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Special Topic: Chesapeake Bay Management

Welfare Implications of Restricted Triazine Herbicide Use in the Chesapeake Bay Region

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Abstract *The United States Environmental Protection Agency has responsibility under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) to formulate pesticide policies on the basis of risk-benefit analyses. To measure the benefits of pesticide use, one must look at the losses in consumer and producer surpluses that would accompany the banning of a particular pesticide. A typical scenario is one in which the banned pesticide is replaced by another that is more costly and/or less effective. The resulting decrease in supply raises the price of the crop on which the banned pesticide is used, and may alter the prices of substitute and complementary crops as well. This article presents a simulation model of corn and soybean production in the Chesapeake Bay drainage area to investigate the economic implications of a local ban on triazine herbicides. It reports estimates of lost producer and consumer surplus and the effect that the ban would have on the profitability of agricultural production in the region.*

The findings reported in this paper are those of the authors and do not represent the position of USEPA or of RFF. The helpful comments of an anonymous referee are most appreciated. Presented at the Conference on the Economics of Chesapeake Bay Management III, May 27–29, 1987.

Introduction

Environmental policy decisions involving the use of pesticides often have widespread economic impacts that are difficult to predict with any degree of precision. Problems arise in determining the extent of pesticide use, the availability of substitutes, and the effect of pesticides on crop yield and farm income. This article presents a simulation of the economic effects of a ban on triazine herbicides in the Chesapeake Bay drainage system. The triazine compounds are heavily used in the region and have been studied as a possible cause of the disappearance of submerged aquatic vegetation from the Bay (see Kemp 1983).[1] The approach presented here can be used to determine the economic impacts on both consumers and agricultural producers of a regional pesticide ban, and some insights are offered into the role of herbicides on corn and soybean crops in the Chesapeake Bay drainage basin.

The simulated triazine ban includes the use of atrazine, cyanazine, metribuzin, and simazine on corn and soybeans in each of the Chesapeake Bay's main drainage areas. Estimates are derived for the annual use of each of these herbicides on these crops. The yield effects on corn and soybeans associated with the ban are estimated and entered into a model that translates the yield effects into changes in social welfare and regional farm income.

Herbicide Use in Chesapeake Bay Drainage Area

This section presents estimates of the use of herbicides on corn and soybeans in the Chesapeake Bay region. The estimates are of total use over the period of a year, ca. 1982/1984, and are based on average use patterns identified for the individual states in the region.

The first step in the research was to estimate the percentage of corn and soybean acres treated with individual herbicides for the states in the bay region. The primary source of data for these estimates is a report prepared by the U.S. Department of Agriculture, National Agricultural Pesticide Impact Assessment Program (NAPIAP) for the Northeast (USDA 1985). The estimates were cross-checked with those from Cooperative Extension personnel in each state. With only minor exceptions it was concluded that the statewide average treatment pattern would apply uniformly within the states of Maryland, Delaware, New York, Virginia, and West Virginia. The estimates of percentage of corn and soybean acres treated with individual herbicides for these states are shown in Tables 1 and 2. As can be seen, atrazine is the most widely used corn herbicide in the region with 100% of the corn acreage in Maryland, Delaware, and Virginia treated, 90% in New York and 81% in Pennsylvania.

For Pennsylvania, survey data from a report by Pennsylvania State University showed considerable variation in the use pattern among farming regions (Hartwig 1980). Whereas Tables 1 and 2 show the statewide average use pattern for each herbicide for Pennsylvania, specific farm region estimates were used in the calculations of herbicide usage for the state.

The second step was to estimate the average annual application rate per treated acre by herbicide by state for corn and soybeans. The primary source of data for these estimates is the *1982 Crop and Livestock Pesticide Usage Survey* conducted by the Economic Research Service, USDA (1982). The estimates were cross-checked with the recommended use rates for individual states (see Cooperative Extension Service 1985, 1986; Pennsylvania State University 1988; Cornell University 1987). The estimates of

Table 1
Percentage of Corn Acreage Treated with Herbicides by State

	Percentage					
	MD	DE	NY	VA	WV[1]	PA
Atrazine	100	100	90	100	100	81
Alachlor	40	40	30	40	40	24
Butylate	5	5	5	5	5	2
Cyanazine	30	30	10	30	30	19
Dicamba	25	25	15	15	12	4
EPTC	5	5	5	5	5	1[2]
Glyphosate			10			1[2]
Metolachlor	35	35	10	35	35	8
Paraquat	55	55	5	55	55	4
Pendimethalin			10			1[2]
Simazine	35	35	5	35	35	6
2,4-D	20[3]	60[4]	15	17[5]	7	7[2]

Unless otherwise indicated below, the source is USDA 1985:
[1]Sperow 1987.
[2]Hartwig 1980.
[3]Ritter 1987.
[4]Webb 1987.
[5]Hagood 1987.

average annual application rates for corn and soybeans treated with individual herbicides for Maryland, Delaware, New York, Pennsylvania, Virginia, and West Virginia are shown in Tables 3 and 4. These tables suggest that the application rates for the same active ingredient and crop across the states are relatively uniform.

