information on the relation of prices of substitutes (cross-elasticity), gives an inaccurate picture to the policy maker of the equilibrium price obtained by the grower. In the case of a significant yield reduction due to a cancellation, prices and therefore acreage and production of substitutes will also increase, dampening the direct effect on the target commodity.

Some of the models reviewed separated out a price elasticity of demand for domestic consumption and another for exports. Because of USDA programs for export enhancement (dumping) and promotion of agricultural products in recent decades, it would appear that reported export market prices may not reflect an equilibrium price. It would also be rather unlikely that elasticities were equal in both markets.

Supply elasticities measure the growers response to a change in the farm gate price of a commodity. The higher the farm price, the greater effort the grower will put into increasing production. This effort can manifest itself in many forms. First, additional acres of land can be planted; second, inputs such as labor, fertilizer and water can be increased. Surprisingly, in the case of fresh vegetables such as lettuce, the higher the price on a given day, the greater the yield per acre. If there is a relative scarcity of lettuce in the market, growers will return to a given field two and three times to capture the maximum total production and income. Data from individual fields in the Salinas Valley of California indicate a positive correlation of about 0.4 over a season between price and yield per acre, which is significant at the 95 percent level. This relationship presents a problem when economic models use planted acres as a measure of production response. In such a case the growers response may be over-estimated and therefore loss in producer surplus may also be over-estimated. Woo (1983) included an adjustment factor for this phenomena in her simulation model of the California lettuce industry.

Supply elasticities in the case of perennial crops that produce a storable commodity such as almonds, prunes, raisins, walnuts and pecans, must take into account carryover inventories when the simulation model predicts a price into the future using short-run elasticities upon which growers will base future plantings. Since many such crops operate under USDA marketing orders, which allow for reserve pools, simulation of short-term price response may over-estimate price increases and therefore the loss of consumer surplus.

Income elasticity measures the change in consumption of a commodity or food groups as consumer income increases. A positive income elasticity indicates increased consumption of a commodity as income increases, beef for example. It can also be interpreted as the increase in consumption as between neighborhoods as one moves from low household-income communities to high household-income communities. If policy makers are interested in changes in the diet of different income groups due to their policy, inclusion of an income elasticity variable in the model would provide very useful additional information.

Underlying Assumptions

Both explicit and implicit major assumptions underlying economic models are reviewed here. These assumptions can effect the final results produced by the model and are therefore important not only in the design of the ideal model but in the interpretation of the results as well.

Because it is frequently impossible to include all of the variables needed in a "real world" analysis, economists use economic simulation models to examine the implications of policy alternatives. To make the problem tractable, economists make certain simplifying assumptions. The first assumption has to do with the **structure of the industry**. Partial and general equilibrium models such as discussed in this paper usually assume a perfectly competitive market structure from the farm gate to the consumer even though analysts are aware that in many cases this does not hold true for some of the specialty crops. For example, the *1992 Progressive Grocer Handbook* reported the top five retail chains grossed over $78 billion, which represents more than 54 percent of the sales of all chain stores in the U.S. In addition, the top five grocery wholesalers reported sales of $38 billion, which was 57 percent of the total in this category. This oligopolistic structure of the industry suggests that basing a model on the assumptions of pure competition may bias the results. George and King (1971) point out that demand elasticities at the farm level are quite different from those at the retail or wholesale level, see Table 3.

As indicated earlier, the level of producer concentration is also increasing. For example, in California, we find that only 72 producers filed reports of treatment of their lettuce with parathion to the California Department of Pesticide Regulation in 1990. Since there were 699 California lettuce producers enumerated in the 1987 Census of Agriculture and 768 enumerated in 1992, a relatively small share of lettuce growers reported using parathion in 1990.

As a countervailing power to increasing concentration of the wholesale and retail grocery sectors, a few firms, through direct ownership or contract, have come to dominate or strongly influence the California/Arizona Lettuce industry. The California Institute for Rural Studies found the nine largest lettuce gower/shippers in California and Arizona control about 40 percent of the market. Clevenger and Shelby, in their 1970 study, found evidence of but no conclusive proof that extraordinary market power was present in the U.S. lettuce market.

Analysts will have difficulty modeling fresh vegetable markets which contain elements of monopoly power. That is, markets with few buyers and/or few sellers and with one firm large enough to influence price (economists call this oligopsony) the resulting producer and consumer surplus would change depending on where in the market chain the bargaining power was located. In general, if market power is exerted, the entities with that power would reduce the quantity handled and increase or decrease the price (selling price or purchase price) to maximize profits. If the market power is at the grower/shipper level, producer surplus would be greater than under perfect competition. If the market power resides at the wholesale or retail level, both producer and consumer surplus would be reduced. If market power on one side of a sale created a countervailing response of concentration on the opposite side of the market such as a large marketing cooperative, the end result would probably be indeterminate and difficult to model.

Vertical integration

Economic theory assumes the industry supply curve is the sum of individual firm incremental cost curves above the average cost curve. When firms in an industry are vertically integrated (ownership of more than one stage of production such as growing, packing, cooling and selling), this assumption may simulate a cost curve that does not exist due to internal firm transfer pricing and very thin markets (very few transactions). It is not clear the direction toward which this may bias the final results.

Model validation

When analysts wish to model a major change or shock such as the cancellation of an important and widely used pesticide like ethyl parathion, there is no good way to validate the model. That is, it is difficult to model an industry's behavior in some earlier time period and then turn around and assume that the industry will continue to behave in the same manner except for a major decrease in per acre yields or a significant increase in costs. Economists generally assume that the loss of a major input causes a shift in the entire supply curve for that commodity. Use of a sector equilibrium model would improve this distinction.

Assumptions concerning the **independence of producing** regions may lead to an incorrect interpretation of results. When defining affected producer groups, analysts implicitly assume that seasonal production patterns are fixed. That is, winter fresh vegetables can only be grown in certain micro-climates and are the same for the same vegetables grown for the spring market, summer market and fall market. Within limits, the crossover date between production areas is flexible. If one seasonal producing area is impacted by the cancellation of a pesticide and the subsequent producing area is not because the pest is not present, the crossover date will shift in favor of the region having a competitive cost advantage, thus dampening the negative affect on consumers. Producer surplus will still decrease in the area affected by the cancellation, but will increase even more so in the area with the competitive advantage. Measuring the change in crossover dates will require components of a spatial equilibrium model.

Monoculture

Implicit also in the models reviewed was the assumption that growers in different seasonal regions grow only one crop, the one requiring the pesticide that was being canceled, thus the choice of a partial equilibrium model. However, in the Western vegetable industry, monocrop growers are rare. Within the largest 25 growers, only 4 specialized in a single vegetable, 3 in potatoes and 1 in carrots (*American Vegetable Grower, 1994*). Of the top twenty vegetable growers in California, the same source reported an average of five different vegetable crops per grower. Many of these vegetables were close substitutes such as different types of lettuce, broccoli, spinach and greens. Thus, if one crop was negatively affected by a pesticide cancellation, the acreage in close substitutes could easily be expanded with little or no negative impact on producer surplus.

The *American Vegetable Grower* also provides information about the decision-making linkage between seasonal producing areas suggesting that these different regions may not be completely independent. The *American Vegetable Grower* reported that a majority of growers operate in more than one growing districts (seasonal zones). For example, among the top twenty California growers, three grew only in one district, six grow in two districts, seven grow in three districts and four grow in four or more districts. Producing in multiple districts allows growers to sell in the market every week of the year and possibly every market day of the year. This time and space diversification allows the grower to spread price and production risks, not unlike dollar cost averaging in the stock market. Further, these same growers will have advance knowledge concerning expected yields in each district where they operate and can shift their crossover dates accordingly to maximize net returns over the entire year. These are multiple-plant firms which are either vertically coordinated or vertically integrated through contracts with a centralized management.

Information

Finally, at least in California, there are entities called "Information Cooperatives" where membership is limited to producers who join together to share market information on a daily basis. There is one cooperative centered on the lettuce industry, one centered on the melon industry and one centered on the fresh tree fruit industry. As the name implies, these are voluntary organizations that share information on prices, volumes shipped and market expectations. The existence of the cooperative suggests that the level of coordination is greater than in the economist's abstract mathematical models which are based on the assumption of many buyers and many sellers each making decisions and price discovery independently.

Producers who obtain price and volume information from government sources receive data which is much "coarser". *Market News Service* provides only ranges of Free On Board (FOB) prices each day based on telephone calls to shippers and no information of the volume of sales at each price. These data, unweighted by volume, are not as useful as that provided by the information cooperative to their members. Some respondents to USDA's market news queries also may not reveal the true price received. The two information channels may in fact have different levels of noise or degrees of precision. The only channel available (published USDA price ranges) to the economic model builder is the one with the greatest level of noise.

Ethyl Parathion in California - An Ex Post Review of Two Case Studies

In December 1991, the U.S. Environmental Protection Agency canceled the registration and use of ethyl parathion. In anticipation of this change and to provide information to this decision-making process, Lichtenberg, Parker and Zilberman published two studies, Lichtenberg et al. (1987) (lettuce) and Lichtenberg et al. (1988) (tree crops). The objective of this section is, using the benefit of hindsight, to compare the results or predictions made in these two studies with what appears to have actually happened in the hope that by highlighting the disparities, future analysis of this type of problem will be improved.

