Short-Run Welfare Implications of Restricting Fungicide Use in Vegetable Production

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Pesticide use in agriculture has resulted in several human health and environmental concerns. For example, concerns about transporting pesticide, pesticide applicator safety, groundwater contamination, and pesticide residues in food are now more prominent in the public perception than perhaps ever before.

A popular public policy response to concerns about pesticides in the environment and in food has been the suspension or cancellation of registered pesticide uses. Apart from their impact as environmental quality and food safety controls, these "pesticide bans" can have important economic consequences of which regulators should be mindful in their deliberations about pesticide suspension or cancellation.

According to a recent study, fungicides (pesticides used to control plant diseases) account for 60 percent of the estimated oncogenic (tumor formation) risk from pesticide residues in food (National Research Council). Of particular concern are potential fungicide residues in commonly consumed vegetables. This article presents estimates of the short-run economic consequences of a ban on fungicide use on nine major vegetable crops. We base this article on information provided by plant pathologists in implementing the National Agricultural Pesticide Impact Assessment Program, U.S. Department of Agriculture (USDA).[1]

Economic Analysis Model

The short-run economic welfare implications of a pesticide ban can be very difficult to assess. While possible cost of production changes and corresponding food price changes can be difficult to estimate, neither calculation necessarily sheds any light on the benefits from removing or reducing the pesticide load in the environment. For example, we rarely account for economic benefits due to improved environmental quality and reduced risks to human health in measuring the impact of pesticide cancellation. Typical measurement of market impacts in production and consumption of the agricultural commodities involved may provide useful information if regulators are mindful of these other benefits which we do not quantify.

We may estimate market welfare impacts of a pesticide ban using the maximum willingness to pay concept (Just, Hueth, and Schmitz). This technique has been pursued (typically ignoring environmental quality and human health risk impacts) via approximating economic surpluses (areas defined relative to demand and supply curves) in analyzing the welfare consequences of a pesticide ban in different regions (for example, Lichtenberg, Parker, and Zilberman). In particular, regional impacts of a pesticide ban may differ since producers in different regions may face different pest problems and may not use certain pesticides in some circumstances.

The following market model may be used to estimate the short-run welfare implications of a pesticide ban:

$$D = D(P) \quad (1)$$

$$S^u = y_o^u A^u \quad (2)$$

$$S^n = y^n A^n \quad (3)$$

$$D = S^u + S^n \quad (4)$$

where;

D = quantity of crop demanded

P = crop price

S^u = quantity of crop supplied by pesticide users

y_o^u = crop yield per acre among pesticide users

A^u = crop acreage of pesticide users

S^n = quantity of crop supplied by pesticide nonusers

y^n = crop yield per acre among pesticide nonusers

A^n = crop acreage of pesticide nonusers.

The model solution provides equilibrium values for crop price, crop quantity demanded, and crop quantity supplied by pesticide users and nonusers denoted by P_o, D_o, S_o^u, and S_o^n, respectively.

If regulators ban a pesticide, we assume users crop yield per acre to change to y_1^u and production cost per acre to change from C_0^u to C_1^u. We assume that pesticide nonusers crop yield per acre, y^n, and crop production cost per acre, C^n, are unaffected by the ban. The model solution corresponding to the pesticide ban gives equilibrium values for crop price, crop quantity demanded, and crop quantity supplied by pesticide users and nonusers denoted by P_1, D_1, S_1^u, and S_1^n, respectively.

With the model and notation above, the welfare impact of the pesticide ban on consumers, I^c, is estimated as

$$I^c = -[(P_1-P_o)D_1 + .5(P_1-P_0)(D_0-D_1)] \quad (5)$$

while welfare impacts on pesticide users, I^u, and nonusers, I^n, is

$$I^u = [P_1 y_1^{\ u} - P_0 y_0^{\ u}]A^u + (C_0^{\ u} - C_1^{\ u})Au \qquad (6)$$

and

$$I^n = [P_1 - P_0]y^n A^n, \text{ respecitvely.} \qquad (7)$$

The welfare impacts I^c, I^u, and I^n estimate the maximum willingness to pay of the effected market participants for the institution of a pesticide ban. Each welfare impact can be negative or positive depending on what the participant loses or gains from the ban.

Crop Production Scenarios and Parameter Estimates. We pursue an economic analysis in this study for the cases of nine major vegetable crops produced in the United States. The crops considered are beans, carrots, celery, cucumbers, lettuce, onions, sweet corn, tomatoes, and potatoes. From among these vegetable crops, we estimated fungicide residues in beans, lettuce, and tomatoes alone to represent 16 percent of the total oncogenic risk due to pesticide residues in major foods (National Research Council). We evaluated two scenarios regarding bans on fungicide use on the nine vegetable crops studied.

