The Impacts of Allocation Strategies for Spatially Regulated Chemical Use

by

Lori Lynch and Janet Carpenter

Working Paper No. 01-01

Date of Submission: February 2001

Lori Lynch is Assistant Professor at the Department of Agricultural and Resource Economics at the University of Maryland, and Janet Carpenter is Research Associate at the National Center for Food and Agricultural Policy in Washington, D.C.

Key Words: spatial regulations, pesticide, 1,3-D, allocation mechanisms

Corresponding Author:
Lori Lynch
llynch@arec.umd.edu

Department of Agricultural and Resource Economics
2200 Symons Hall • University of Maryland • College Park, MD 20742-5535 • USA • Tel. (301) 405-0057

The Impacts of Allocation Strategies for Spatially Regulated Chemical Use

Lori Lynch
Department of Agricultural and Resource Economics

Janet Carpenter
National Center for Food and Agricultural Policy

Abstract: Spatial regulations can restrict chemical use more efficiently by linking benefits to the costs. California has instituted such a spatially based regulation of an agricultural fumigant to meet air quality standards. We examine the implications of alternative allocation mechanisms: use allocated based on a first come, first served basis; on quotas linked to historical use; and on the highest-value use. Although there are distributional impacts by crop, the overall change in aggregate value from using a highest value use mechanism rather than a first come, first served approach is estimated to be less than nine million.

Subject Code: Q2

Keywords: spatial regulations, pesticide, 1,3-D, allocation mechanisms

Impacts of Allocation Strategies for Spatially Regulated Chemical Use

A spatial element in a chemical or emission regulation can more directly link the environmental benefits with the costs of achieving them. Areas with higher levels of pollution may need stricter regulations to achieve minimum standards. Alternatively, regions where the benefits of emission reductions are very valuable may choose to impose stricter regulations than regions with more pollution but less valuable environmental amenities. Similarly, geographic regions may vary by their ability to absorb or dissipate environmental pollutants. Both the Clean Air Act and the Clean Water Act have incorporated spatial dimensions to achieve minimum standards. Under the Clean Air Act, areas, such as the Los Angeles basin, demand higher emission reductions to achieve the mandated uniform air quality standards. Under the Clean Water Act, states may impose stricter standards to achieve the desired total maximum daily loads (TMDL's) based on the value of the water resource to be protected.

Although the Endangered Species Act proposed voluntary limits on chemical use in areas where endangered species may be affected and the use of the herbicide Atrazine is restricted in certain areas of Iowa and Wisconsin where the likelihood of the pesticide leaching into ground and surface water is high, as a rule, pesticide regulations have not incorporated a direct spatial component. This is true even though research has demonstrated the differential impacts of chemical regulations by region and has stressed the need for disaggregated analyses (Lichtenberg, Parker and Zilberman (1988), Carpenter, Giannessi and Lynch (2000), Van Sickle, Brewster and Spreen(2000)). However, in 1994 California introduced a spatially based pesticide regulation which limits the amount of a fumigant pesticide that may be used in a 36-square mile area. The regulation seeks to ensure that ambient air concentrations of the pesticide emissions do not exceed air quality standards. This pesticide limit will be binding only in areas of relatively concentrated use, where the air quality standard may be violated. Yet, given there is more than one farmer contributing to the adverse environmental effect, some method of allocation of the right to use the polluting substance must be determined for areas where the regulation is binding. Our paper examines the impacts of different allocation strategies by region and by crop.

Researchers have developed models to analyze pest control decisions and impacts under a variety of strategies and chemical regulations (see survey by Carlson and Wetzstein (1993)), yet no papers were found examining the efficient allocation of a limited supply of a chemical on a spatial format. In the more traditional regulation case, researchers have found that bans or regulations of particular chemicals may actually benefit some producers while negatively impacting other producers. Analyzing the disaggregated impacts of a pesticide ban by regions and crops, Lichtenberg, Parker and Zilberman (1988) found a large redistribution of income among producers in different regions between pesticide users and nonusers. A pesticide regulation's impact on consumer and producer surplus can be different in the presence of other market distortions, such as price support programs (Lichtenberg and Zilberman, 1986). Other models that look at the effect of pesticide cancellations permit estimation of the welfare changes for competing crop farmers (Taylor, Lacewell, and Talpaz, 1979). Alternative regulations such as quotas and marketable permits were found to be welfare enhancing for the regulation of methyl bromide (Lynch,1996, Deepak, Spreen and Van Sickle, 1996).

Since the California spatial regulation is not an outright ban (cancellation) or a tax, an allocation strategy is needed to determine who will have the right to use the available pesticide. If the growers' demand for the pesticide exceeds the established limits, chemical manufacturers and distributers might estimate a price in each region to ensure that only the permitted quantity is demanded. Under this method, the chemical companies would earn all the rents of the regulation. In addition, a pricing approach may be ineffective unless cross-regional trading can be prohibited. Otherwise, a farmer could simply travel to a nearby region where the chemical is in excess supply and purchase it at a lower price. Alternative allocation strategies include use allocated on a first come, first served basis, on a quota system by crop linked to current or historical use, or on the highest value use.