Harvested acreage estimates for corn and soybeans by county are available from the *1982 Census of Agriculture*. To estimate pesticide use, counties are assigned to watersheds, and these assignments are based on visual examination of the U.S. Geological Survey's *Hydrologic Unit Map*. The Chesapeake Bay drainage subbasin was identified for each county and the proportion of the county's land area in each subbasin was determined. Table 5 summarizes the corn and soybean acreage estimates by Chesapeake Bay subbasin. As can be seen, the Susquehanna River subbasin accounts for about half of the corn acreage in the bay region, whereas the Eastern shore accounts for about half of the soybean acreage.

For states other than Pennsylvania, multiplying the estimates of percentage of acres treated with herbicides (Tables 1 and 2) times the average application rate per treated acre (Tables 3 and 4) produces estimates of average annual application rates per census acre. Estimates of total annual use of herbicides on corn and soybeans are calculated by multiplying the estimates of the average annual application rate per census acre by the number of census acres in the Chesapeake Bay region by state.

Since the percent of acres treated with herbicides varies in Pennsylvania according to farm production region, a separate set of herbicide use coefficients was calculated for the typical census acre in each farm production region. By multiplying these use coeffi-

Table 2
Percentage of Soybean Acreage Treated with Herbicides by State

	MD	DE	NY[1]	VA	WV[2]	PA[3]
Acifluorfen	15	15	5	13	13	5[4]
Alachlor	55	55	40	38	30	56
Bentazon	10	10	5	10	10	1
Dinoseb	5[5]	5[6]		4	4	
Glyphosate	10[6]	10[6]	12	12	12	.3
Linuron	90	90	50	58	35	36
Metolachlor	35	35	40	18	30	45[4]
Metribuzin	5	5	50	22	35	16
Oryzalin	5	5		10	10	
Paraquat	50	50		40	40	4
Trifluralin	5	5	10	15	15	8
Vernolate				5	5	
2,4-DB	20[5]	10[6]		2	2	.2
Pendimethalin	10[6]	10[6]	10	12[7]	5	1

Unless otherwise indicated below, the source is USDA 1985:
[1]Hahn 1987.
[2]Sperow 1987.
[3]Hartwig 1980.
[4]Lanini 1984.
[5]Ritter 1987.
[6]Webb 1987.
[7]Hagood 1987.

cients by the number of census acres in each of the bay regions, total annual use is estimated.

Table 6 shows the herbicide use estimates by Chesapeake Bay subbasin; Table 7 shows the herbicide use for the entire region. As can be seen, atrazine is the most heavily used corn/soybean herbicide (3.8 million lbs/yr), followed by alachlor (2.8 million lbs/yr) and metolachlor (1.4 million lbs/yr).

Yield Effects of Individual Herbicides

USDA (1985) estimated the average percentage of corn and soybean yield loss by state for both current levels of herbicide use and after removal of specific herbicides. These estimates, displayed in Tables 8 and 9, were made by Extension Service and Experiment Station personnel in each state.

The estimates in Tables 8 and 9 are drawn directly from the USDA (1985) report on the Northeastern states, which was released as part of the national pesticide assessment by commodity program, a cooperative effort of the state universities and the U.S. Department of Agriculture. The assessment procedure . . . "draws upon the knowledge of experts in entomology, nematology, plant pathology, weed sciences, and related sciences. The experts, in consultation with colleagues both within and among disciplines, were asked to draw upon research and demonstration plots, field disciplines, and pest control surveys to develop the information base." The increased yield loss estimates as a result of hypothetically removing the triazine herbicides were made by identifying the resulting weed problems and alternative control practices. The efficacy of the possible herbicides that would be substituted for the triazines was assessed in terms of each state's growing conditions and farming practices. For example, in Maryland and Delaware, average corn yield losses due to weeds are projected to increase from a current level of 4.9% to 17.9% with the hypothetical removal of the triazine herbicides (Table 8). This projection is partially based on: (1) field plot research that has shown that alternatives to the triazines do not work as well as controlling the spectrum of weed pests in the region's sandy soils, and (2) on the practice of growing corn near to vegetable crops. This practice limits the alternatives to the triazines since several herbicides (such as 2,4-D) would damage the vegetable crops as a result of drift from corn fields (Ritter 1987).