The first fungicide restricting scenario considered involved assessment of the impact of a ban on the use of a class of fungicides often referred to as ethylene bisdithiocarbamate's (EBDC's). The EBDC fungicides, the most widely used group of fungicides in the world, include the fungicides *mancozeb*, *maneb*, *mitiram*, and *zineb*. In recent years, mancozeb has been the predominant EBDC used by vegetable growers. Here, the use of fungicide chlorothalonil on vegetable crops is permitted as well as other fungicide alternatives for disease control. In the second scenario, we considered the economic impact of a ban on the use of *chlorothalonil* while permitting use of alternative fungicides, including the EBDCs. Chlorothalonil is now a popular fungicide used to control various vegetable crop diseases in different regions of the United States. The EBDCs and chlorothalonil share about 45 percent of the U.S. market, in terms of active ingredients applied, of the major fungicides used in agriculture (National Research Council).

Parameter estimates needed to carry out the analysis based on the previously specified economic model include information on yields, control costs, and acreages involved ($y_0^{\ u}$, $y_1^{\ u}$, $C_0^{\ u}$, $C_1^{\ u}$, A^u, A^n) as well as demand elasticities. Table 1 shows the technical parameter estimates used in this study corresponding to each scenario and also shows the source of the parameter estimates (Fungicide Benefits Assessment Project, Davis; Johnston). For each of the nine vegetable crops and two production scenarios considered, we used the economic model with the market and technical parameters to estimate economic welfare impacts. Extension plant pathologists compiled state-by-state estimates of acres planted

Table 1.
Parameter Estimates Utilized in Estimating Economic Welfare Impacts[a]

	y_0^u	y_1^u	$c_0^u - c_1^u$	A^u	A^n
	Cwt.	Cwt.	Dollars	1,000 ac.	1,000 ac.
EBDC ban					
Beans	20.2	19.8	-13.92	531.7	953.4
Carrots	268.8	263.3	-23.34	47.6	27.9
Celery	557.0	552.0	-104.13	14.2	21.8
Cucumber	151.2	138.1	-31.30	132.2	251.8
Lettuce	302.0	281.5	-161.17	98.0	145.0
Onions	363.0	351.7	-34.45	101.1	69.9
Sweet corn	87.1	82.7	-12.52	207.1	456.8
Tomato	506.0	449.9	-12.45	176.5	219.7
Potato	263.6	252.1	-34.19	680.7	472.7
Chlorothalonil ban					
Beans	20.2	19.9	4.50	195.7	1,289.4
Carrots	268.8	261.3	27.00	34.0	41.5
Celery	557.0	533.6	12.06	13.5	22.5
Cucumber	151.2	143.1	-7.62	115.0	269.0
Lettuce	302.0	302.0	b	b	243.0
Onions	363.0	332.6	-3.95	41.3	129.7
Sweet corn	87.1	86.0	7.36	101.1	562.8
Tomato	506.0	412.5	9.00	111.9	284.3
Potato	263.6	261.3	-1.52	360.4	793.0

a. Scenario vegetables include those grown for both fresh and processing markets.
b. No use reported.
Source: Fungicide Assessment Project (Davis, Johnson).

and treated with fungicides, numbers and rates of fungicide application, target diseases, expected yield changes and alternatives to these fungicides for each vegetable crop. The pathologists based the estimates on expert opinion by pathologists in their state.

We developed base yields, production, crop exports and commodity price data from USDA and state agriculture department publications. The acres treated quantity is the sum of the estimated acres treated for each state. The projected changes in yields are weighted averages based on the expected yield changes and treated acres for the individual states.

We determined disease control costs using unpublished estimates and pesticide distributor price lists. We developed price elasticities of demand using published sources (Huang, Pinstrup Andersen). We based the control cost changes on expected alternatives, estimated application rates, and fungicide prices from pesticide handbooks, chemical price lists, and agricultural chemical companies.

We note before considering short-run welfare results that limiting available pesticides can have severe consequences for the effectiveness of remaining pesticides. As EBDC's and chlorothalonil provide broad spectrums of control, there is little chance of pathogens developing resistance to these major-use fungicides. In contrast, plant pathologists warn that fungicides which are more specific in their mode of action and spectrum of control are likely to develop resistance problems if consistently used alone. Examples include metalaxyl and triadimefon. These specific fungicides are often either formulated with an EBDC or chlorothalonil or used in combination with an EBDC or chlorothalonil in spray schedules. Studies by Miranowski and Carlson and Dover and Croft show the importance of control strategies to avoid pest resistance.

Results

Examining the effects of bans on uses of EBDCs and chlorothalonil illustrate the short-term economic implications of withdrawing from use any agricultural registered pesticide used on crops when equally efficient replacements are not apparent. The primary effects of using less efficacious alternatives are redistribution of revenue between user and nonuser growers and higher commodity cost to consumers.