This paper examines that impacts of these three different allocation strategies for the quantity of the fumigant 1,3-dichloropropene (1,3-D) permitted in each geographic area between the variety of crops that use it.[1] California suspended its use in April 1990 after detecting emission levels above air quality standards in Merced County. In 1994, California reintroduced 1,3-D with regulations that set maximum limits on use within spatially delineated areas. These limits are currently binding in only a few areas. Agricultural producers used more than 2.4 million pounds of 1,3-D in California in 1997. However, the restrictions are expected to become binding in more regions as methyl bromide is phased out under the Clean Air Act and Montreal Protocol if growers shift to 1,3-D in its place. 1,3-D is considered the most effective alternative to methyl bromide for many crops. As the phaseout of methyl bromide proceeds, allocation of the limited amount of 1,3-D use in each geographic area will be

[1] 1,3-D acts primarily as a nematicide but also controls viruses, bacteria, soil insects and fungi.

necessary.

The demand for 1,3-D is estimated assuming the phaseout of methyl bromide has been completed. Data from the California Pesticide Use database is used. This database provides detailed spatial information on all pesticide applications as well as application dates. We analyze which crops receive the "right" to use the limited amount of 1,3-D available in each region using the various strategies outlined above. The efficiency and distributional aspects of each strategy based on the factor market impacts, i.e. the value of marginal product and its scarcity or shadow value of 1,3-D, are evaluated. This type of methodology has been used to analyze the impacts of the ban of methyl bromide (Carpenter, Gianessi, and Lynch, 2000; Lynch, 1996; Sunding, et al., 1996; Yarkin, et al.,1994).

Background

In 1992, the Montreal Protocol, an international treaty to reduce ozone-depleting substances worldwide, identified methyl bromide[2] as a class I ozone depletor. Due to this identification, the U.S. Clean Air Act required that all production and importation of methyl bromide be ceased by January 1, 2001. In 1998, the U.S. Congress amended the Clean Air Act to harmonize the U.S. phaseout with the international schedule under the Montreal Protocol, with reductions of 25% by 1999, 50% by 2001, 70% by 2003 and 100% by 2005.

Economically viable alternatives to methyl bromide are being sought for crops that are grown in

---

[2]Methyl bromide is an agricultural fumigant that is widely used in California to control diseases, nematodes, and weeds.

California using methyl bromide. Researchers have identified 1,3-D, either alone or in combination with other chemicals such as chloropicrin, as the best alternative to fumigation with methyl bromide in terms of the lowest per-unit cost (Carpenter, Gianessi, and Lynch, 2000). However, the wide-scale availability of 1,3-D as a replacement for methyl bromide is uncertain due to restrictions on its use.

Current restrictions include a limit on the total amount of 1,3-D that may be applied within 36 square mile areas, referred to as townships (California Department of Pesticide Regulation (DPR),1999). The township limit depends on the depth and timing of applications as these impact emission levels and thus air quality. A total of 90,250 lbs. of 1,3-D per township is allowed if all applications are made to a depth greater than 18 inches between the months of February and November. The permitted quantity is reduced if applications are made at shallow depths or during the months of December or January. The lower permitted quantities are calculated by counting each pound applied at a shallow depth (i.e., less than 18 inches) during February through November as 1.9 pounds. Similarly, the amount of 1,3-D used is weighted more heavily for applications during December or January. If all applications are made at a shallow depth between February and November, the permitted quantity is 47,500 lbs[3].

Model

In a first-best world, a directly linked policy instrument would result in the growers internalizing the production externality, i.e. the societally imposed costs of air-borne 1,3-D emissions would be part

---

[3]In addition to the township caps, growers must maintain a 300-foot buffer zone around occupied structures, which is greater than the current buffer zone requirements for methyl bromide treated acres. Growers must also meet soil moisture requirements that may reduce the efficacy of 1,3-D. Also, the maximum permitted application rate for 1,3-D is 24 gallons per acre for tarped fumigation and 35 gallons for untarped fumigation.

of the production cost calculations and would lead to the optimal level of chemical use from society's perspective. A Pigouvian tax or abatement subsidy might be the optimal instruments to impose on 1,3-D users (Baumol and Oates, 1988). In order to actually apply one of these mechanisms, policy makers would need to measure emissions on each farm and derive the actual costs to society of these emissions in terms of human health and other environmental impacts. The marginal social cost of the pollution and the optimal tax or subsidy cannot be easily determined. Calculating the exact costs related to 1,3-D emissions is complicated and costly, as is measuring the emissions from each field.

Given the difficulty and expense of calculating the social costs of 1,3-D use, a tax or subsidy mechanism is untenable. Therefore, the California DPR has chosen to limit use by geographic location as the most efficient way of achieving air quality goals by ensuring emission levels below the regulated levels. Given a predetermined permitted quantity of use, the distributional and efficiency impacts between regions and crops can be compared under different scenarios for allocating the allowed 1,3-D use between producers in these geographic areas.