To the extent that the USDA yield loss estimates under- or overstate the potential for herbicide substitution or other actions growers may take to mitigate the losses resulting from a herbicide ban, the estimates of economic loss are similarly misstated.

Economic Assessment Model

The cornerstone of the model is the characterization of the crop-specific producer supply functions. Consider a simple agricultural production function for a single crop,[2]

$$Y = f(x). \tag{1}$$

Table 3
Average Annual Application Rates for Corn Herbicides by State

	(lbs AI/Acre)					
	MD	DE	NY	VA	WV[1]	PA
Atrazine	1.6	1.6	2.0	1.3	1.3	1.6
Alachlor	2.0	2.0	2.0	1.7	1.7	1.7
Butylate	2.3	2.3	4.5	3.8	3.8	3.5
Cyanazine	1.6	1.6	2.5	1.6	1.6	1.5
Dicamba	.3	.3	.4	.2	.2	.5
EPTC	4.5[2]	3.5[3]	5.0	4.5[2]	4.5	2.6[4]
Glyphosate			2.0			1.5[4]
Metolachlor	1.6	1.6	2.2	1.4	1.4	1.7
Paraquat	.4	.4	1.0	.4	.4	.4
Pendimethalin			1.5			1.2[4]
Simazine	2.0	2.0	1.8	1.1	1.1	1.9
2,4-D	1.2	1.2	.7	1.0	1.0	.5[4]

Unless otherwise indicated below, the sources are Maryland/Delaware, USDA 1982; New York, Roberts 1981; Virginia, USDA 1982; Pennsylvania, Hanthorn 1980:

[1]Set equal to Virginia rates.

[2]Cooperative Extension Service 1985.

[3]Cooperative Extension Service 1986.

[4]Midpoint of recommended rates; Pennsylvania State University 1988.

AI = active ingredient.

Table 4
Average Annual Application Rates for Soybean Herbicides by State

	(lbs AI/Acre)					
	MD	DE	NY[1]	VA	WV[2]	PA[3]
Acifluorfen	.34	.34	.50	.50	.50	.50
Alachlor	1.94	1.94	2.50	1.93	1.93	2.50
Bentazon	.50	.50	1.00[4]	1.00	1.00	1.00[5]
Dinoseb	1.17	1.17		.91	.91	
Glyphosate	1.00[6]	1.00[7]	1.10[4]	1.10	1.01	2.50[5]
Linuron	.53	.53	1.00	.60	.60	.50
Metalachlor	1.19	1.19	2.00	1.10	1.10	2.00
Metribuzin	.37[6]	.31[7]	.38	1.50	1.50	.25
Oryzalin	.75[6]	.75[7]		.75	.75	
Paraquat	.17	.17		.47	.47	.35
Trifluralin	1.00	1.00	.75[4]	.69	.69	.60
Vernolate				2.14	2.14	
2,4-DB	.50	.50		.50	.50	.50
Pendimethalin	1.00[6]	1.00[7]	1.25	.80	.80	.85[5]

Unless otherwise indicated below, the sources are Maryland/Delaware, USDA 1982; New York, Roberts 1981; Virginia, USDA 1982; Pennsylvania, Hanthorn 1980:

[1]Hahn 1984.
[2]Set equal to Virginia rates.
[3]Lanini 1984.
[4]Cornell University 1987.
[5]Midpoint of recommended rates; Pennsylvania State University 1988.
[6]Cooperative Extension Service 1985.
[7]Cooperative Extension Service 1986.
AI = active ingredient.

Table 5
Crop Acreage in Chesapeake Bay Subbasins (000)

Subbasin	Corn	Soybeans
1 Susquehanna	1,196	69
2 Eastern Shore	414	506
3 West Chesapeake	90	15
4 Patuxent	39	12
5 Potomac	560	81
6 Rappahannock	118	85
7 York	71	99
8 James	113	77
Total	2,601	944

Source: County estimates from *1982 Census of Agriculture*.

