A LOOK AT THE ECONOMIC EXTERNALITIES OF PESTICIDE USE

HUH SHIN-HAENG*

The use of agricultural pesticides has been a controversial issue. Manufactured pesticides used in agricultural production by farmers have increased dramatically over the past three decades to make more food available. However, their indiscriminate use has created special problems such as poisoning, toxic residues on foodstuffs, interaction hazards on man, and harm to fish and beneficial wildlife.

This paper deals with external problems related to pesticide use and tries to solve conceptually some of the problems mentioned above. The specific objectives of this paper are; to describe the effects of pesticide use, to find out the reason for the failure to achieve efficiency in production, and to seek possible solutions for selected problems.

THE EFFECTS OF PESTICIDE USE

In general, the effects of pesticide use can be classified as either beneficial effects or adverse spillover effects. The benefits of pesticide use in agricultural production include yield increases, input savings, and improvements in the quality of agricultural products. Headley[1] found that the marginal value of a one-dollar expenditure on chemical pesticides was approximately $4.00. If the marginal product were interpreted as an average value, he estimates, it implies annual benefits of about $1.8 billion attributable to chemical pesticides used on crops in the U.S. Therefore, he concludes that chemical pesticides are a highly productive input, comparable to commercial fertilizer, and that the marginal value product of pesticide exceeds the marginal factor cost by a considerable amount. Headley and Lewis[2] indicated that the use of insecticides during 1945–1958 has been associated with yield increases in some selected areas averaging from 41 to 54 percent.

Chemical weed control practices reduce labor requirements on farm. Both studies done independently by Harris[3] and Holstein[4] show that it

* Senior Fellow, Korea Rural Economics Institute.

[1] J.C. Headley "Estimating the Productivity of Agricultural Pesticides", *American Journal of Agricultural Economics*, February 1968, p. 13 and 21.

[2] J. C. Headley, and J. N. Lewis, *The Pesticide Problem: An Economic Approach to Public Policy,* Resources for the Future, Inc., The Johns Hopkins Press, 1967.

reduced labor requirements on about 1 million acres of cotton grown annually in Mississippi by some 20 hours per acre. As a result, weed control costs were reduced by an estimated $10 per acre and, in addition, mechanical harvesting operations were facilitated and the quality of the lint improved. It is difficult to estimate quality effects, but there is a considerable body of experimental data relating to fruit and vegetable crops. As an example, the proportion of wormy fruit in California in 1956 was 21 to 23 percent without insecticides and 0.5 percent using guthion.[5] At present no one could estimate all the benefits from using chemical pesti cides in a country

As already mentioned, adverse spillover effects can be listed as pesticide residues, hazards to man, and harm to fish as well as beneficial wild life. Headley and Lewis stated in relation to pesticide residues in the soil as follows:[6]

> "The increasing quantities of chemicals applied directly to the soil to control weeds and nematodes and the deposition of large quantities of insecticides and herbicides applied directly to the soil to control weeds and nematodes and the deposition of large quantities of insecticides and herbicides applied in above-ground pest control practices have caused some concern as to the possible effects on populations of beneficial soil organisms and chemical properties of soils."

One evidence of pesticide residues, found in 1950, was that one-half of the amount of benzene hexachloride (BHC) applied to the soil was still present after 3 years. This chemical has caused problems of off-flavor in potatoes and canned carrots, tomatoes, lima beans, peaches, and plums.[7]

Headley and Lewis also point out many harmful effects on human health, which may arise from occupational hazards in the formulation and application of pesticides, from accidental or incidental exposure of members of the public to toxic substances, and from toxic residues on food or raw materials following the treatment of plants, livestock, and food containers.[8] In addition, environmental pollution problems caused by the manufacture and use of pesticide are serious.

Although there are many beneficial effects of pesticides on fish and wildlife, many pesticide chemicals are highly toxic to fish and animals. For instance, pesticide use in agriculture, residential areas, and forestry are harmful to animal populations.

[3] V. C. Harris, "Weed Control in Cotton Over a Ten Year Period by Use of the More Promising Materials and Techniques", *Weeds*, Vol. 8, 1960.