Growers in township k choose to grow crop i using the best available pest management technology h. For any individual grower, the market price of the crop i, $P_{i,}$, the variable input costs, a vector v, and the technology input costs, a vector w, are all exogenous. Growers maximize a per acre net revenue function by selecting variable inputs per acre for each crop in each technology, x_{ihk} , and technology inputs per acre for each crop in each technology, $m_{ihk,}$ given production function $f(x_{ihk}$, $m_{ihk,})$ such that $r_{ikh}(P_i,v,w) = \max\ P_i f(x_{ikh},m_{ikh}) - vx_{ikh} - wm_{ikh}$. Thus, net returns per acre, $r_{ihk}(P_i$, v, $w)$, are a function of crop price, P_i, and input costs, v and w. A township's overall profit, p_k is maximized by choosing l_{ikh}, the number of acres in crop i in technology h given the net revenue per acre in the different technologies and different crops. The number of total acres planted in each township is constrained by the total number of acres in the 36 square mile township, A_k. Thus implicitly by the action of each grower choosing l_{ikh}, each township solves the following maximization problem:

$$\begin{aligned} \max \quad & \pi_k = \sum_i^I \sum_h^H r_{ikh}(P_i,v,w) \cdot l_{ikh} \\ s.t. \quad & A_k \geq \sum_i^I \sum_h^H l_{ikh} \\ & l_{ikh} \geq 0 \end{aligned} \tag{1}$$

If a particular chemical $h=1$ is restricted to less than M_k in each location k, each township faces a second constraint, $M_k \geq \sum_i^I m_{ik1} l_{ik}$

The Lagrangian in this case with two constraints would be:

$$\begin{aligned} L = & \sum_i^I \sum_h^H r_{ikh}(P_i,v,w) \cdot l_{ikh} + ?_k (A_k - \sum_i^I \sum_h^H l_{ikh}) + \\ & ?_k (M_k - \sum_i^I m_{ik1} l_{ik1}) \end{aligned} \tag{2}$$

$?_k$ is the shadow price for the land constraint (the quasi-rents for land in region k) and $?_k$ is the shadow price for the technology or chemical constraint. Using the first-order profit maximization conditions, each township would have an optimal land allocation and the optimal use of each technology. The first-order condition for the land variable is:

$$\frac{dL}{dl_{ikh}} = r_{ikh} - ?_k = 0$$
$$\frac{dL}{dl_{ik1}} = r_{ik1} - ?_k - ?_k m_{ik1} = 0 \tag{3}$$

which demonstrates how land will be used for each crop in each technology in a given township based on its net revenue per acre. If the net revenue per acre for a particular crop is less than the quasi-rent for the land in that township, $?_k$, no acres of the crop will be grown, l_{ikh} =0. If the shadow value of land is positive, then growers in this township would want to plant more acres as they are making a positive net revenue. In addition to the quasi-rent of the land, the shadow value of each additional unit of the regulated chemical for the particular township must be considered when allocating land to growing crops using this technology. As can be seen by the first order condition for l_{ik1}, the crop must have a sufficiently high net revenue per acre to cover $?_k$ and $?_k$ in townships where the chemical restriction is binding to justify its use.

$$\frac{dL}{d?_k} = A_k - \sum_i^I \sum_h^H l_{ikh} = 0$$
$$\frac{dL}{d?_k} = M_k - \sum_i^I m_{ik1} l_{ik1} = 0$$
$$\left[\frac{dL}{d?_k}\right] ?_k = 0$$
$$\left[\frac{dL}{d?_k}\right] ?_k = 0 \tag{4}$$

Using the equations in (4), we also find that the shadow value of the land will be positive only if all the land in the township is use to grow crops. If the shadow value is zero, then the number of acres used would be less than A_k, indicating that the net revenue for crops in this township is equal or less than zero. Similarly, the shadow value of using the chemical will be positive only if demand for the chemical in the township exceeds M_k. If $?_k$ equals zero, then the constraint is not binding leading one to believe that the net revenue using the restricted chemical does not exceed the net revenue of an alternative technology.

The choice of technology is incorporated into the problem as a putty-clay model with fixed proportions technology or, as it is often called, a linear response and plateau (LRP) formulation to generate supply by township. This results in the plateau appearance of the supply curve. Each straight portion of the supply curve for a particular crop reflects one township's production of crop *i*. Berck and Helfand (1990) demonstrate that the linear response and plateau or von Liebig model performs well. The von Liebig functional form assumes that the crop responds linearly to the addition of a limiting input until a different input becomes limiting. Although this function does not allow perfect substitution between inputs, i.e., the crop needs a combination of inputs to grow, it has been shown that a smooth crop production function can be derived from the LRP form by aggregating the effects of heterogenous inputs. Lanzer and Paris (1991) have also demonstrated the validity of the fixed proportions assumption for fertilizers.