Parathion was first registered in the United States in 1948. In May of 1986, the EPA first took formal notice of parathion's high toxicity to farm workers and wildlife. Although the total number of parathion injuries reported in Doctors First Report of Pesticide Injury in California decreased only slightly in 1987, the remaining years until cancellation can be characterized as having reduced the hazard significantly. That is, most injuries were classified in the 'possible' category as opposed to the high proportion of illnesses classified as 'definite' in the early years. See Table 1.

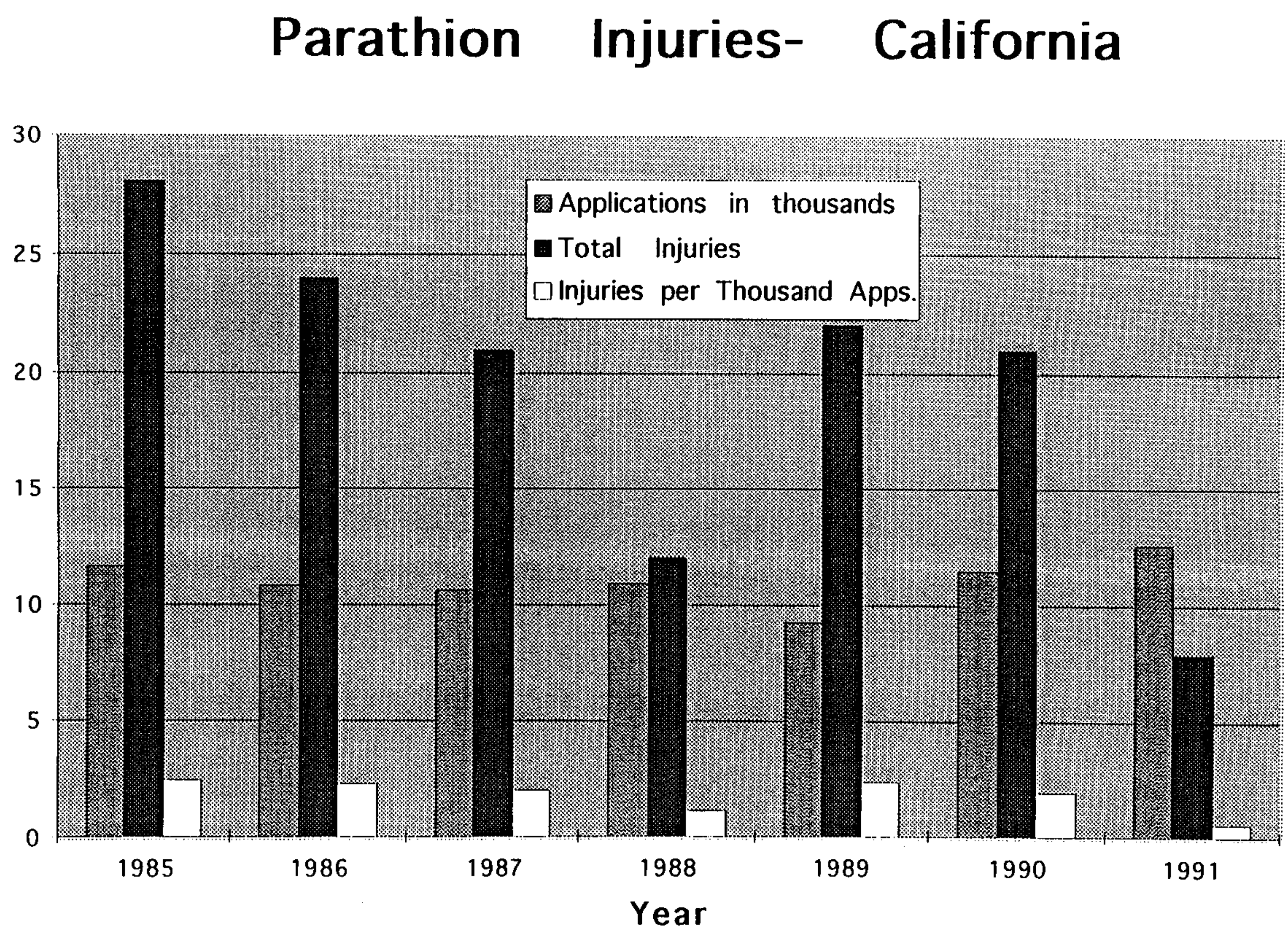
Using all reported injuries, the injury rate per 1,000 applications was calculated, (see Figure 3 and Appendix Table 1). Injury rates exceeding 2.0 per thousand applications were observed in 1985 and 1986. O'Malley 1994, reported the illness rate for parathion in California during the period 1982 to 1990 was about twice the median illness rate for all organophosphate pesticides. The EPA felt the risk to workers was so high that in December of 1986, registration restrictions were published for parathion, limiting its use and requiring certified applicators. Except for 1989, the injury rate per thousand applications dropped substantially until in 1991, the last year before cancellation, when the injury rate was only 0.48 per thousand applications. Clearly, the administrative action of chemical registration was working. All of these changes were made with very scant information on unreported illnesses, chronic or acute.

In September 1991, the EPA and parathion registrants reached an agreement canceling most uses of ethyl parathion. For California, this agreement ended the use of parathion on some economically very important crops, including lettuce, almonds, prunes and plums. It is unlikely that EPA had available the data showing the very low injury rate for 1991.

Figure 4 shows the total reported use of parathion in California from 1980 to 1991. Use in California tends to mirror parathion use in all the U.S. where it had been decreasing steadily since 1980. Figures 5, 6 and 7 show that parathion use on almonds, plums and prunes on the other hand had increased in terms of the number of acres treated per year. Acreage treated increased 115 percent for almonds, 100 percent for plums and 82 percent for prunes over this period. This growth rate is significantly higher than the rate of increase in planted acres of the same crops.

In their study of the impact of cancellation of parathion on three tree crops, Lichtenberg et al. (1988) budgeted the cost of substitute pesticides that were effective on the target pest (scale and curly leaf) and assumed the marginal cost of production increased accordingly but that yields would remain unchanged. Based on their model we would expect yields to remain constant, but growers would expect to adjust their output downward, due to the increased marginal cost and consumers would adjust their purchases

Figure 3



Parathion Injuries- California
30
25
20
15
10
5
0
Applications in thousands
Total Injuries
Injuries per Thousand Apps.
1985
1986
1987
1988
1989
1990
1991
Year

Figure 4

Parathion Use - California
(All Uses)