[4] G. T. Holstein Jr. et al., "Weed Control Practices, Labor Requirements and Costs in Cotton Production", *Weeds*, Vol. 8, 1960.

[5] Headley and Lewis, *op. cit.*, p. 67.

[6] Headley and Lewis, *op. cit.*, p. 77.

[7] C. H. Mahoney, "Flavor and Quality Changes in Fruits and Vegetables in the United States Caused by Application of Pesticide Chemicals", *Residue Review*, Vol. 1, 1962.

[8] Headley and Lewis, *op. cit.*, p. 81.

THE FAILURE OF PARETO OPTIMALITY

In general, an external effect is commonly recognized when the activity of one party affects the utility or production of another party that has no control over the initial party's action. As a consequence it is concluded that the existence of external economies in a competitive industry entails an equilibrium output that is below optimal.[9] In other words, the existence of an externality implies that the equilibrium solutions attainable may not be Pareto optimal, unless special arrangements are made.

Based on the previous review in relation to adverse effects of pesticide use, let us formulate an external relationship between different production functions. For simplicity, if we classify all goods into two categories: Y goods for which pesticides are used; and Q goods which are indirectly affected by pesticides used for Y goods, assuming that there are positive relationships between Y goods and pesticide and indirect-negative rela tionships between the Q goods and pesticide. Suppose that land and capital except pesticide are fixed in a whole economy, then Y is a function of labor (L_y) and pesticide (E_y).

$$Y = Y(L_y, E_y) \tag{1}$$

Without loss of generality, the following are assumed to be held:

$$\frac{\partial Y}{\partial L_y} > 0, \quad \frac{\partial^2 Y}{\partial L_y^2} \leq 0$$

$$\frac{\partial Y}{\partial E_y} > 0, \quad \frac{\partial^2 Y}{\partial E_y^2} \leq 0.$$

Even though pesticide is not used for Q goods, the output of Q goods depends in part upon the amount of Y goods produced by using pesticides. Thus, Q is a function of labor(L_q) and Y:

$$Q = Q(L_q, Y). \tag{2}$$

Substituting (1) into (2) yields

$$Q = Q(L_q, Y(L_y, E_y)). \tag{3}$$

Note the producers of Q goods could not control the factors used by producers of Y goods.

Total profit function from the society's point of view can therefore be written

$$\Pi = P_y Y(L_y, E_y) + P_q Q(L_q, Y(L_y, E_y)) - w(L_y + L_q) - P_e E_y. \tag{4}$$

To maximize the profit take the derivative of Π with respect to L_y, L_q, and E_y and set them equal to zero. Then, through a simple algebra, we get

[9] E. J. Mishan, *Economics for Social Decisions: Elements of Cost-Benefit Analysis*, Praeger, 1973, p. 85.

$$P_y \frac{\partial Y}{\partial L_y} + P_q \frac{\partial Q}{\partial Y} \frac{\partial Y}{\partial L_y} = w \tag{5}$$

$$P_q \frac{\partial Q}{\partial L_q} = w \tag{6}$$

$$P_y \frac{\partial Y}{\partial E_y} + P_q \frac{\partial Q}{\partial Y} \frac{\partial Y}{\partial E_y} = P_e \tag{7}$$

where

w = price of labor,
P_y = price of Y goods,
P_q = price of Q goods,
P_e = price of pesticide.

Expression (5), (6), and (7) are the first order conditions for profit maximization from the social point of view.

From the private firm's point of view, however, the first order conditions become

$$P_y \frac{\partial Y}{\partial L_y} = w \tag{8}$$

$$P_q \frac{\partial Q}{\partial L_q} = w \tag{9}$$

$$P_y \frac{\partial Y}{\partial E_y} = P_e \tag{10}$$

Expression (8) and (9) imply that each competitive producer hires, for its own profit maximization leading efficiency in production, labor until the value of its private marginal product equals the wage rate. Expression (10) means that each competitive producer of Y goods buys and uses, for the same purpose, pesticides until the value of its private marginal product equals the price of pesticide.