Table 6
Herbicide Use for Corn and Soybeans in the Chesapeake Bay Region:
By Subbasin (1,000 lbs AI/yr)

	Subbasins								
	1	2	3	4	5	6	7	8	Total
Atrazine	1,788	660	145	63	797	154	92	147	3,846
Alachlor	889	852	88	44	483	142	120	133	2,751
Butylate	400	51	10	5	127	22	13	21	649
Cyanazine	321	196	43	18	244	56	34	54	966
Dicamba	65	30	7	3	26	4	2	3	140
EPTC	63	88	20	9	109	27	16	26	358
Glyphosate	44	52	2	1	9	10	12	9	139
Metolachlor	363	429	57	27	292	75	55	71	1,369
Paraquat	188	138	21	10	117	42	34	39	589
Pendimethalin	27	50	2	1	8	8	10	8	114
Simazine	217	285	63	27	261	46	28	44	971
2,4-D	52	129	22	9	89	20	12	19	352
Acifluorfen	<1	27	1	1	5	5	6	5	52
Bentazon	1	28	1	1	6	8	10	8	63
Dinoseb	<1	28	1	1	3	3	4	3	44
Linuron	22	234	7	6	32	29	34	27	391
Metribuzin	20	25	<1	<1	16	28	32	25	146
Oryzalin	<1	21	1	<1	5	7	8	6	48
Trifluralin	1	28	1	1	6	8	10	8	65
Vernolate	0	6	0	0	5	9	11	8	39
2,4-DB	<1	40	2	1	4	1	1	1	50

Subbasins are: 1, Susquehanna; 2, Eastern Shore; 3, West Chesapeake; 4, Patuxent; 5, Potomac; 6, Rappahannock; 7, York; 8, James.
AI = active ingredient.

Denote the output by Y and let the n-vector x represent inputs. Let e be a scalar measuring pesticide application, and $\phi(e)$ be a function of e. If pesticide applications neutrally affect the production of Y,

$$Y = f(x)\phi(e). \quad (2)$$

The corresponding cost function can then be written as,

$$C = [C(P, Y)\phi(e)], \quad (3)$$

where P is an n-vector of input prices. Assuming f(x) is characterized by constant returns to scale, neutral shifts in the production function due to changes in pesticide policy imply, in the case of pesticide bans, proportional decreases in the productivity in all inputs, while leaving the mix of inputs unchanged.[3]

Throughout the analysis, we assume that factor prices remain constant. This assump-

Table 7
Herbicide Use in Chesapeake Bay Region by Crop
(1,000 lbs AI/yr)

	Corn	Soybeans	Total
Atrazine	3,846	—	3,846
Alachlor	1,850	901	2,751
Butylate	649	—	649
Cyanazine	966	—	966
Dicamba	140	—	140
EPTC	358	—	358
Glyphosate	45	94	139
Metolachlor	1,019	350	1,369
Paraquat	476	113	589
Pendimethalin	26	88	114
Simazine	971	—	971
2,4-D	352	—	352
Acifluorfen	—	52	51
Bentazon	—	63	63
Dinoseb	—	44	44
Linuron	—	391	391
Metribuzin	—	146	146
Oryzalin	—	48	48
Trifluralin	—	65	65
Vernolate	—	39	39
2,4-DB	—	50	50

AI = active ingredient.

tion along with hypothesized "pesticide-neutrality" implies that all factor demand equilibria lie on a ray from the origin. Moreover, the ray may be determined from a single observed factor demand equilibrium. As the neutrality of pesticides will not induce any factor substitution if factor prices are held constant, the production and cost functions [equations (2) and (3)] can be treated *as if* they were generated from a linear, fixed input coefficient (Leontief) production process. This concept is a maintained assumption and forms the foundations of our economic assessment model.

Pursuing the supply function derivation under the Leontief assumption, let us consider the producer cost minimization problem. Following Ferguson (1969):

$$\underset{x}{\text{Min:}} \left\{ \sum_i P_i x_i | Y = \min(x_1/a_1, \ldots, x_n/a_n) \right\}, \tag{4}$$

where x_i are the n productive factors; a_i are technological constants conditioned upon weather, soil characteristics, pesticide policies, etc.; Y is the output rate of a single crop; and P_i are the n input prices.