The EBDCs, as a group, and chlorothalonil have similar but not equal spectrums of control. Although each fungicide is the major alternative to the other for disease control on the vegetables in this study, there are differences in efficacy and cost of control. Alternatives considered in the study include copper hydroxide, copper sulfate, iprodione, anilazine, triadimefon, benomyl, metalaxyl, ziram, tin and sulfur. According to plant pathologists, the alternatives to both EBDCs and chlorothalonil are less efficacious and their use typically results in lower yield. This, of course, depends on the occurrence and severity of disease. In this study, we considered all alternatives available in each of the two scenario bans. We based the use of each of the alternatives in determining economic effects on their spectrum of control and current proportion of acres treated.

Diseases to control, which vary by crop and region, include blights, rots, molds, rust, spots, cankers, Rhizoctonia, Sclerotinia, anthracnose, downy mildew, powdery mildew, Cercospora, Alternia, Botrytis, purple blotch, Colletotrichum, Septoria, and damping-off. Temperature and humidity influence the occurrence and severity of these diseases.

Scenario 1: An EBDC Ban. The EBDCs represent both extensively and intensively used fungicides on the nine crops with about 2.0 million treated acres. Model results shown in Table 2 show that prices would increase, ranging

Table 2.
Projected Crop Prices with EBDC Ban or Chlorothalonil Ban

Crop	1985-89 annual price	Price elasticity of demand	Projected price (change) EBDC ban		Chlorothalonil ban	
Beans	11.36	-0.60	11.49	(1%)	11.40	(0%)
Carrots	9.85	-0.52	10.09	(2%)	10.09	(2%)
Celery	12.13	-0.61	12.20	(1%)	12.44	(3%)
Cucumber	9.37	-0.78	9.73	(4%)	9.56	(2%)
Lettuce	14.02	-0.37	15.06	(7%)	14.02	(0%)
Onions	10.17	-0.78	10.41	(2%)	10.43	(3%)
Sweet corn	5.70	-0.87	5.80	(2%)	5.71	(0%)
Tomato	3.35	-0.82	3.55	(6%)	3.56	(6%)
Potato	5.80	-0.84	5.98	(3%)	5.82	(0%)

from seven percent for lettuce to one to two percent for beans, carrots, celery, onions, and sweet corn. The higher prices would change revenues to all growers, both users and nonusers of the banned fungicides. For all growers, an EBDC ban would cause a total change in grower revenue of about $9 million, ranging from a $30 million gain to lettuce growers to a $16 million loss to potato growers (Table 3).

For previous users, a ban of EBDC fungicides would result in short-term decreases in revenues to some growers and increased revenue to others. This would depend on the extent to which reductions in yield and associated higher prices offset higher control cost. For the user-growers of the nine crops, an EBDC ban would result in an estimated $110 million total decrease in revenues. Potato growers would account for $38 million of the $110 million in lost revenues. As noted earlier, the estimates reflect short-term effects only. Among the longer term mechanisms needed for identifying longer term impacts, the uncertainty of determining the increased pest resistance which occurs with the use of fewer pesticides would be important. Longer term effects on changes in costs and returns also would be affected by new chemical and nonchemical controls, and other factors.

For nonuser growers, we estimated the higher vegetable prices with no change in yield to result in an expected windfall gain of $119 million in increased revenue with the ban of EBDC's. The short term higher prices with no change in yield or control cost would range from an estimated $45 million to lettuce growers to $1-22 million to the other vegetable growers.

We estimate a ban on EBDC's to increase short-term costs to consumers of these vegetables by a total of about $219 million. We expect the total impact on producer revenue and consumer cost, or the impact on society of banning EBDC use on the nine vegetables, to be a decline in total welfare of $210

Table 3.
Projected Changes in Grower Net Revenue and Consumer Cost

	Projected change in:				
Crop	All grower net revenue	Users net revenue	Nonuser net revenue	Consumer cost	Total impact
			----- $1,000,000 -----		
EBDC ban					
Beans	-5.82	-8.40	2.59	4.01	-9.83
Carrots	1.21	-0.63	1.83	4.93	-3.72
Celery	-0.93	-1.79	0.85	1.41	-2.34
Cucumber	-0.18	-13.82	13.64	20.49	-20.68
Lettuce	30.08	-15.34	45.42	75.08	-45.00
Onions	-0.48	-6.57	6.09	14.76	-15.24
Sweet corn	-1.91	-6.02	4.11	5.92	-7.83
Tomato	3.09	-19.35	22.43	39.45	-36.37
Potato	-16.02	-38.17	22.15	53.35	-69.37
Total	9.04	-110.09	119.11	219.40	-210.38
Chlorothalonil ban					
Beans	1.32	0.36	0.97	1.11	0.21
Carrots	3.18	0.52	2.66	4.80	-1.62
Celery	2.51	-1.41	3.93	6.23	-3.72
Cucumber	1.41	-6.43	7.84	11.10	-9.69
Onions	3.11	-9.31	12.42	16.20	-13.10
Sweet corn	0.84	0.22	0.62	0.73	0.11
Tomato	6.47	-24.20	30.67	41.63	-35.16
Potato	0.35	-3.58	3.94	5.72	-5.36
Total	19.19	-43.83	63.05	87.52	-68.33

million. Welfare losses would range from an estimated $69 million on potatoes to $2 million on celery.