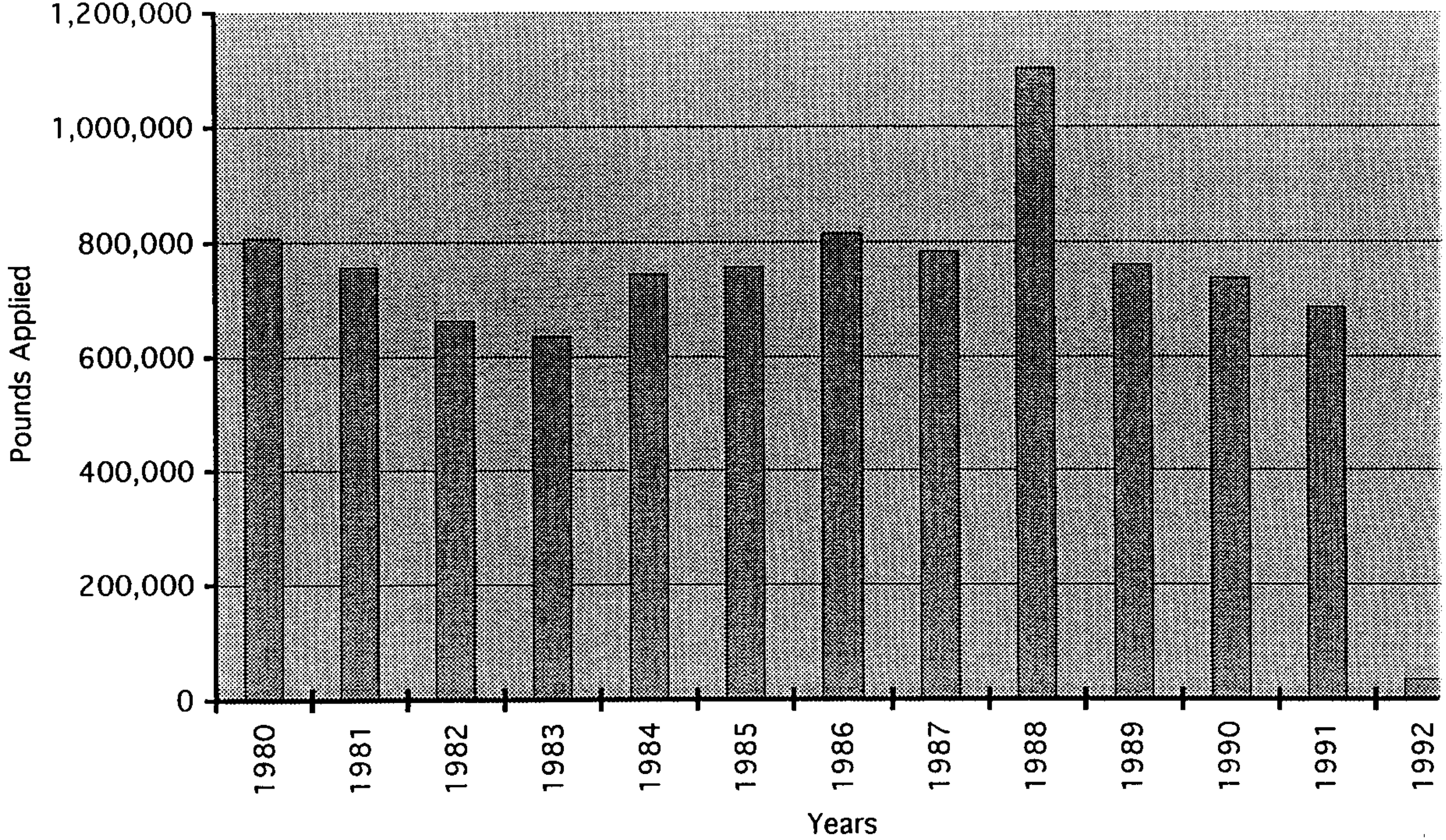


Figure 5

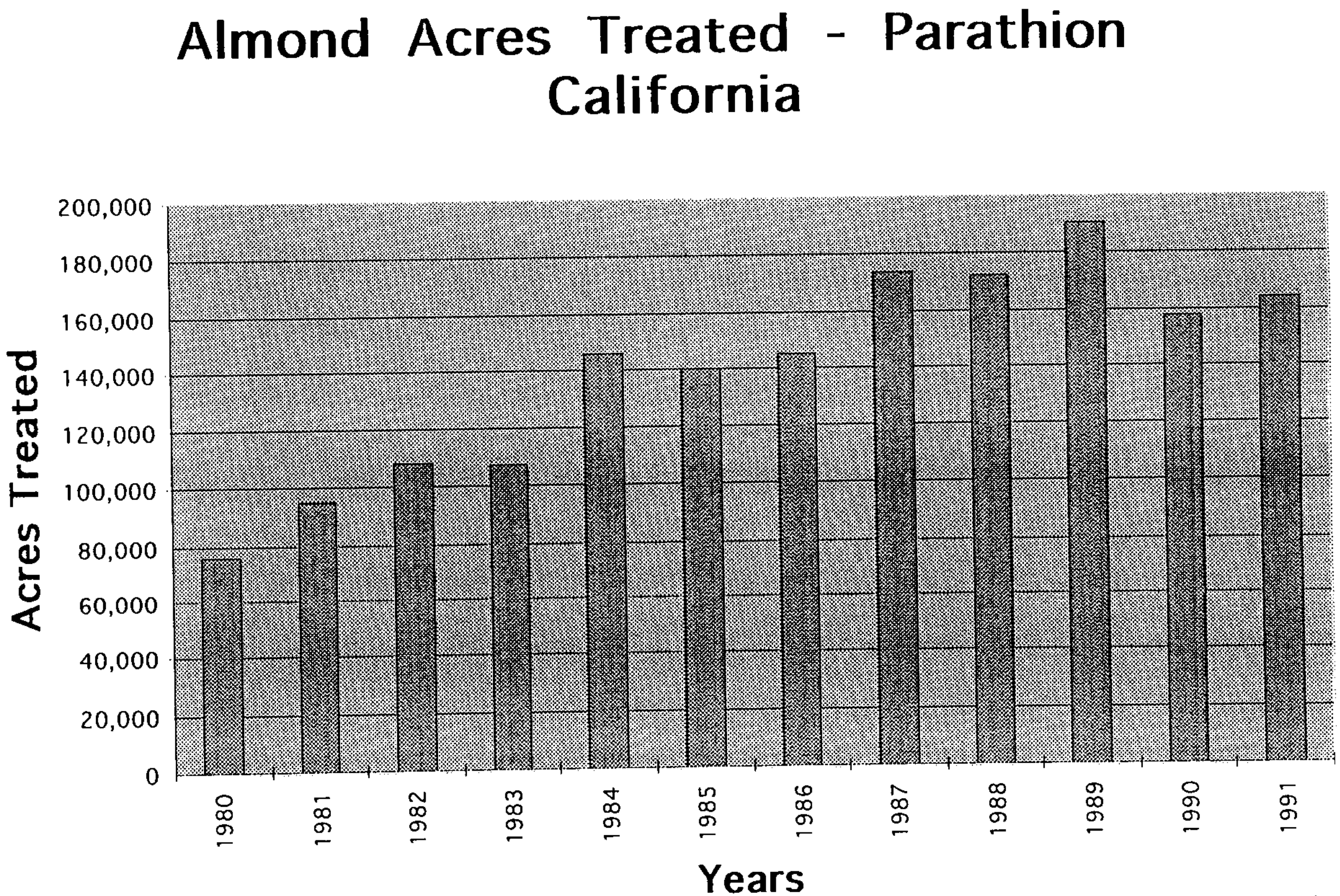

Almond Acres Treated - Parathion
California
Acres Treated
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
Years