The solution to the above problem implies that the optimal factor demands are·

$$x_i = a_i Y, \tag{5}$$

Table 8

Average Percentage Corn Weed Yield Losses by State[1]

Weed Control Practice	Average % Yield Loss			
	MD/DE	PA	VA	NY
Current controls	4.9	.7	1.3	.7
Remove:				
Atrazine	17.8	17.5	1.3	17.5
Cyanazine	4.9	1.5	7.9	1.5
Dicamba	14.2	8.7	3.0	8.7
Paraquat	35.3	.7	6.2	.7
Simazine	4.9	.7	2.8	.7
2,4-D	4.9	6.2	3.9	6.2
Acetanilides	15.4	1.5	3.6	1.5
Thiocarbamates	4.9	1.6	2.1	1.6
Triazines	17.9	43.8	10.1	43.8

[1]Farm management practices held constant except for additional cultivation and substitution for removed pesticides. New York rate set equal to Pennsylvania; West Virginia not included in the farm income impact analysis.

Source: USDA 1985.

Table 9

Average Percentage Soybean Weed Yield Losses by State[1]

Weed Control Practice	MD/DE	VA
Current controls	7.9	1.8
Remove:		
Acifluorfen	16.7	1.8
Bentazon	16.7	1.8
Linuron	23.3	5.1
Metribuzin	7.5	2.8
Trifluralin	7.5	4.2
Vernolate	7.5	1.9
Acetanilides	40.0	3.2

[1]Farm management practices held constant except for additional cultivation and substitution for removed herbicides. No estimates provided for New York, Pennsylvania, or West Virginia; increased yield loss for these states assumed to be zero for triazine ban (metribuzin).

Source: USDA 1985.

which lead to the minimum cost function

$$C = Y\left(\sum_i P_i a_i\right), \tag{6}$$

and the output supply (marginal cost) equation

$$S_Y = \partial C/\partial Y = \sum_i P_i a_i. \tag{7}$$

If pesticide policies change, the technology constants are affected. We represent this effect by an augmentation term δ, which equals unity under baseline conditions. After a change in pesticide policy, the output supply equation becomes

$$S'_Y = \sum_i P_i\ \delta a_i. \tag{8}$$

Finally, for any region, an upper bound on cultivatable acreage exists (x_1^*). This bound determines the maximum output (Y^*) and implies that the regional supply function becomes perfectly inelastic at Y^*. When productivity is augmented, maximum producible output is

$$Y^{*\prime} = x_1^*/\delta a_1. \tag{9}$$

To perform the welfare calculations, all regional supply functions are horizontally summed to obtain the prepolicy aggregate supply relationship. The aggregate demand relations are drawn from House's (1982) elasticity of demand estimates, in conjunction with assumed demand linearity and zero cross-price effects. Postpolicy values for δ are embedded in the regional supply equations, and the postpolicy equations are aggregated once again. Postpolicy consumer and producer surplus estimates are used to evaluate the net change in economic welfare from pre- to postpolicy.

The database containing the requisite production information is the Firm Enterprise Data System (FEDS), developed and maintained by USDA. FEDS contains sample operating budgets, which describe the complete cost structure for producing an acre of a particular crop in over 200 specific regions of the United State. Each crop- and region-specific prepolicy supply curve in our economic assessment model is based on 1980 FEDS data (the latest available) and factor prices and planted acreage prevailing in 1986.

Figure 1 displays a simple demand and supply diagram for a particular agricultural commodity. The original supply curve is labeled S^0 and the relevant demand curve is labeled D. The market clearing price and quantities are P_m^0 and Q_m^0, respectively, whereas the actual production is Q_p^0 suggesting farmers are short-run profit maximizers with respect to the government administered target price P_t.[4]

We consider a pesticide policy that has the effect of reducing the yields and increasing pesticide costs, thus causing the supply curve to shift upward and to the left. The new market clearing quantity is Q'_m at a price equal to P'_m, whereas actual production is equal to Q'_p. In the hypothetical example depicted by Figure 1, the marginal cost of production rises, the price of the agricultural commodity rises, and the quantity demanded falls. These features of the pesticide policy cause the combined producer and consumer surpluses to change. The net change in this measure of societal welfare is