Scenario 2: Chlorothalonil Ban. Chlorothalonil is the singularly most extensively used fungicide on the nine vegetable crops, with an estimated total of 387,000 treated acres. As shown in Table 2, we estimated prices to increase, ranging from six percent for tomatoes to zero to three percent for the other vegetables. The higher prices would increase revenues to all growers by $19 million, ranging up to a $6 million gain to tomato growers. For the user growers of the nine crops, a chlorothalonil ban would result in an estimated $44 million loss in revenues.

For nonuser growers, we estimated the higher vegetable prices with no change in yield to result in an expected windfall gain of $63 million in increased revenue with the ban of chlorothalonil. We also estimated a ban on chlorothalonil to increase short-term costs to consumers of these vegetables by a total of about $88 million. We expect the total impact on producer revenue and consumer cost, or the impact on society, of banning chlorothalonil use to be a decline in total welfare of $68 million.

We emphasize that the illustrated impacts reflect bans on registered uses of only nine crops. Farmers use EBDC's and chlorothalonil, however, for disease control in many vegetable, fruit, and other specialty crops, as well as some field crops.

Policy Implications

Short-run welfare impacts associated with banning the EBDC's or chlorothalonil on vegetable crops will have adverse economic consequences for consumers and user growers. However, an opinion common to the public, and some legislators and regulators of agricultural pesticides is that such pesticides that have potential adverse effects on human health or the environment should be removed from use as quickly as possible. In past years, many have criticized the Environmental Protection Agency for its slow removal of the higher risk pesticides. However, in some respects, the agency's general time frame of several years, from initial review to a decision to ban, has reduced economic shocks of some bans on production costs and short term prices.

Compared with "quick decisions" of less than a year, some positive effects of giving longer notices of potential bans are: (a) more user growers have enough notice to adjust to alternative controls or alternative crops; (b) a reduction in the short-term effects of bans on consumer prices of those foods important to good health; (c) less impact by imports on U.S. commodity markets; and (d) less opportunity for resistance problems that occur with fewer alternative chemical controls.

An alternative to cancellations and suspension of pesticides is the adjustment of maximum legal limits. While this alternative is available under current regulation, it is not considered as a first choice alternative. However, this is often the first choice in Canada and some European countries (Carlson). This regulatory alternative may offer a means of reducing human health and environmental risks while softening short-run economic consequences.

By adjusting the maximum legal limit, we allow farmers, processors, and others to adjust their application. For example, they can use lower dosages, limit late season use, or switch methods of application to prevent crops having unacceptable tolerances and being confiscated or rejected by private or public inspectors. An example specific to fungicide use, would be to lengthen the days to harvest interval from the last application.[2] Many of the EBDC uses on vegetables, for example, are important during the early to midseason growth period. By extending the days to harvest interval, the levels of residue on the harvested commodity would be reduced. The adjustment of maximum legal limits, as a first choice alternative, could be used as a prelude to, or as an alternative to the decision to cancel or suspend a registered pesticide use. We expect this alternative to lessen the adverse impact of regulation relative to an outright ban.

In contrast with most field crops, vegetables and other specialty crops represent limited markets to pesticide manufacturers, formulators, and distributors. Further, these crops require more intensive use of pesticides in number of applications. In addition to the adjustment of the maximum legal limit, other programs that would focus indirectly on reducing pesticide use include: (a) enhanced programs to inform minor use and specialty crop pesticide applicators concerning risks and regulations; (b) enhanced use of Extension personnel in providing advice to growers and monitoring use of pesticides; (c) enhanced record-keeping required of applicators to monitor use of pesticides used on vegetables, fruits, and other minor-use specialty crops, nearly all of which require intensive use of chemical control; and (d) enhanced record-keeping required of manufacturers and distributors on minor use and specialty crop pesticides exported and sold in domestic markets.

It is possible that such alternatives to outright pesticide bans can protect human health and the environment. This may be done without inducing the high cost of short-term production cost and commodity price shocks that redistribute revenue among growers and increase cost to consumers.

Notes

1. The estimates were developed for research purposes and are not an official USDA response to any Environmental Protection Agency regulatory action.
2. This was the major recommendation proposed to reduce the use of fungicides in the U.S. Department of Agriculture study (Johnston).

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