Given the LRP formulation, the value of the marginal product equals the value of the average product. In addition to the per unit cost for the chemical, w, growers would be willing to pay the shadow value or quasi-rent of the technology constraint in the township to use the pesticide up to the value of the marginal product. We can use this relationship to determine the highest-value use of the constrained pesticide, i.e. the implicit shadow value of the chemical if the regulation is binding, and thus the most efficient allocation of the chemical between the competing crops in the township.[4]

As regulations change, growers may have to choose alternative pest management technology. Change in pest management technology will likely alter per acre yield and costs, and thus net revenues. Using the equations in (3), we find that a grower will be indifferent between using technology 1 and another technology if $r_{ik1} - ?_k - ?_k m_{ik1} = r_{ik2} - ?_k$. Thus without computing the full model, we can calculate $?_{k,}$ the shadow value for the constrained pest management technology, using the net revenues from using the restricted pest management input and from the alternative technologies. We compute the maximum shadow value for pest control technology h=1 with respect to technology h=2, the next best alternative as determined by crop and region that a grower would be willing to pay by crop (Yarkin, et al., 1994; Lynch, 1996). Therefore the implicit value of using a unit of the restricted chemical is

$$?_k = \frac{r_{ik1} - r_{ik2}}{m_{ik1}} \tag{5}$$

[4]This approach assumes constant prices which from an industry perspective may not be realistic if yield and acreage changes are large. Growers may find that the relative profitability of a crop changes and switch to another crop. Depending on price elasticities, price changes may compensate for some of the decreased yield and/or increased costs following the technology change.

The change in net revenue is derived from price-weighted changes in per acre yields and changes in per acre costs. The label rate or recommended use per acre for crop *i* in region *k* is used to proxy m_{ik1}. For perennial crops, the shadow value is calculated similarly using the change in net revenue over time assuming a discount rate of 4 percent for the expected length of the crop's life. The net revenue stream for perennials varies by crop; for example, peaches are replanted every 28 years, while almonds are replanted every 40 years.

Data

The California Pesticide Use Database provides detailed spatial information on all pesticide applications, which allows calculation of pesticide use by township. Using 1997 pesticide use data, the current use levels of 1,3-D and methyl bromide in each township are computed. We calculate the demand for 1,3-D assuming that all major methyl bromide users will switch to 1,3-D (90 % of all uses) given the assumptions about application technology and rates outlined in Table 1. Table 2 presents the county-level estimated unrestricted level of demand for 1,3-D as actual pounds, adjusted pounds as applied to the restriction, and number of acres after a methyl bromide ban. Sixteen counties are expected to use 1,3-D, with the major users being Monterey and three San Joaquin Valley counties. If unrestricted, demand for 1,3-D use is calculated to increase from 2.4 million pounds to 15.3 million following the methyl bromide phaseout. Table 3 presents the crop-specific level of use of 1,3-D after the methyl bromide phaseout, and includes almonds, grapes, peaches, prunes, potatoes, strawberries, sweet potatoes, nurseries, tomatoes, and carrots. Strawberries are expected to be the major user at 4.8 million lbs., or 9.1 million adjusted lbs.

The 1997 pesticide use data were modified in order to address issues in the reporting of methyl bromide use. First, treated acreage for methyl bromide use in perennial crops may be overstated due to reporting of spot treatments on less than one acre as full acre treatments. Therefore, all records with application rates of less than 50 lbs. per acre were deleted. Second, an adjustment was made for unspecified methyl bromide use. More than 2.5 million pounds of methyl bromide use is not reported as used on any particular crop, accounting for approximately 9,000 treated acres (15 percent of area treated with methyl bromide). County agricultural commissioners in those counties with a large amount of unspecified use were surveyed for further information on which crops were being fumigated. All unspecified use in Siskiyou County (32,757 lbs.) was assumed to be for strawberry nurseries. Unspecified use in Orange County (250,435 lbs.) was assumed to be strawberry acreage. The breakdown of unspecified uses in Fresno, Madera, and Tulare counties, which together account for more than 1.7 million pounds of the unspecified methyl bromide use, is attributed to perennial crops. Unspecified use in other counties is not included.

Fifty-five townships were estimated to be over the limit. Growers would choose to use almost 10 million more lbs. of 1,3-D than is permitted. While many of the 16 counties have only one township where the restriction binds, others have several. Table 4 outlines the number of townships in each county where the restriction is binding as well as the adjusted pounds of 1,3-D over the limit. Monterey and Santa Cruz counties together have 13 townships where the restriction binds. Merced and Kern counties have 14 townships where the restriction impacts growers. Ventura County alone has 6 townships.

To compute the per crop shadow values for using the restricted chemical, per acre crop values were obtained from California agricultural commissioner data. Strawberries' yield loss was assumed to be 5 percent. Strawberry growers are assumed to switch their pesticide technology from 1,3-D to use a combination of metam sodium and chloropicrin, with an increase in costs of $520 per acre (Sunding, et al.). Other annual crops' yields decrease 10 percent, assuming they switch from 1,3-D to metam sodium. Costs for annual crops increase $100 per acre. Perennial quasi-rent values were calculated using yield loss assumptions provided by a University of California nematologist McKenry. Yield losses for perennial crops were assumed to be between 5 and 20 percent, depending on whether nematode-resistant rootstocks were used. Yield and cost change assumptions for perennials were based on Carpenter, Gianessi, and Lynch (2000). The quasi-rent value of a pound of 1,3-D varies by crop from a high of $28 for wine grapes to a low of $0.50 for olives. Table 5 contains the computed average values of 1,3-D use by crop relative to the next best alternative.