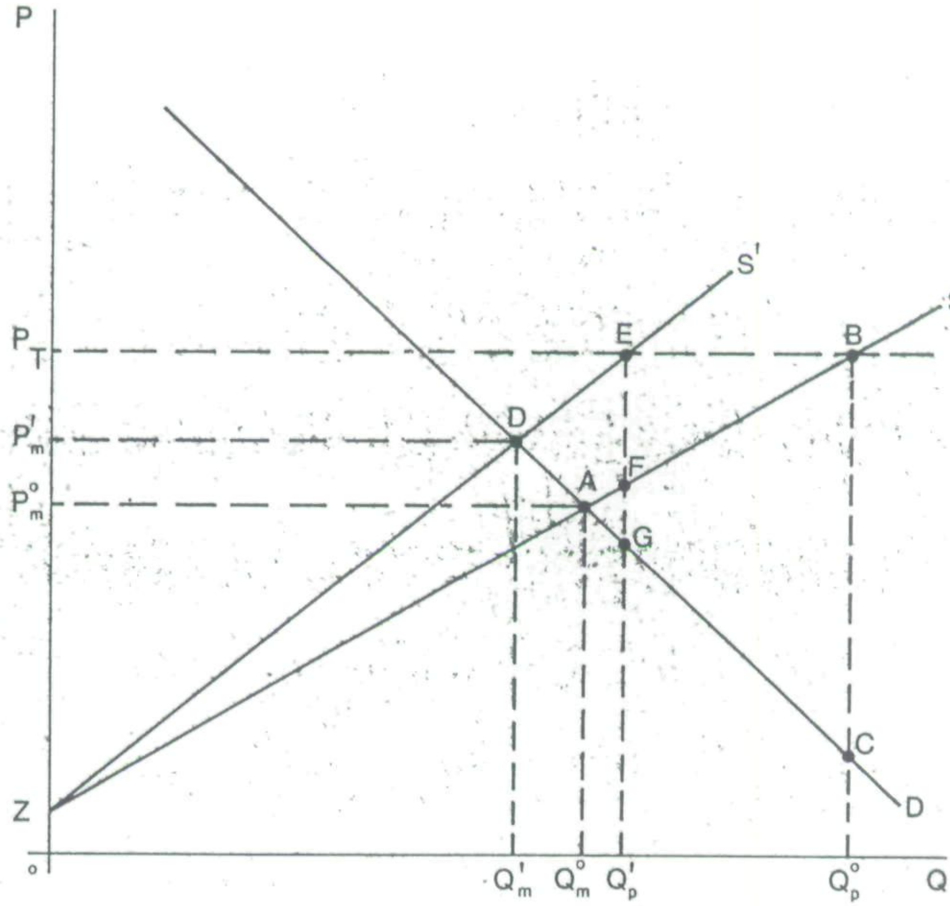

Figure 1 Agricultural commodity demand and supply.

given by the area ZDA and can be employed to value the cost of the policy to society at large (see Kopp et al. 1985).[5]

The model employed in this study contains a linear demand curve similar to that portrayed in Figure 1, but utilizes a stepped supply function, where the height of each step corresponds to the marginal production cost in a specific FEDS supply region and the length of each step corresponds to the total quantity produced in that region. Using this framework, pesticide policies again lead to increases in production cost and reductions in output and are portrayed graphically with the aid of Figure 2 as increases in the heights and reduction in the lengths of steps corresponding to regions affected by the policies.

The hypothetical example portrayed by Figure 2 shows that one of the affected regions, identified as area 1, is an efficient producer where marginal production cost is less than market price. However, the marginal cost of area 2 exceeds the market price P_m, and this area is able to make a profit due to the agricultural policy that provides a target price P_t (and associated deficiency payment) greater than the market price.

The situation portrayed by Figure 2 describes that effect of a triazine ban in the Chesapeake Bay drainage area. Some areas affected by the ban are efficient producers and their loss in producer surplus, analogous to area 1, is estimated by the model. On the