Figure 6

Plum Acres Treated - Parathion California

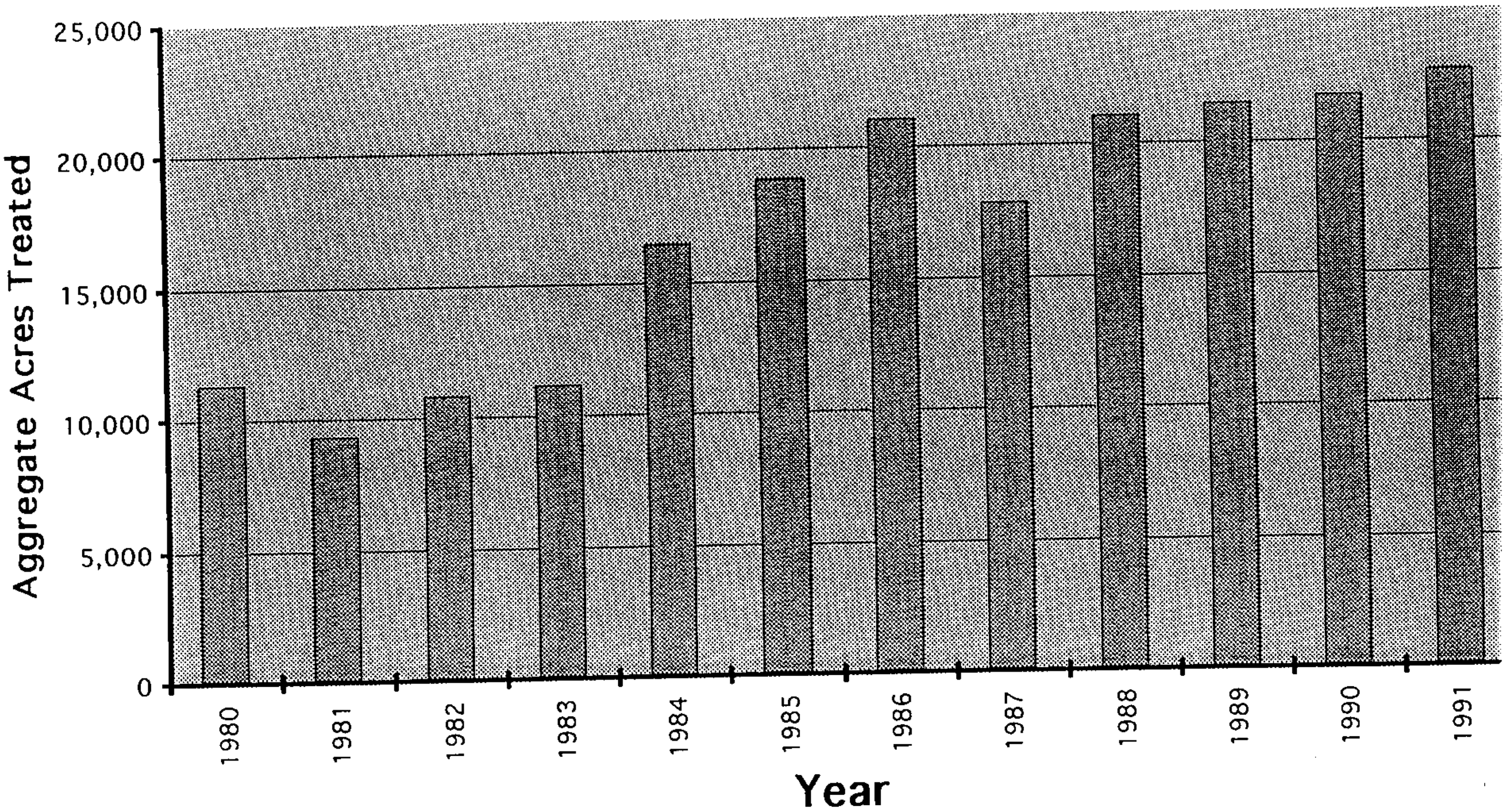


Figure 7

Prune Acres Treated - Parathion California

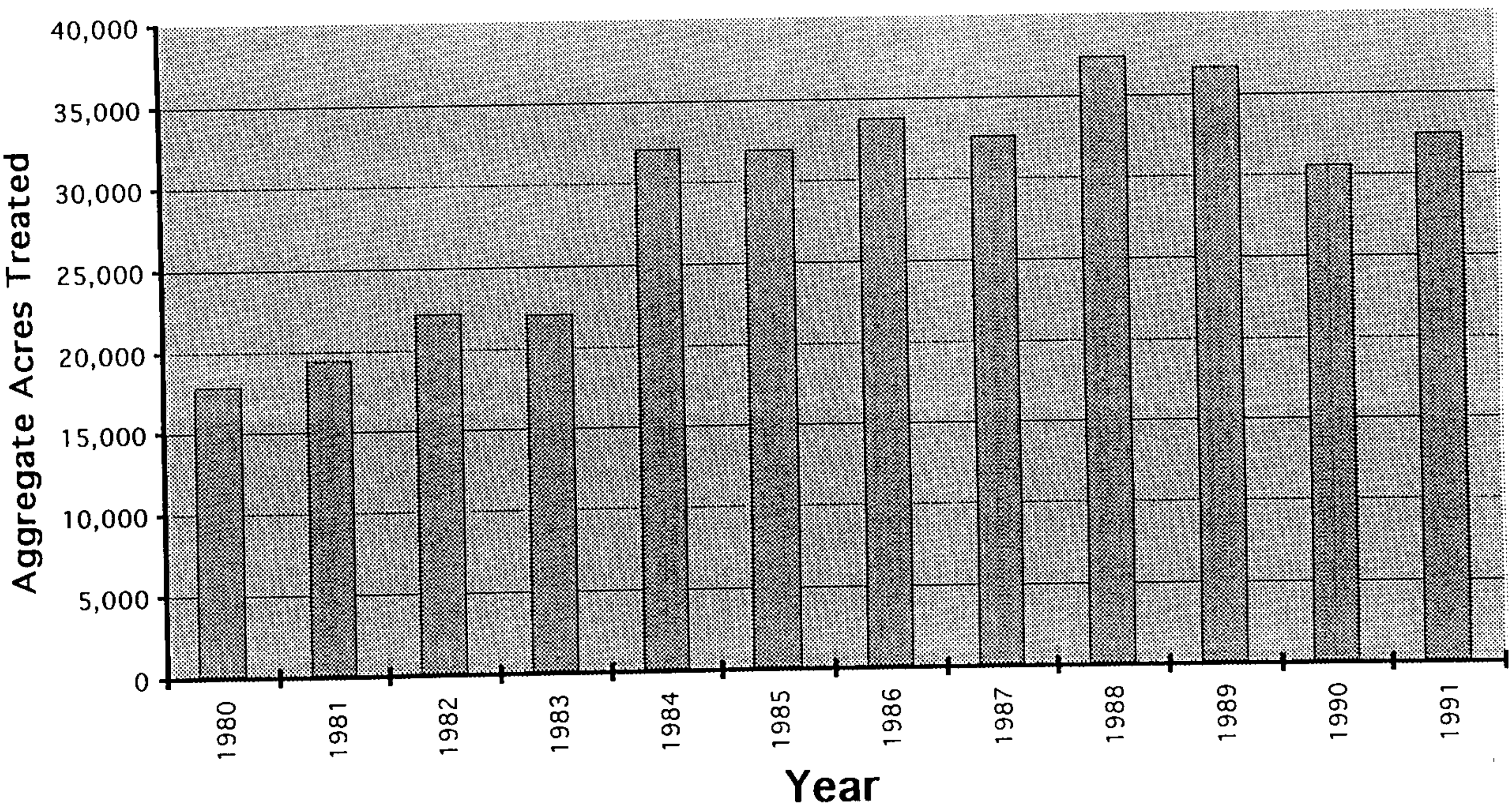


Figure 8

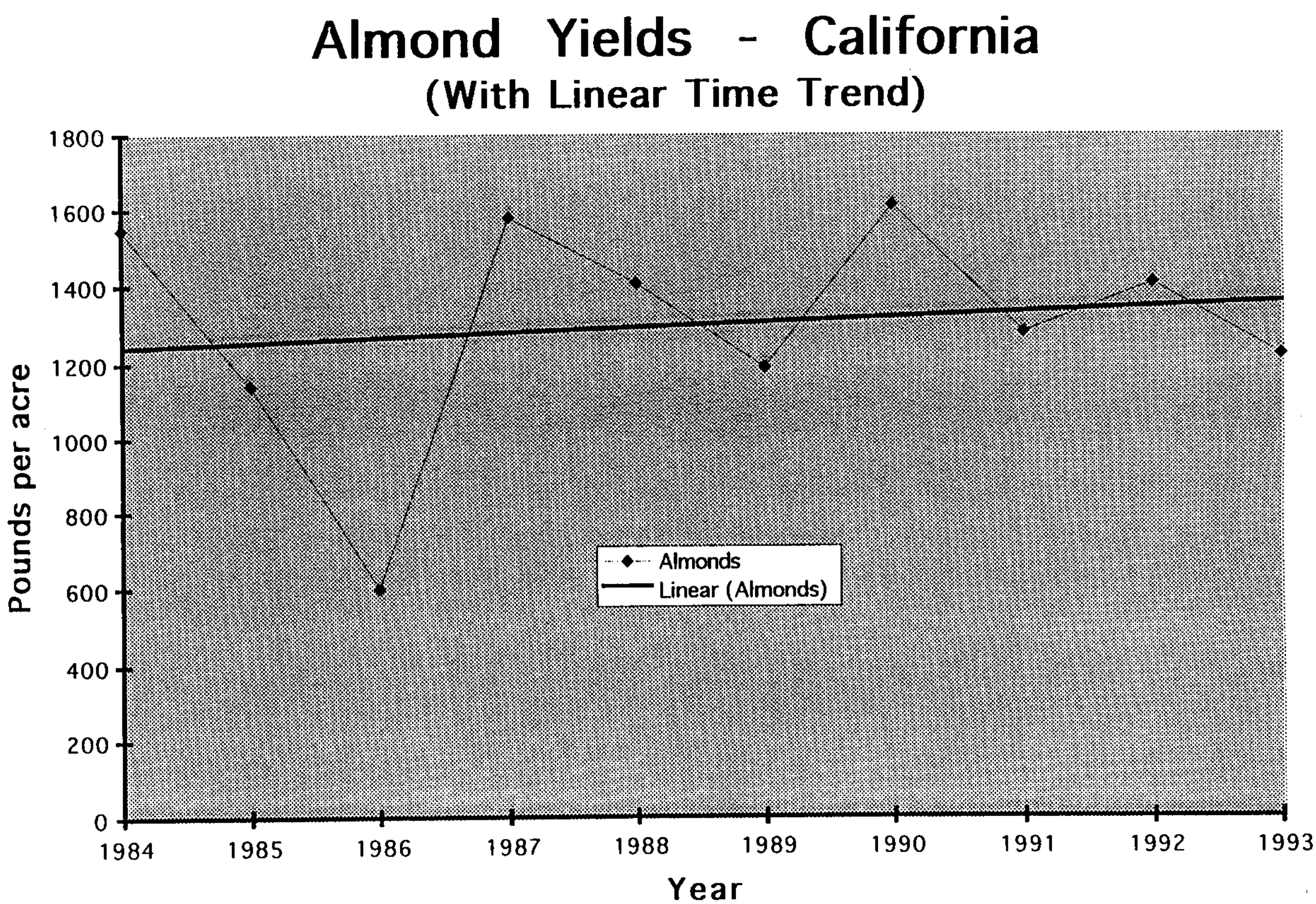

Almond Yields - California
(With Linear Time Trend)
Pounds per acre
1800
1600
1400
1200
1000
800
600
400
200
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
Year
Almonds
Linear (Almonds)

Figure 9

Plum Yields - California
(With Linear Time Trend)