The difference between expression (5) and (8) is

$$P_y \frac{\partial Q}{\partial Y} \frac{\partial Y}{\partial L_y} \tag{11}$$

and again the difference between expression (7) and (10) is

$$P_q \frac{\partial Q}{\partial Y} \frac{\partial Y}{\partial E_y}. \tag{12}$$

By assumption we know that

$$P_q \frac{\partial Q}{\partial Y} \frac{\partial Y}{\partial L_y} < 0 \quad \text{and} \quad P_q \frac{\partial Q}{\partial Y} \frac{\partial Y}{\partial E_y} < 0.$$

Thus, the values of the social marginal product of L_y and E_y are smaller than the values of the private marginal product of either of them under the assumption of a perfect competitive market. Therefore, their decisions on profit maximizing production would be nonefficient unless the cross effect of Y on Q $(\partial Q/\partial Y)$ is zero.

MEASURING THE EFFECTS OF PESTICIDES

People see the enormous adverse effects from the use of pesticides and have a tendency to imagine only that impact, without considering any beneficial effects. Before we say bad or good about pesticide, we should evaluate the net effects of pesticide use. According to Owens[10] it is estimated that if pesticides were withdrawn fron farm use, crop and livestock production would drop by 25–30 percent and retail food prices would increase substantially.

First of all, we must establish a framework to measure the social benefits from the increased productivity in agriculture resulting from pesticides. A simple idea on a framework to estimate the realized social rate of return on public and private funds invested in hybrid-corn research, was developed by Griliches[11] in 1958. A similar model in which the basic idea is the same as Griliches' was also utilized by Headley and Lewis in 1967, to assess the benefits of pesticide.[12]

Suppose we have an ordinary demand curve represented by DD and a supply curve represented by SS of an agricultural commodity before farmers apply a newly developed pesticide for that crop, as shown in Figure 1. Assume that the supply curve shifts from SS to S'S' as a result of using a new pesticide. The demand curve does not shift at all because the use of pesticide could not do anything about demand shifters for that commodity. We assume again a competitive market where prices are not supported and where output is not restricted so that prices are determined by the force of supply and demand themselves. As a result of shifting the supply curve from *SS* to *S'S'*, the output of the commodity, say corn, supplied increases as much as Q_0Q_1. This expansion of output lowers the price of corn from P_0 to P_1. Now, consumers enjoy more output at a lower price. Clearly the society as a whole gains an additional consumer surplus represented by P_0 P_1AB, the cost saving represented by P_1FEC as profit for producers, and an extra gain represented by CBE. The area BEQ_0Q_1 is not considered a gain because there is an opportunity cost for producing pesticides. Thus, net social benefits resulting from the use of new pesticide would be the area ABEFP_0. However, the estimated social benefits will vary depending upon the elasticities of supply and demand. Such a measurement of benefits is rather a simple notion.

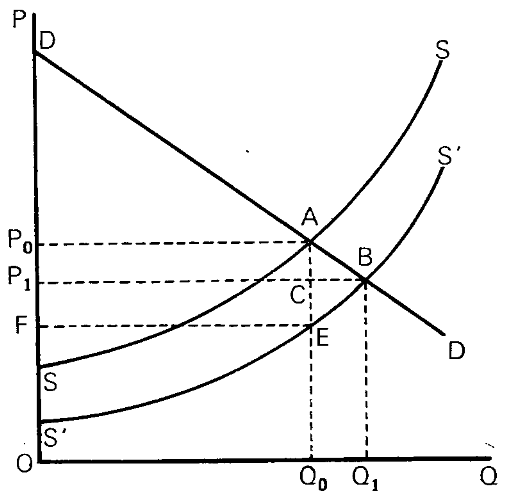
[10] E. W. Owens, *GNP, Pesticides, Man and the County Agent, Staff Paper P7114,* Department of Ag. ricultural & Applied Economics, University of Minnesota, August 1971.

[11] Zvi Griliches, Research Costs and Social Returns: Hybrid Corn and Related Innovations, *Journal of Political Economy,* October 1958.