Policy Scenarios and Results

The California regulations on 1,3-D can be used as a case study of the impacts of different allocation mechanisms that a state might use to determine which crops receive the limited pesticide within the impacted areas. Pesticide use may be allocated in several manners: on a first come, first served basis; through quotas by crop based on current or historical use; or with marketable permits based on highest-value use. The crops in a township that are able to use the limited quantity of 1,3-D will be determined by the allocation strategy implemented. If use is allocated on a first come, first served basis, which seems likely in the absence of an alternative distribution scheme, the outcome may be suboptimal as higher-valued crops with few available alternatives might be effectively banned from using 1,3-D. Strawberries, for example, are planted in the fall and might not be treated early enough to be assured availability of 1,3-D. A second distribution scenario is to assign each crop within a township a quota based on its use of 1,3-D in proportion to the total demand in the township. For example, if in a particular township 50 percent of the total demand for 1,3-D is for carrot acreage, then carrots would get half of the quotas. Finally, state officials could distribute the limited amount based on a bidding system for rights. The users with the highest value crops would receive the right to use the chemical as these users would outbid other users. The maximum bid a grower would make is the shadow value per pound of 1,3-D compared to the next best alternative strategy. Thus this strategy has the users with the highest-value crops in each township using 1,3-D until the township limit is reached. Growers could potentially trade these rights in the long run if new technologies became available.

Our analysis uses these shadow values for each crop to compare the impact of the alternative distribution mechanisms. Using the computed value of 1,3-D, the aggregate values of the different strategies are compared by county, crop and for the state as a whole. Tables 6 and 7 present the results by allocation mechanisms by county and by crop. Table 8 shows the aggregate results for the state.

One interesting result is that distribution based on the highest value use does not always maximize the county-level or crop-level aggregate value. This is due to counting shallow applications as 1.9 lbs. toward the limitation even though only 1 lb. of 1,3-D is used. For shallow rooted crops, the shadow value $?_k$ was divided by 1.9 to determine the highest value use allocation for each lb. of 1,3-D actually applied. As a result, we find that in some counties (Del Norte, Orange, Shasta, Sonoma) allocating according to the highest value use had a lower aggregate value than a quota based or first come, first served allocation strategy. Sonoma County has a higher aggregate value from a quota sytem with the highest value use allocation strategy having an aggregate value $1.1 million lower. The highest value strategy has an aggregate value $0.7 less than the first come, first served system as well. Sonoma only has one township that binds.

In the other counties (Monterey, Kern, Merced most noticably), the highest value allocation achieved the highest aggregate value. The largest difference between the various strategies appears in Merced County where the aggregate value under a first come, first served system is $4 million less and under a quota system is $4.2 million less than allocation based on highest value. Merced County has 6 townships binding. In Monterey, which has the greatest number of townships binding, the difference is $0.9 million between the allocation based on highest value use and a first come, first served system. Kern, where 8 townships are binding, had a difference of $1.1 million between highest value and first come, first served and $1 million between highest value and quota.

Differences between crops were also explored to determine distributional issues. Almonds had the largest difference at $5.8 million between highest value and quota and $5.5 million between highest value and first come, first served. Strawberries would also fare better under a highest value scenario at $3.8 million difference compared to first come, first served, but only $0.6 million compared to a quota system. Peaches, soil applications, walnuts, and pepper would all be better off if a highest value approach was used instead of first come, first served and quotas. Nurseries and potatoes would fare better under highest value relative to first come, first served but not relative to a quota system. Sweet potatoes fared worse with highest value compared to quotas (-$0.6 million) or first come, first served (-$0.4 million). Broccoli, carrots, grapes, lettuce, prunes, tomatoes and watermelon also fare worse under a highest value scenario. The value of having an unrestricted supply of 1,3-D is $200 million as shown in Table 8. Compared to unrestricted use, using quotas by crop to allocate the limited use achieves an aggregate value of $138 million, by first come, first served, a value of $135 million, and by the highest value use, a value of $144 million. Therefore if 1,3-D was allocated to be used by the crops with the highest value in each township, the cost of the 1,3- restriction would be $54 million. The first come, first served strategy has the least aggregate value resulting in a cost of $65 million from the restrictions on use, $11 million more than the highest value use.