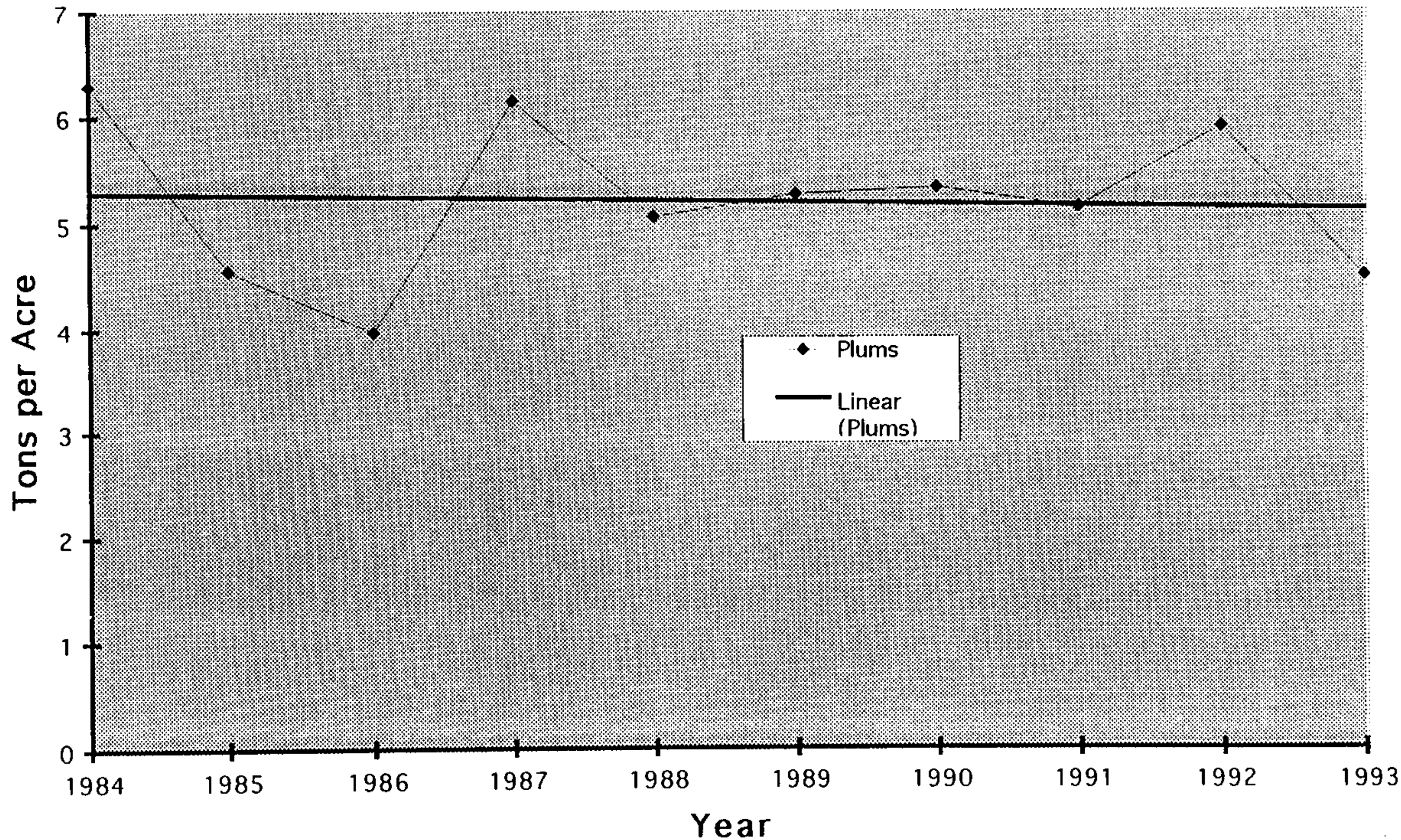
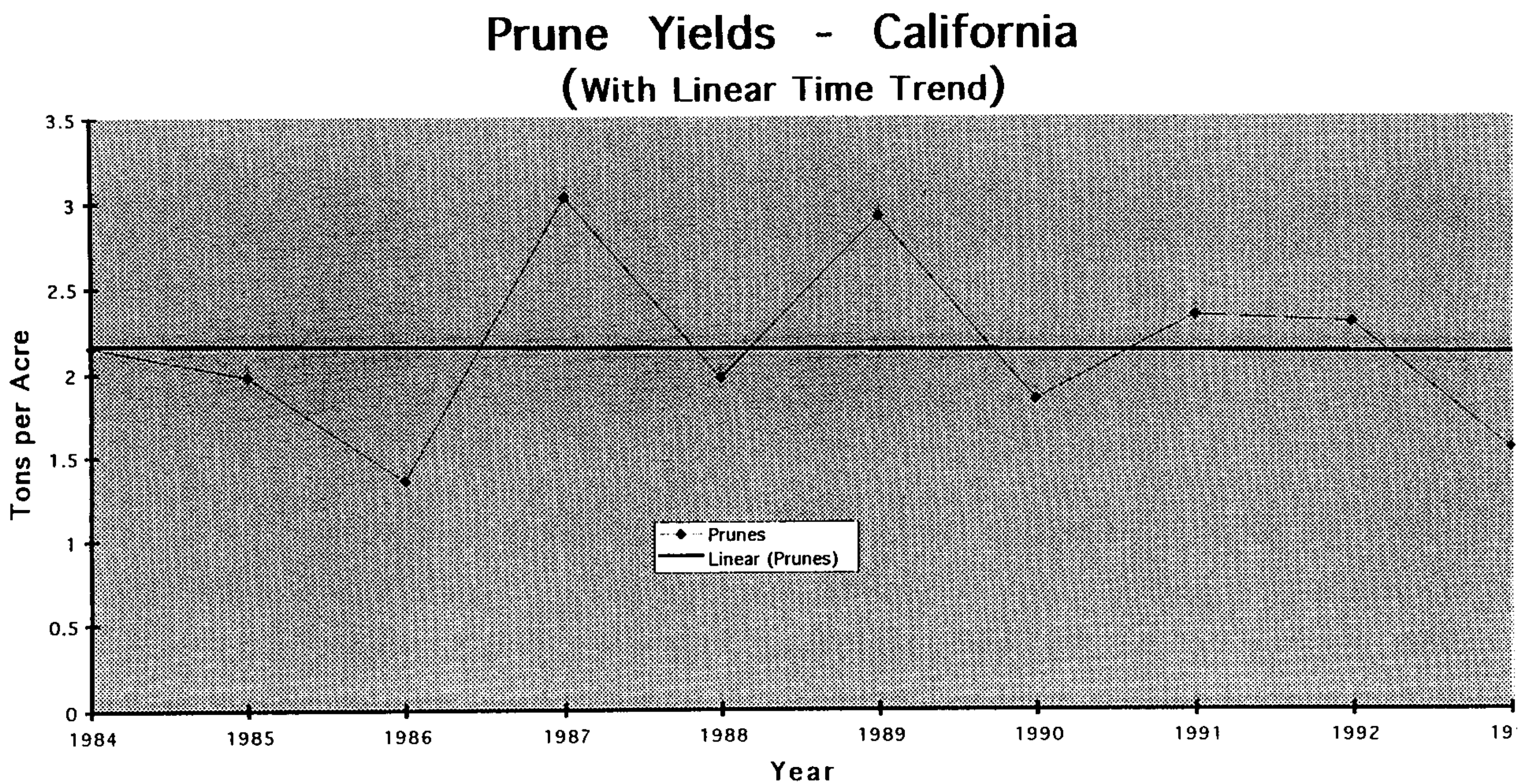


Figure 10



Prune Yields - California
(With Linear Time Trend)
3.5
3
2.5
2
1.5
1
0.5
0
Tons per Acre
Prunes
Linear (Prunes)
1984
1985
1986
1987
1988
1989
1990
1991
1992
19
Year

to the new higher equilibrium market price. The producer surplus would increase for growers who did not previously use parathion and would decrease for those growers that did. Although it was assumed that no yield loss would occur, economic theory asserts that in adjusting to the increased marginal costs, users would decrease output in some manner which for all practical purposes would have to be reflected in a lower yield per tree or a reduction in the number of trees harvested.

Ex post, it is possible to compare changes in yields, bearing acreage and total production between 1991, the last year before cancellation and 1992, the first post-parathion year. In California, for all three crops, almonds, plums and prunes, the bearing acreage **increased** between 1991 and 1992. See Figures 8, 9 and 10 (The time series data for non-bearing acreage was incomplete.) Yields per bearing acre **increased** except for prunes but all yields were greater in 1992 than the 10-year trend line. Statistically, 1992 yields were not significantly different from the yields of the previous 10 years.

Why didn't the growers respond as the impact models had predicted with a decrease in total production (acreage X yield)? There is no one single answer, but one or more of the following scenarios may have occurred: (1) The pests may have built up a tolerance to parathion unnoticed by the growers and the substitute pesticides were relatively more effective than expected, in turn providing better pest control. (2) The cost increases per acre were such a small portion of total variable cost that the budgeted increase became lost in the background noise (high variances in the flow of information to the decision maker) and grower expectations remained unchanged. (3) The form of the production function assumed in the study was mis-specified. (4) The fineness of the data base is not sufficient (not enough detail such as individual farm data) to detect changes that in fact occurred. (5) One year may be too short a time period to respond to the change in costs even though a short run supply elasticity was used in the model. (6) Growers may not behave as "marginal analysts" as assumed in the impact model.

The Lettuce Case Study

In their report to the U.S. Environmental Protection Agency, Lichtenberg et al. (1987) used a partial equilibrium model (very similar to their tree crop model) to analyze the impact of cancellation of parathion on lettuce. The study included all U.S. lettuce growers, but concentrated on California and Arizona producers because this region produces about 92 percent of the nation's supply. Lettuce growing was divided into four distinct seasons which were associated with different geographic/micro-climate areas. These production areas were assumed to operate in an independent manner. The report recognized that market concentration may exist in the lettuce industry but assumed that all markets were perfectly competitive.