[12] Headley and Lewis, *op. cit.*, p. 42.

FIGURE 1

MEASURING BENEFICIAL EFFECTS OF A NEW PESTICIDE



If we turn to the measurement of adverse spillover effects resulting from the application of pesticides, it is not so easy. Langham and Edwards[13] point out that there has been little effort to meas ure externalities because there is an insufficient basis in economic theory and no systematic way to estimate and report the effects. Mishan said that the value individually attributed to the spillover effect is subjective. This may be true when we try to evaluate environ mental pollution and hazards on man caused by manufacturing and handling pesticides. Mishan suggests some methods to calculate the economic worth of a person's life. One way is to directly calculate the loss of potential earnings or discount a victim's expected future earnings to get the present value of potential loss caused by use of pesticides. Suppose there are n persons associated with the adverse effects of pesticides. Of course, each person gets different proportiom of the effects. After we convert the effects into money terms and linearly add them up, we have

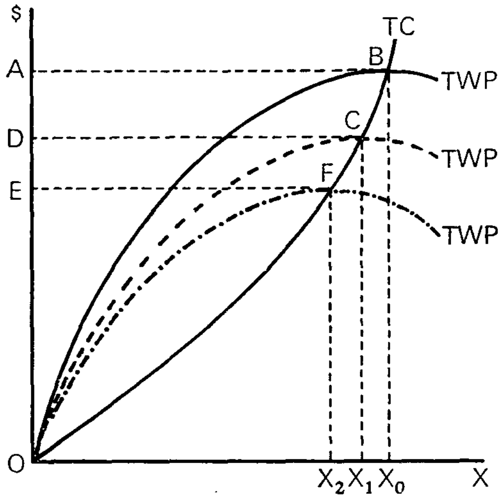
$$-\sum_{i=1}^{n} V_i \qquad (13)$$

A minus sign is used because of the negative effects to the society.

Let us move on to the measurement of environmental pollution caused by the use of pesticides. Suppose we have a valuable resource X. We may have a hypothetical curve of the consumer's total willingness to pay for utilizing that resource, represented by TWP, and total cost curve represented by TC shown in Figure 2. It is not difficult to imagine that the quality of X declines because of the polluted environment caused by the expansion of chemical pesticide use. Then the total willingness to pay shifts from TWP to TWP″ through TWP′, assuming that TC remains constant. The net loss to the society will be the area ABx_0x_2FE.

[13] M. R. Langham and W. F. Edwards, Externalities in Pesticide Use, *American Journal of Agricultural Economics*, December 1969, p. 1197.

FIGURE 2
MEASURING POLLUTION EFFECTS OF PESTICIDE USE



How about pesticide residue in the soil? The residue causes two negative effects on the next crop: low quality and low productivity of the next crop. This implies that we have a decrease in demand as well as supply shown in Figure 3. Before pesticides are utilized, the society gets the consumer surplus in the area DAP_0. After we use pesticides, we will have consumer surplus in the area $D'BP_1$. The net loss would be the difference between DD'CA and P_0P_1BC. Of course, this depends upon the elaticities of demand and supply.

Finally, we should add all the negative effects resulting from the use of pesticides and compare them to the beneficial effects. The method of policy formulation with respect to pesticide use is based on a comparison between both positive and negative effects.

APPROACHES TO SOLUTION

From the society's point of view, the criterion that we are going to use is the social welfare function. Headley and Lewis[14] stated the society's objective as "securing that level of pesticide usage, given the technology at any point in time, that provides the maximum positive benefits over and above the negative benefits or costs associated with that level of usage". They build up a decision framework for an optimal level of pesticide use. We have a hypothetical relationship between positive benefits from the use of pesticides and its use, which is represented by TB. TC shows total cost of pesticides at market prices. In this situation the optimum use of pesticides will be OE_0 where both tangencies of TB and TC are the same. However, we have external costs occuring from the use of pesticides. TC_e represents the total cost of pesticides including external costs. As a result, the level of optimum use will be OE_1, which is smaller than OE_0, as shown in Figure 4.