Table 9 reports the acres that will be prohibited from using 1,3-D. The state total is between 26,000 and 27,000 acres regardless of allocation strategy, which is a third of the acreage for which growers are expected to demand 1,3-D[5]. Strawberries face the largest loss under restricted use with more than 13.5 thousand acres (57% of the 1997 California strawberry acreage) forced to use the next best technology with quota allocations and 13.3 thousand acres under highest value allocation. Under first come, first served, more than 14.6 strawberry acres (62 %) must find alternative pest management strategies. Sweet potato growers on 4,605 acres (52 % of the 1997 California sweet potato acreage)

---

[5]Total irrigated vegetable acres in California was 1.2 million in 1997 (USDA NASS, 1997) and fruit and nut trees planted with fumigation in any one year is 10,783 acres (Carpenter, Gianessi, and Lynch, 2000) for a potential of 1.21 million acres impacted.

are restricted from using 1,3-D under the high value allocation strategy with almost 4,000 acres (46%) restricted under first come, first served. About 3,700 acres of sweet potatoes (42%) will be prohibited from using 1,3-D under the quota system. Approximately 2,400 acres of nurseries will be restricted from using 1,3-D under the highest value allocation, with approximately 2,100 acres restricted under quotas or first come, first served. Almonds and carrot growers will face restrictions on their acreage as well. Almond growers are permitted to use 1,3-D on 1000 more acres (0.002 %) if a high value allocation strategy is used compared to the other two. Carrot growers will be prohibited from using 1,3-D on almost 2,000 acres (0.08%) under the highest value allocation. They will have it for almost 800 acres more if a first come, first served allocation strategy is followed. Peaches will be able to use 1,3-D on almost all acreage under a highest value allocation. Walnut growers fare well under both high value and quotas.

Further Research and Conclusions

Demand for 1,3-D is estimated to increase from 2.4 million to 15.3 million lbs. following the phaseout of methyl bromide. In 55 townships, demand is predicted to exceed the permitted level of use under current township restrictions. Growers planting on one-third of the acreage for which there would be 1,3-D use if it was not restricted will be forced to seek alternative pest management strategies. To date, the California DPR has not established an allocation strategy per se. They have assigned the rights and responsibilities for allocation of 1,3-D use to the pesticide application companies. The rents associated with the chemical restriction could exceed $40 million if 1,3-D is distributed to its highest value use. Is it in society’s best interests that private companies earns these rents if they increase the price to incorporate the scarcity or shadow value? Could the state better use these funds by having growers bid for the right to use the pesticide? If quotas were allocated based on use and resale of quotas was permitted, this could compensate growers for some of the costs imposed by the restrictions.

From a county-level perspective, most counties (13 of 17 where township restrictions are binding) would achieve a higher aggregate value use of 1,3-D by allocating the chemical to the highest value use. Three counties fare better with allocation based on proportional quotas. Examining individual crops, results show that 6 crops fare better with highest value while 5 fare better with a quota system. These gains to growers by crop or by county assume no transaction costs. The gains to the state, counties and growers may dissipate through the costs of establishing and implementing an allocation mechanism. Considering the modest difference in aggregate impacts between the three allocation schemes, the mechanism with the lowest administrative cost would be preferable. Allocation based either on quotas or on a first come, first served basis may require lower transaction costs than a bidding system.

The analysis is limited by the assumption that no crop will geographically relocate following the methyl bromide phaseout and the subsequent restrictions on 1,3-D use. Yet some crops may be able to shift to another township where the township restriction is not binding. Growers however are assumed to be growing the most profitable crop in the most profitable area considering both soil conditions and climate. Therefore, any shift would likely decrease profits. In some cases, crops may not be able to relocate in the short-run because the growers own the land they farm, the restrictions in the nearby township are also binding, or there is no other region characterized by the optimal growing conditions.

In addition, the analysis does not permit price adjustment as yields decrease. For most of the crops, less than 10 percent of the acres planted to the crop in 1997 will be prohibited from using 1,3-D under any of the allocation strategies. Yield losses on these acres are assumed to be between 5 and 10 percent. Therefore including price changes would probably not alter the conclusions. However for strawberries and sweet potatoes, the affected acreage is a much larger percentage. Both of these crops will see over 40 percent of the acres impacted by the restrictions thus at a minimum, the overall crop supply will decrease 2 percent. Within the crops themselves, there would not be much difference in aggregate values between the different allocation strategies even if the price changes were incorporated. However, these two crops may fare relatively better in the high value allocation strategy if their price changes were included.

Since these regulations are being imposed due to air quality concerns and impacts on human health, a modification of the regulation may more closely link the benefits and costs of the pesticide regulation. For example, the regulation might impose tighter restrictions in areas where the external costs of the pesticide use are highest, for instance in more highly populated areas, and allow higher use levels in less populated areas. A system might be explored using marketable permits or taxes to divert use from more populated areas to less populated area. Each area has its limited amount which growers can use or sell to another area if the “receiving” area was less populated. This mechanism may permit use at higher levels of use in a more rural area which could have high value crops such as strawberry nurseries.

References

Baumol, William J., and Wallace E. Oates, *The Theory of Environmental Policy*, New York: Cambridge University Press, 1988.

Berck, Peter and Gloria Helfand, "Reconciling the von Liebig and Differentiable Crop Production Functions," *American Journal of Agricultural Economics,* November: 985-996, 1990.

California Department of Pesticide Regulation, "Suggested Permit Conditions for 1,3-Dichloropropene Pesticides," January 12, 1999.

Carlson, G. A. and M. E. Wetzstein, "Pesticides and Pest Management," *Agricultural and Resource Economics*, Carlson, Zilberman and Miranowski, eds., Oxford University Press, 1993.