To observe the uneven impact of cancellation on different growers, five groups in the Central Coast area of California were defined. Group 1 consisted of lettuce growers in the Central Coast Area using parathion to control insects other than lettuce root aphid who, when parathion was canceled, would shift to a more expensive pesticide but would incur no loss in yield. Group 2 consisted of growers along the Central Coast using parathion to control lettuce root aphid. Loss of parathion was assumed to cause a yield decrease of 25 percent. Group 3 consisted of Central Coast growers using parathion to control other insects as well as lettuce root aphid. These growers would also incur a 25 percent decrease in yields resulting in a marginal cost increase of about 33 percent in every season. Group 4 were Central Coast growers using parathion to treat foliar aphids and leaf miners. These growers were assumed to incur no yield loss but their marginal costs would increase due to the use of more expensive pesticides. Although not recognized in the study, an individual grower would most likely have land in each of the groups so that all of the impact would not fall on just a few growers.

Lettuce growers in other Western producing areas were assumed to also incur increased costs as they substituted other more expensive chemicals for parathion but with no yield loss.

Due to a change in consumer tastes and preferences, California head lettuce growers face new competition from leaf lettuce and romaine lettuce. From 1984 to 1993, according to County Agricultural Commissioner's Annual Crop Reports, Romaine lettuce acreage in California has increased from 6,800 to 16,100 acres, a 2.4 fold increase. Leaf lettuce acreage also increased during the same period from 17,000 acres in 1984 to 35,400 acres in 1993.

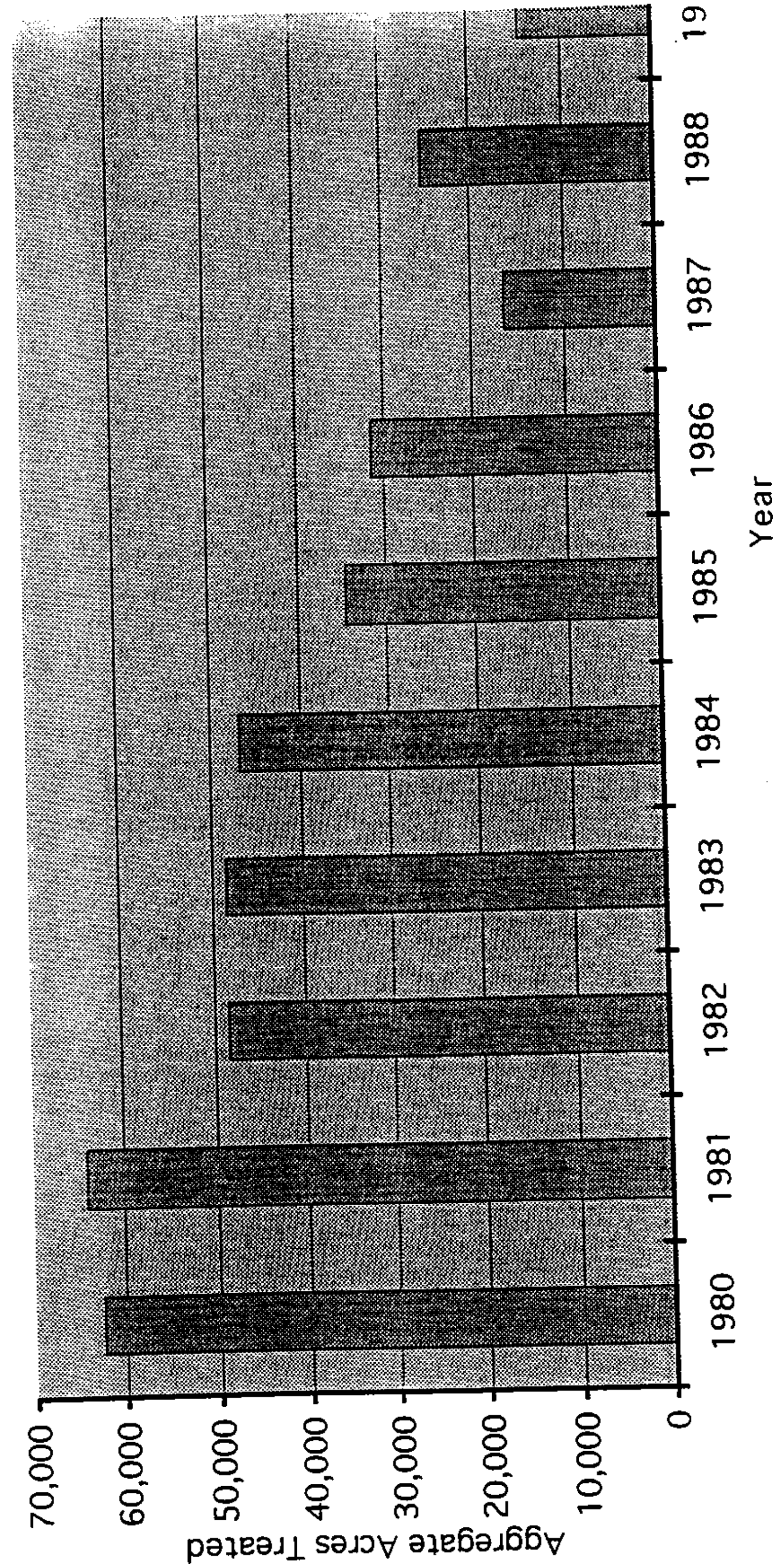
Clearly, the lettuce root aphid is the most injurious pest with which growers must contend, and apparently, it can be controlled only by ethyl parathion. Failure to control it results in an imputed 25 percent loss in yield. The authors, based on the opinion of a single entomologist, estimated that 20,000 acres of lettuce out of the approximately 77,000 acres planted in the Central Coast area were infested with the lettuce root aphid. This area was estimated to produce 89 percent of the nation's lettuce in the summer season. A 25 percent yield loss on the 12,750 acres reported by California DPR as being treated at the time of the study would no doubt have a major impact in the industry. Projecting into the future, the authors estimated that the infested acreage would increase to 50 percent of planted acres due to an expected expansion of the host plant resulting from urbanization, exacerbating the negative economic impact.

At this point, it may be beneficial to look at what has occurred in the lettuce industry in the time since the 1987 study.

1. **Parathion Use** - As shown in Figure 11, parathion use on lettuce statewide continuously declined until 1991 when its registration was canceled. We find, using a county-by-county summary of 1990 parathion use in lettuce reported to the

Figure 11

Lettuce Acres Treated - Parathion California



California Department of Pesticide Regulation (DPR) (see Table 2) that there were 4,541 treated acres in all of the Central Coast counties compared to the 28,500 acres predicted in the study for EPA. Kern County growers, in the San Joaquin Valley, were the largest users of ethyl parathion in 1990 with 5,500 acres treated although almost 50 percent of these acres were treated twice. We find that total lettuce acres treated in California in 1990 was 7,482 acres compared to the 72,800 acres (including Arizona) assumed in the 1978 EPA study, or about 10 per cent of that assumed in the model. Equally important, we find that 40% of DPR's reported 12,292 acres of lettuce treated with parathion in 1990 represents multiple applications to plantings. Thus, DPR reports aggregate treated acreage, including repeated applications, and not the actual land area of lettuce treated.

2. **Yield Loss** - Given the dire prediction of 25 percent yield losses from untreated lettuce root aphid infestations, it is logical that growers would continue to treat this pest with parathion up and until the cancellation went into effect. Private data was made available by one of the largest grower/shippers in the Central Coast area. These data included yield and harvest date for lettuce for several thousand acres of lettuce identified by the Department of Pesticide Regulation site location identification number (field), grown each year between 1985 and 1992. Yields for each field were compared for 1991 and 1992 on eight different ranches. Using analysis of variance, we could not reject the hypotheses that the mean yields of all fields on each ranch were not significantly different at the 95 percent level of confidence. In other words, statistically, the mean yields weren't significantly different between 1991 the last year for parathion use and 1992 the first year after cancellation. On one of the eight ranches, 1992 yields had a higher variance than in 1991.

3. **Yields/Prices** - The Lichtenberg et al. (1987) report used seasonal average prices and seasonal average yields over a five year time period (1981-1985) for their model. As pointed out earlier, there is a positive correlation between FOB prices and yields. Using USDA's *Market News Service* average daily prices for Salinas-Watsonville, matched with the growers' yield for individual fields for the first date harvest commenced, the correlation between price and yield was +0.4, see Figure 12. A linear regression model of the same data set described above provided an estimate of this relationship. The relationship is expressed by the equation, Yield = 603.7 cartons per acre + (FOB price X 18.9 cartons) and was significant at the 95 percent confidence level. In other words, beginning at base level of 603.7 cartons per acre, on average the yield per acre of lettuce will increase about 19 cartons per acre for each $1.00 increase in the FOB price. It appears logical that this relation should be included in an impact model when total production is expected to decrease and prices increase. Ignoring this behavior causes the model to underestimate yield and thus overestimate the acreage needed to achieve a market equilibrium.