As alternative control methods, Headley and Lewis list the following:

1. Preventing the introduction and spread of pests.

[14] Headley and Lewis, *op. cit.*, p. 24.

FIGURE 3
EFFECTS OF PESTICIDE RESIDUE IN SOIL

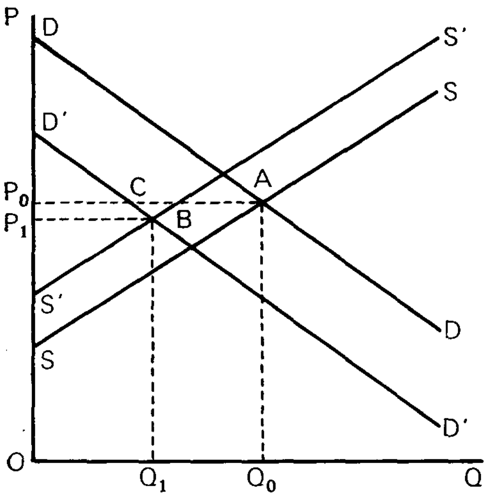
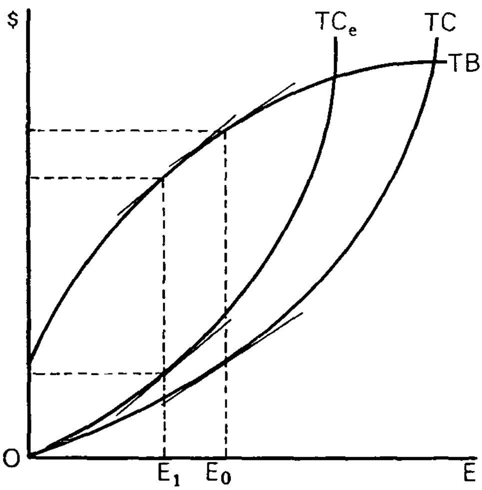


FIGURE 4
OPTIMUM USE OF PESTICIDES CONSIDERING
EXTERNAL COSTS



2. Cultural practices and sanitation.
3. The use of natural enemies of pests.
4. Developing resistant plant varieties.
5. The use of pre-emptive sterile insects.
6. Alternative ways of using pesticides.

They emphasized that before any administrative actions are taken to alter the relative price of pesticides or to prohibit the use of certain material the existing alternatives to the use of chemicals with adverse side effects should be examined.

Taylor[15] stated with respect to decision making in bureaucratic and legal systems that if regulations and policy power are to be employed, the regulations must be reasonable, equitable, effec tive, enforceable, widely understood, and reasonably "popular". His state ment suggests that before one takes any action in terms of policy with regard to pesticide use, he should collect all the reliable data and examine them carefully.

[15] G. C. Taylor, "Economic Issues in Controlling Agricultural Pollution", *American Journal of Agrciultural Economics,* December 1969, p. 1185.

SUMMARY AND CONCLUSION

The amount of pesticides produced and used for various purposes has increased dramatically over the past three decades. However, their indiscriminate use has created many problems such as pollution, poisoning, toxic residues, and some other hazards. This paper deals with some external problems arised from use of pesticides.

Generally, the effects of pesticide use are classified into two: beneficial effects and adverse spillover effects. The benefits of pesticide use in agricultural production include yield increases, input savings, and improvements in the quality of agricultural products. The concept of consumer surplus and other simple graphs are employed to measure some effects of pesticide use.

The existence of external economies in a competitive industry entails an equilibrium output that is below optimal. This implies that the equilibrium solutions attainable may not be Pareto optimal unless special arrangements are made. Therefore, from the society's point of view, any action in relation to the use of pesticides should be taken after a thorough examination has been made with regard to the beneficial and adverse effects of pesticides.

JOURNAL OF RURAL DEVELOPMENT
Vol. II, No. 1 April 1979

發行兼編輯人 金 甫 炫 發行處 韓國農村經濟研究院
印 刷 人 柳 健 洙 印刷所 三和印刷株式會社
1979年 4月 27日 印刷, 1979年 4月 30日 發行

定期刊行物 登錄 바—790(1978. 10. 17)