Carpenter, Janet, Leonard Gianessi and Lori Lynch, *The Economic Impact of the Scheduled Phase-out of Methyl Bromide in the U.S.*, National Center for Food and Agricultural Policy, Washington D.C., 2000.

Deepak, M. S. ; Thomas H. Spreen, and John J. VanSickle, "An Analysis of the Impact of a Ban of Methyl Bromide on the U.S. Winter Fresh Vegetable Market," *Journal of Agricultural and Applied Economics* 28, 2 (December 1996): 433-43.

Lanzer, Edgar A. and Quirino Paris, "A New Analytical Framework for the Fertilizer Problem," *American Journal of Agricultural Economics*, 63:93-103, 1991.

Lichtenberg, Erik, Douglas D. Parker and David Zilberman, "Marginal Analysis of Welfare Costs of Environmental Policies: The Case of Pesticide Regulation," *American Journal of Agricultural Economics*, 70(4):867-874, 1988.

Lichtenberg, Erik and David Zilberman, "The Welfare Economics of Regulation in Revenue-Supported Industries: The Case of Price Supports in U.S. Agriculture," *American Economic Review*, 76(5):1135-1141, 1986.

Lynch, Lori, *Agricultural Trade and Environmental Concerns: Three Essays Exploring Pest Control Regulations and Environmental Issues*, Ph.D. Dissertation, University of California at Berkeley, 1996.

Sunding, David, D. Zilberman, C. Yarkin, M. Roberts, and J. Siebert, *Economic Impacts of Methyl Bromide Cancellation*, Department of Agricultural and Resource Economics, University of California at Berkeley, 1996.

Taylor, C.R., R.D. Lacewell and H. Talpaz, "Use of Extraneous Information with an Econometric Model to Evaluate Impacts of Pesticide Withdrawals." *Western Journal of Agricultural Economics*, 4(1):1-3, 1979.

USDA National Agricultural Pesticide Impact Assessment Program, The Biologic and Economic Assessment of Methyl Bromide, 1993.

USDA National Agricultural Statistics Service, *1997 Census of Agriculture*.

Van Sickle, John J., Charlene Brewster and Thomas H. Spreen, "Impact of a Methyl Bromide Ban on the U.S. Vegetable Industry," Agricultural Experiment Station Bulletin No. 333, Department of Food and Resource Economics, University of Florida, 2000.

Yarkin, Cherisa, David Sunding, David Zilberman, and Jerry Siebert, "All Crops should not be Treated Equally," *California Agriculture*, May-June, 1994.

Table 1. Application Rate Assumptions

Crop	Type of Fumigation	1,3-D Rate (lb./acre)	Application Depth
Almond	Broadcast	332	>18”
Carrots	Bed[**]	81	<18”
	Broadcast[**]	114	<18”
Grapes	Broadcast	332	>18”
Lettuce	Bed	76	<18”
Nursery	Broadcast	235	<18”
Peach	Broadcast	332	>18”
Peppers	Bed	76	<18”
Strawberry	Broadcast	235	<18”
Sweet Potato	Broadcast	190	<18”
Tomato	Bed	76	<18”
Walnut	Broadcast	332	>18”
Watermelons	Bed	114	<18”

[**] Half of the carrot acreage is assumed to be bed fumigated, the other half broadcast fumigated.

Table 2. Estimated 1,3-D Demand After Methyl Bromide Phaseout by County

County	Lbs.	Adjusted lbs.	Acres
Monterey	2,187,757	4,080,302	12,068
Kern	1,675,556	2,733,800	11,064
Merced	1,649,560	2,601,456	7,485
Ventura	1,335,387	2,528,461	6,355
Fresno	1,200,507	1,313,085	4,971
Tulare	917,710	959,242	3,036
Stanislaus	842,319	1,213,464	4,452
Santa Barbara	790,010	1,442,433	3,377
San Joaquin	676,743	861,205	2,586
Santa Cruz	647,303	1,229,876	3,164
Orange	393,905	748,420	1,855
Sonoma	377,538	387,446	1,310
Imperial	338,551	643,246	3,803
San Diego	292,617	555,973	2,448
Sutter	284,061	326,978	983
Riverside	238,309	383,929	1,849
STATE TOTAL	15,262,600	24,047,487	77,404

Table 3. Estimated 1,3-D Demand After Methyl Bromide Phaseout by Crop

Crop	Lbs.	Adjusted lbs.	Acres
Almonds	1,232,485	1,232,485	4,354
Carrots	1,020,605	1,939,149	10,103
Grapes	1,421,319	1,421,319	5,187
Nurseries	1,572,312	2,872,025	7,111
Peaches	305,467	305,467	1,022
Potatoes	264,134	501,854	1,873
Prunes	189,794	189,794	616
Soil Application	1,849,393	1,979,048	6,154
Strawberries	4,765,296	9,054,062	20,322
Sweet Potatoes	1,109,126	2,107,340	5,994
Tomatoes	192,452	365,659	2,539
Walnuts	336,764	336,764	1,108
STATE TOTAL	15,262,600	24,047,487	77,404