Table 2

Summary of 1990 Pesticide Use Reports
Ethyl Parathion in Head Lettuce

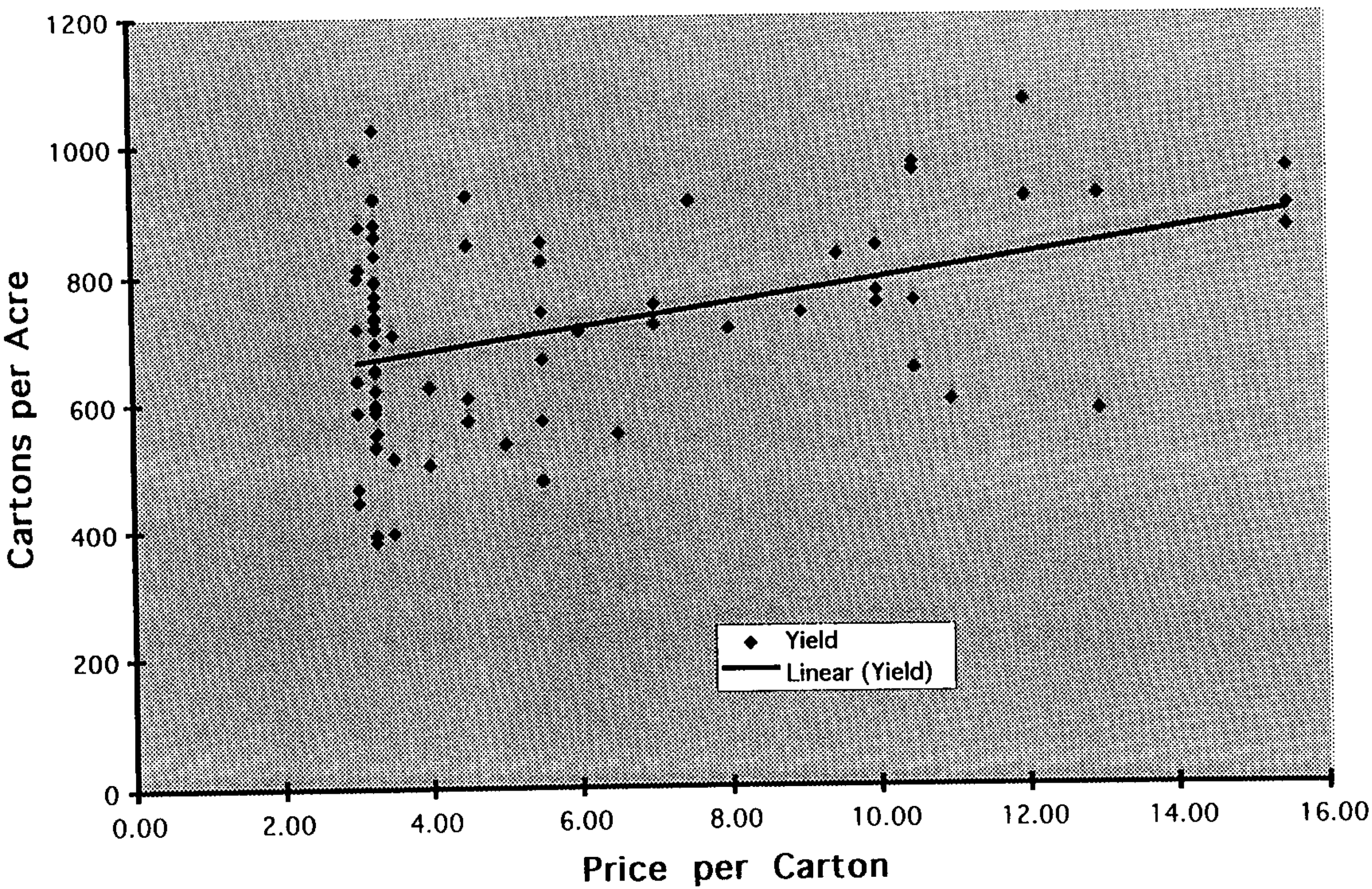
County	Applications	Land Area Treated	Aggregate Acres Treated
Imperial (DPR)	12	N.S.	391.3
Imperial (CIRS)	12	320.3	391.3
Kern (DPR)	128	N.S.	5,500
Kern (CIRS)	128	2,166	5,500
Monterey (DPR)	238	N.S.	3,583.7
Monterey (CIRS)	238	2,928.1	3,583.6
Riverside (DPR)	78	N.S.	1,859
Riverside (CIRS)	78	1,334.5	1,859
San Benito (DPR)	60	N.S.	866.3
San Benito (CIRS)	60	640.3	866.3
Santa Clara (DPR)	5	N.S.	65.5
Santa Clara (CIRS)	5	65.5	65.5
Santa Cruz (DPR)	1	N.S.	26.9
Santa Cruz (CIRS)	1	26.9	26.9
All Counties (DPR)	522	N.S.	12,292.2
All Counties (CIRS)	522	7,481.6	12,292.6

N.S. = Not stated

Source: Department of Pesticide Regulation, State of California, "1990 Pesticide Use Report, Summary by County and Chemical," Unpublished Report prepared for CIRS; CIRS Analysis of Individual Pesticide Use Reports from Raw Data Tape provided by DPR.

Figure 12

Lettuce Yields and Prices - California
(1991)



As Lichtenberg et al. (1988) point out, the distributional impact of a pesticide cancellation is more affected by the choice of the elasticity of supply coefficient for the commodity than by the imputed coefficient of elasticity of demand. In other words, changes in consumer and producer surplus are more sensitive to the slope of the supply curve chosen (steepness or flatness) than to the choice of the demand curve, however they are both important. Thus it is worthwhile to review the results of a number of studies which have estimated these coefficients, see Table 3.

Six published studies were found where price elasticities of demand (slope/steepness of the demand curve) were econometrically estimated or were referenced as their source. Two of the studies made separate estimates by marketing season (Woo (1983) and Clevenger/Shelly (1974)). These two studies found price elasticities of demand that are in close agreement except for the summer season. For the summer season, Woo found a very inelastic demand (very steep slope) of -0.17 indicating that it would require a very large increase in price to cause a significant decrease in the quantity demanded. This value of the elasticity coefficient is in the range found for food staples. Clevenger and Shelly (1974) found a very elastic demand for this season indicating a much greater consumer sensitivity to price changes. An elasticity of -1.43 indicates that an increase in price would be associated with a greater than proportional decrease in the quantity purchased. An elasticity coefficient in this range might be associated with foods that have high value added components or a convenience item in the consumer's shopping list.

Inelastic demand coefficients (steep slopes), when used in the type of model reviewed here, tend to cause sharp decreases in consumer surplus (the total food expenditure would increase) when there was only a moderate decrease in supplies. An elastic demand coefficient such as found by Clevenger and Shelby (1974) would have an opposite effect.

As noted earlier, distributional impacts on producers and consumers are very sensitive to changes in the coefficient for the elasticity of supply. Four econometric studies were found that estimated supply elasticity for lettuce. The wide range of estimated coefficients reported in these studies is difficult to explain. The three studies estimating seasonal supply responses (Woo (1983), Sunding (1994) and Lichtenberg et al. (1987)) are in fairly close agreement for the coefficients for winter, spring and summer. Their estimates for the fall season diverge widely, ranging from 0.53 (very insensitive) to 1.38 (very sensitive). The greater the coefficient, the greater the production response to market price changes. Low coefficients imply increases in producer surplus for small increases in market price. Coefficients greater than 1.0 imply a producer surplus decrease as market price increases.

Table 3

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Price Elasticity of Demand and Supply

Source	Demand Elasticity	Supply Elasticity	
Sunding, 1994		(California/Arizona)	
U.S. Domestic	-0.44	Winter	0.39
		Summer	0.25
		Spring/Fall	0.68
Wu, 1983			
U.S. Domestic		Short Term	Long Term
Winter	-0.18	0.12	0.39
Spring	-0.17	0.14	0.41
Summer	-0.17	0.18	0.25
Fall	-0.15	0.21	0.53
Clevenger/Shelley, 1974			
U.S. Domestic			
Winter	-0.18		
Spring	-0.10		
Summer	-1.43		
Fall	-0.033		
Lichtenberg, et al, 1987		Winter	0.39
U.S. Domestic	-0.12	Summer	0.25
Export	-0.10	Spring	0.68
		Fall	1.38
Osteen, 1994			
U.S. Domestic	-0.15	Short Term	Long Term
		0.23	1.7
George and King 1971			
U.S. Domestic			
Farm level	-0.095		
Retail level	-0.14		

Note: All demand coefficients carry a negative sign indicating the higher the price, the less will be purchased and all supply elasticities are positive ie., a higher price will induce an increase in supply.

Summary, Conclusions and Policy Implications

Current federal policy for evaluating the continued registration of a pesticide apparently divides the task into two parts. First, total net benefits to users and consumers are estimated, in the case of agricultural pesticides, by the U.S. Department of Agriculture (NAPA). At the USDA, this task is subdivided into biological and economic components. The economic model is based on the imputed biological parameters. The risk portion of the EPA benefit/risk analysis is determined in-house by the EPA drawing on a wide variety of sources both state and federal. While the benefit side of the ratio is reduced to a dollar value through the economic model, the risk side is evaluated only in physical terms due to the non-market characteristics of damages, such as injury to workers, including coincidental and accidental exposure, and injury to non-workers. The weight attached to injuries and illnesses that were unreported and thus did not enter the official statistics is unknown. Damages to the environment, both short and long-run are also included in the equation even if unquantified.