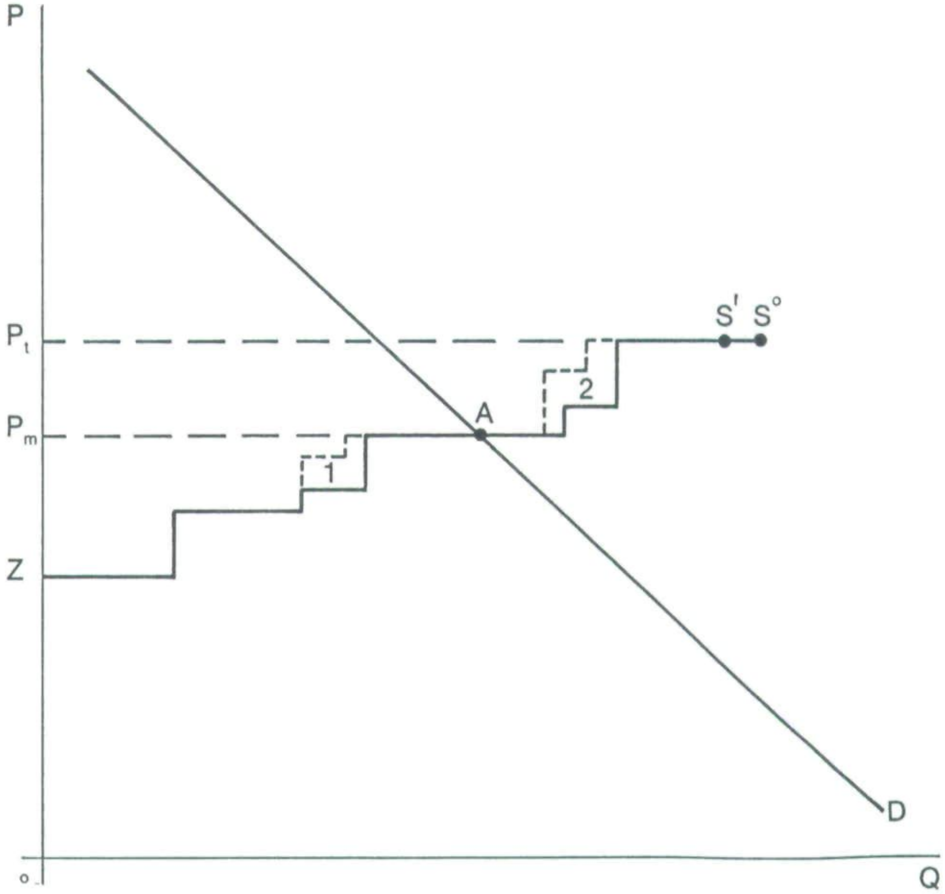

Figure 2 Effect of pesticide policies.

other hand, some areas are relatively inefficient and suffer profit losses due to the pesticide policy. These losses are estimated by the model and are analogous to area 2. In the case of corn, where the majority of corn-producing regions are not affected by the policy, the market price of corn remains unchanged and the only welfare effects are associated with the lost producer surplus and the decline in profits.

Table 10 presents the results of two hypothetical pesticide bans discussed in the previous section. For each policy we examined the effect of yield loss and added pesticide cost on agricultural production functions for corn and soybeans in the Chesapeake Bay area. Using these supply relationships and the model described previously, we present changes in total production and the net change in producer and consumer surplus.

The information in Table 10 describes the loss to society resulting from the hypothesized pesticide policies. Although these losses may be spread thinly over many segments of the population, farmers in the Chesapeake Bay area will bear the brunt of the cost. To consider these local agricultural impacts, Table 11 shows the estimated declines in the profits of state corn producers due to the ban on triazines under scenario B (impacts on soybean producers are trivial).

The local agricultural impacts of a ban on triazines have been quantified in terms of

Table 10

Estimates of Welfare Loss Associated with the Illustrative Pesticide Policies

	Soybean Scenario		Corn Scenario	
	Scenario A[1]	Scenario B[2]	Scenario A[1]	Scenario B[2]
Change in production thousands of bushels	−14	−14	—40,500	−40,500
Net change in producer[3] and consumer surplus thousands of dollars	−299	−795	−4,000	−70,000

[1]Scenario A assumes a $7.50 increase in per acre pesticide cost as a result of the ban on metribuzin (soybeans) and triazines (corn).

[2]Scenario B assumes a $12.50 increase in per acre pesticide cost. The $12.50 increase in pesticide cost should be viewed as an upper bound on the potential cost increase.

[3]Since the market price did not change by a significant amount, there is no significant change in consumer surplus, only a decline in producer surplus.

lost profits. Profits are calculated as the difference between gross revenues and production costs. We employ the 1986 target price for corn ($3.03 per bushel) in the revenue calculations, whereas cost is calculated as the expenditures on the sum of both fixed and variable factors of production.

Generally speaking, in competitive markets profit lost would be equal to the change in producer surplus; however, as noted above, in the case of subsidized markets such as corn, lost profits can greatly exceed lost producer surplus. This inequality between profit and producer surplus loss is due to the fact that producers incurring marginal costs in excess of the market price ($2.35) are not included in the producer surplus estimates. A

Table 11

Distribution Impact of Corn Scenario B: Declines in Profit by State in Millions of Dollars

State	Lost Profits[1]
Delaware	$ 3
Maryland	33
New York	39
Pennsylvania	89
Virginia	17
Total	$183

[1]Profits are calculated as the difference between the sum of fixed and variable costs of production and the 1987 target price for corn set by the Food Security Act of 1985 at $3.03 per bushel. In 1987 the market price of corn was approximately $2.35 per bushel.