Table 4. Counties Where 1,3-D Township Restrictions are Expected to be Binding

County	# of Townships Over Limit	Adjusted lbs. of 1,3-D Over Limit
Del Norte	1	4,760
Fresno	2	67,753
Kern	8	776,586
Merced	6	1,663,506
Monterey	9	2,687,809
Orange	2	271,297
Riverside	1	60,085
San Diego	1	123,162
San Joaquin	3	115,288
Santa Barbara	2	970,649
Santa Cruz	4	743,407
Shasta	1	28,936
Sonoma	1	26,768
Stanislaus	4	148,210
Sutter	1	29,388
Tulare	3	94,405
Ventura	6	1,855,946
STATE TOTAL	55	9,667,953

Table 5. Average Value of 1,3-D Use by Crop

Crop	$/lb.	Crop (cont'd.)	$/lb.
Almonds	22.87	Onions	8.01
Apricots	17.00	Oranges	17.00
Beans, Dried	1.89	Ornamental Turf	5.75
Beans, Succulent	1.45	Parsley	7.80
Beets	1.09	Peaches	16.00
Broccoli	4.58	Peppers, Bell	12.12
Brussels Sprouts	6.72	Peppers, Chili	6.69
Cabbage	5.00	Perennial Nurseries	17.85
Cantaloupe	3.16	Plum	17.00
Carrots	4.28	Potatoes	2.71
Cauliflower	5.90	Prunes	5.00
Celery	3.35	Soil Application	12.55
Cherries	17.00	Spinach	3.63
Chinese Radish	5.00	Strawberry	6.97
Cotton	5.00	Strawberry Nurseries	4.66
Cut Flowers	2.77	Sugarbeet	2.15
Grapes	26.38	Sweet Potato	3.51
Grapes, Wine	28.06	Tomatoes	9.35
Lemon	17.00	Tomatoes, Processing	3.86
Lettuce, Head	6.60	Uncultivated Areas	17.00
Lettuce, Leaf	7.06	Walnut	4.50
Melons	3.52	Watermelons	4.63
Nectarine	27.00	Yams	3.50

Olives	0.49	

Table 6. Aggregate Value of 1,3-D by County Under Different Distribution Mechanisms

County	Quotas ($)	First come, first served ($)	High value ($)
Del Norte	988,819	983,514	967,024
Fresno	18,332,894	18,082,382	18,380,115
Kern	10,854,325	10,730,525	11,839,733
Merced	6,094,832	6,321,223	10,279,862
Monterey	11,269,995	10,519,964	11,446,162
Orange	3,557,899	3,656,119	3,630,106
Riverside	3,026,621	3,343,666	3,587,832
San Diego	1,794,254	1,758,477	1,849,911
San Joaquin	7,279,926	6,788,889	7,544,844
Santa Barbara	2,249,173	2,088,394	2,268,681
Santa Cruz	3,016,454	2,868,761	3,175,024
Shasta	1,121,587	1,090,496	1,018,312
Sonoma	17,494,554	17,105,136	16,373,143
Stanislaus	8,462,024	8,076,982	8,514,385
Sutter	2,672,789	2,667,388	2,852,928
Tulare	14,065,707	14,028,563	14,118,287
Ventura	3,843,569	3,175,165	4,028,333

Table 7. Aggregate Value of 1,3-D by Crop Under Differing Distributional Mechanisms

Crop	Quotas ($)	First come, first served ($)	High value ($)
Almonds	12,475,773	12,802,625	18,327,554
Broccoli	127,534	140,578	46,155
Carrots	3,092,917	3,097,054	2,885,742
Grapes	44,286,376	44,244,151	43,950,354
Lettuce	796,680	804,052	658,861
Nurseries	11,818,352	11,620,239	11,740,989
Peaches	4,376,826	4,271,840	4,875,922
Peppers	1,534,549	1,855,094	1,867,962
Potatoes	675,189	585,207	628,226
Prunes	917,762	910,624	821,920
Soil Application	29,399,989	29,279,812	29,717,160
Strawberries	18,399,543	15,243,669	19,036,917
Sweet Potato	1,522,511	1,326,709	886,781
Tomatoes	1,413,092	1,579,023	1,214,535
Walnuts	2,137,594	2,106,560	2,162,000
Watermelon	669,550	690,638	596,803

Table 8. Aggregate Value of 1,3-D Use Under Differing Distributional Mechanisms

Distribution Method	$
Unrestricted	200,288,999
Quotas	137,995,679
First come, first served	135,155,902
High value	143,744,940

Table 9. Acreage Not Allowed to be Treated with 1,3-D by Crop

Crop	Quotas	First come, first served	High value
Almond	1,785	1,723	726
Broccoli	317	270	491
Carrots	1,219	1,144	1,918
Grapes	232	219	193
Lettuce	303	291	551
Nurseries	2,113	2,081	2,404
Peaches	104	146	22
Peppers	663	312	511
Potatoes	235	286	191
Prunes	20	25	83
Soil Application	390	410	347
Strawberries	13,541	14,686	13,308
Sweet Potato	3,703	3,986	4,605
Tomatoes	357	140	615
Walnuts	14	37	22
Watermelon	175	125	310
STATE TOTAL	25,867	26,030	27,351