From this mix of quantified and unquantified risks the EPA is charged with making the decision to cancel or renew registration of the subject pesticide. Until now, there appears to be little or no middle ground to take into account trade-offs at the margin. In essence, average risks are balanced against average benefits although any first year economics student would be pleased to demonstrate the superiority of incremental analysis in decision making.

Earlier, we cited Howitt's list of five key questions concerning the internalization of pesticide externalities. Based on the data and models reviewed in preparing this report, we can only comment on one of Howitt's points. The question is, are current standards adequate? That is, have the restrictions placed on pesticides reduced damages and injuries to the same level that would have obtained from optimum level of internalization? There is no way under existing policy that this hypothesis can be tested. It would appear that only if the non-market benefits and damages are quantified and given monetary values can this hypothesis be tested. As pointed out earlier, contingent valuation, while not perfect as a tool to provide values for non-market goods and services, is still the best technique available.

The use of a ratio such as benefit/risk as a decision criteria provides only a yes/no answer to the cancellation question. However, by including these dollar-denominated damages within a sector economic equilibrium model, the incremental trade-offs can be observed. Including damages and injuries as arguments within the model produces three additional benefits. First, the model will provide direct information on "who benefits and who pays, including that segment of society currently being ignored," the farm worker and the pesticide applicator. Second, taking into account within the model all directly affected participants who are stake-holders in this decision, the bias towards maintaining the status quo will be greatly reduced or eliminated. Third, the additional information provided to decision makers with respect to changes in crop mix and location of production will be more accurate and comprehensive.

Allowing trade-offs at the margin such as were highlighted by the substantial reduction in the number of Doctor's First Reports of Pesticide Injuries after the label restrictions were placed on parathion is a very good example. Testing the model for changes in the level and distribution of net benefits could provide decision makers with significantly more information than is available when following current decision making policy.

No economic or biological model is any better than the quality of the data entered into those models. In fact, elegant models can provide a false sense of confidence in the final results. This raises the point alluded to several times in the report, namely, how confident can policy makers be in the precision of the input data and therefore the resulting output if very important variables and parameters are subject to large errors? How is it possible that ex-post analysis can find no significant change in yields or production when yield losses of up to 25 percent were forecast by biological scientists? The heavy reliance on a single "expert" to forecast future losses subjects the model and its results to any biases held by that lone individual.

Reports reviewed for this study reported changes in producer and consumer surplus measured in the tens of millions of dollars. If the preliminary estimates are anywhere near the true state, there is strong justification for funding rigorous agronomic/entomological research. This would provide empirical data to replace the subjective estimates now used of yield loss functions under alternative pesticide scenarios in all major producing areas.

The continued reliance on Doctor's First Reports of Pesticide Injury as the only source of data on farm worker and pesticide applicator injury will cause a severe under-estimation of the dollar value of externalities. Under-reporting in turn bias decisions concerning label restrictions, education, safety inspections and cancellation in favor of the status quo. Howitt's 1975 study made clear that there was significant under-reporting of farm worker injuries over and above the chronic illnesses that have always been unreported. Random sample interviews by bilingual enumerators from non-governmental agencies will be required on a regular basis if this data gap is to be filled.

Economic modelers should also heed the advice of Smith (1994). She urged policy researchers to use increasing amounts of sensitivity analysis for key variables to observe the stability (robustness) of the model and the final results. That is, researchers are advised to run their computer models while varying one key parameter at a time over a wide range while holding all others constant to determine the impact (cost) of an error either in measuring the variables or structuring underlying assumptions. Certainly any model of the fresh vegetable industry should be tested for the impact of noncompetitive markets and the impact on production decisions made by vertically coordinated or integrated firms. Due to the migratory nature of seasonal vegetable production, shifts in the location of production due to the loss or gain in competitive advantage of one region over another should be explored. Finally, using the example of the wide range of published estimates of the demand and supply elasticity for head lettuce, it is imperative that sensitivity analysis also test the impact of an equally wide range of elasticities.

The loss of information due to the "coarseness" of the data base used in these models contributes to the lack of credibility of model results. Ignorance of the variance, skewedness and peakedness of critical statistical distributions and sole reliance on averages and averages of averages over time and space makes interpretation of model results an almost impossible task. Economists must prepare to change the way they do policy research.

A short article by McCloskey in *Scientific American* (1995), may point the way out of this methodological rut to the benefit of researchers and policy makers. McCloskey makes the case, based on the fact that the cost of a computation has decreased by half every 18 months over the past 20 years, that researchers are no longer bound (limited) to reasoning from a few highly simplified, mathematically tractable assumptions. Due to the lowered cost of computation, researchers can now build more realistic models of economic behavior and validate them to the real world. Micro level data (all the moments of the distribution) can be carried through to the final results. Efficiency and equity require governmental agencies to utilize the best methodologies and data bases available. Failure to do so leads to governmental failure and erosion of trust from the groups most dependent on it for protection.

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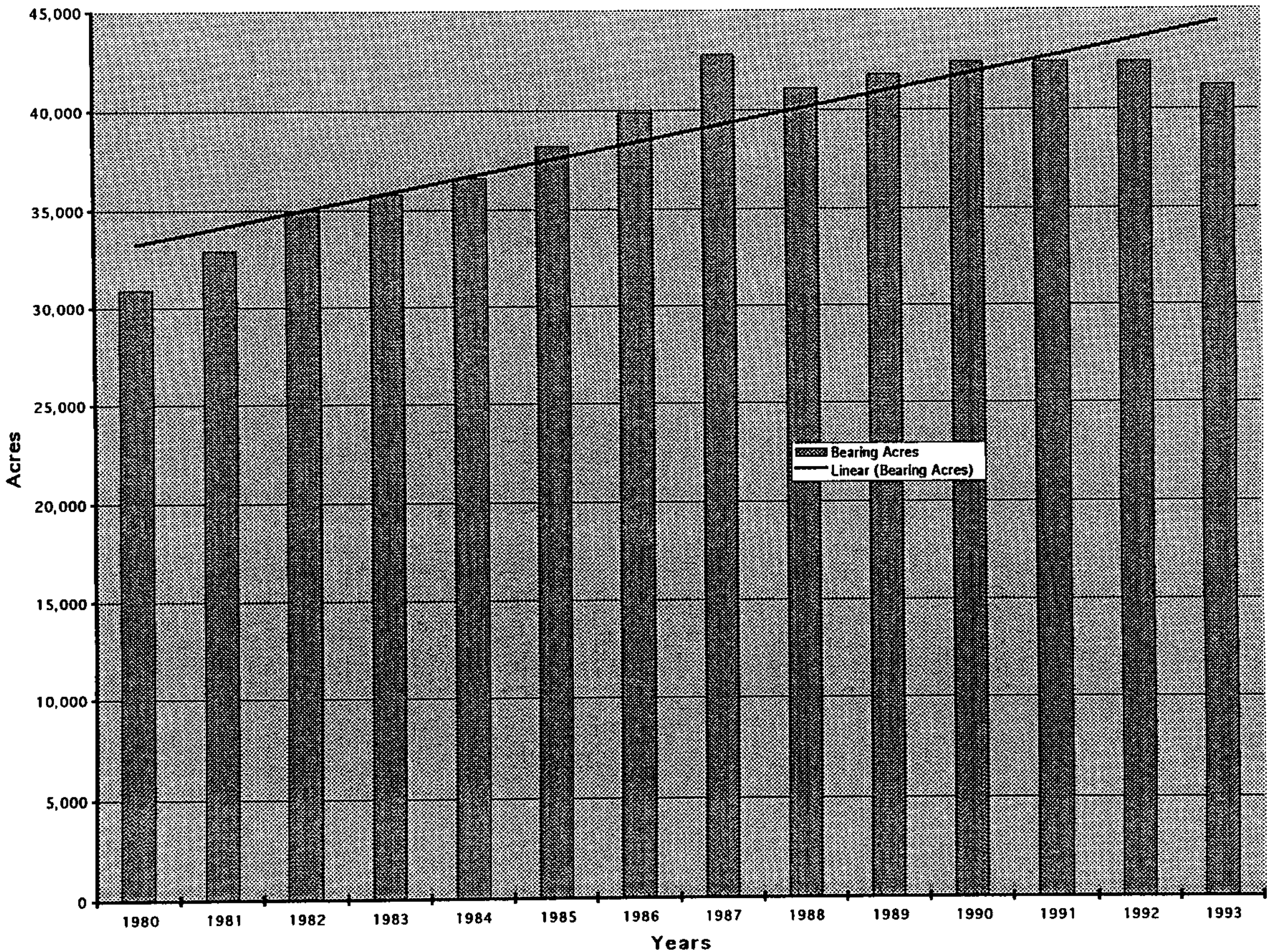
Appendix Table 1

Pesticide Injuries from Parathion
California, 1985-1991

Year	1985	1986	1987	1988	1989	1990	1991
Applications in thousands	11.64	10.805	10.625	10.89	9.34	11.45	12.53
Total Injuries	28	24	21	12	22	21	8
Injuries per Thousand Apps	2.4	2.22	1.98	1.1	2.37	1.9	0.56

Plum Acreage - California
(With Linear Time Trend)



Appendix Figure 3