large portion of corn production in the Chesapeake Bay region exists on this; due to the existence of the subsidized $3.03 target price, the profit loss we calculate exceeds the lost producer surplus. In our example of the triazine scenario B, lost producer surplus amounts to $70 million, whereas aggregate profit loss is estimated to be in excess of $180 million. In terms of lost profits, Pennsylvania is hardest hit, followed by Maryland and New York.[6]

Some caveats with respect to these results should be borne in mind. Those particular aspects of the modeling structure that bear significantly upon the results are discussed in Kopp et al. (1985). The results of this study are most sensitive to the USDA estimates of yield loss and increased pesticide cost. As stated previously, if the USDA estimates do not accurately account for possible herbicide substitution or other producers mitigate the effects of the pesticide ban, the economic impacts reported in Tables 10 and 11 will be misstated. Moreover, both our assessment model and the USDA yield estimates assume taht the basic agricultural practices will not change in any substantive way in response to the ban. This implies, for example, that a no-till farm practice will not be replaced by a tillage practice in response to the ban. Certainly, one can imagine pesticide bans sufficiently broad in their impacts as to induce such changes, but since we have no information describing the pattern of agricultural practice evolution as a result of such a ban, we have not included the possibility of such events in this present analysis.

Conclusions

The relationships among agricultural practices, pesticide use, and environmental quality concerns can be complex. One relationship not explored in the simulations in this article is the relationship between the practice of limited tillage farming and pesticide use. Limited-till farming has been adopted by many corn growers in Maryland and Delaware and is considered an environmentally beneficial practice since it lessens the erosion of topsoil. However, limited-till requires additional use of herbicides to control weeds. A ban limiting herbicide use in the Chesapeake Bay area could force limited-till farmers to return to conventional tillage, resulting in increased sedimentation in Chesapeake Bay. In drainage areas farther from the bay, limited-till farming is not as popular, and the environmental consequences of an herbicide ban could be quite different.

Another aspect complicating policy decisions involving pesticide use is the continual change in the types of pesticides used on crops and the strategies used for pest control. As older products become less effective, newer products are introduced, and other nonchemical means for controlling agricultural pests are promoted. It is difficult to predict what the choices of pesticides used on any particular crop will be in the future.

This article estimates the amount of triazine herbicides used in the Chesapeake Bay drainage area and simulates the economic effects of a potential ban on their use. Although such a ban is not now under consideration by the U.S. Environmental Protection Agency or the states, this methodology could be used to simulate the economic effects of other more likely targets of actions to protect the water quality of the bay or to further control pesticides that pose unreasonable risks to the environment.

Notes

1. Triazine compounds have since been discounted as a cause of environmental degradation in the Chesapeake Bay.

2. A sensitivity analysis (Kopp et al. 1985) shows that welfare estimates arising from a crop-switching model are little different than those from a single crop model.

3. The assumption of pesticide neutrality is similar to an assumption employed in Kopp et al. (1985) termed ozone neutrality. In this earlier work, increases in ambient ozone concentrations were found to reduce the yields of major field crops but not to differentially affect the productivity of the factor inputs. This "neutrality" simplifies the production activity modeling since changes in ozone will not induce input substitutions in addition to yield losses. The same neutrality with respect to herbicide bans has not, to our knowledge, been systematically investigated. We assume neutrality here for modeling ease.

4. Of course, in the case of soybeans there is no target price, only a support price (loan rate).

5. Following Lichtenberg and Zilberman (1986), we note that the agricultural policy giving rise to the target price P_t generates a dead weight loss to society equal to the area ABC. The dead weight loss may be defined using Figure 1 as the difference between the cost of producing the surplus output ($Q_p^0 - Q_m^0$) given by the area under the line segment AB and the value of the surplus given by the area under the demand curve from A to D. After the supply curve shifts in response to the pesticide policy, the new dead weight loss is equal to the area DEG. The difference in the areas ABC and DEG depends upon the elasticity of demand and supply, and the nature of the supply curve shift. If the dead weight loss grows in response to the pesticide policy, the welfare losses due to the policy are exacerbated; similarly, declines in dead weight loss helps to mitigate the welfare loss due to increased resource use. If one desired to abstract the pesticide policy analysis from consideration of national agricultural welfare implications, one could calculate the additional societal resources (i.e., agricultural factors of production) required to produce a given level of agricultural products with pesticide bans in place. Such a measure of resource cost is itself a valid indicator of social loss (see Diewert 1983). In the context of Figure 1, the added resources required to produce output Q_p' are equal to the area ZEF.

6. Pennsylvania experiences the greatest loss due to the magnitude of its planted corn acreage.

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