*Journal of Rural Development 9 (June 1986): 73~83* 

# A REVIEW ON EXTERNALITIES OF AGRICULTURAL PESTICIDE USE

PARK SEONG-KWAE*

## I. Introduction

The rapid technological development of agriculture around the world is well known. Some aspects of this have been the subject of intensive study. Hence we can have some insights into the relationships between agricultural factor and product prices, and cosumer prices for food and fiber. Furthermore, we have some understanding not only of the economic forces that have led to the type of technological development observed in agriculture but also of the impacts that public policy, especially traditional agricultural policy, has had on agricultural production.

Until recently, however, relatively little attention has been given to the externalities (i.e. unintended side effects affecting other uses of natural resources) with which the application of agricultural technology is associated.

Externalities resulting from both output-increasing and input-saving technologies are of current interest [1]. Some side effects are the results from the overall organization of agricultural production. For example, specialization by farm or by geographic region has led to a concentration of production, so in certain areas the assimilative capacity of the natural environment for waste materials has been exceeded and harmful side effects have become apparent [2].

Socially serious problems have arisen from the intensive use of agricultural pesticides, which farmers have found profitable to use along with complementary crop production [3]. In particular harmful environmental effects have been associated with pesticides usage in agricultural production. The specific costs of these have often represented a relatively small portion of production costs [4]. Hence, the incentive economizing on these materials was weak, and thus they frequently were overused, even from the viewpoint of the producers' internal cost calculus.

The more general problem of technological externalities arises from the failure of economic institutions to reflect certain social costs in private production decisions which may lead to a situation where from a social

* Research Associate. Fellow. Korea Rural Economics Institute. Seoul. Korea.

standpoint relatively too much of the private good and too little of the environmental good are produced [3]. In this paper I shall concern myself with the physical, biological, economic aspects of environmental effects, measurement problems in specifying the magnitude, possibility of a solution, and research needs.

## II. Nature of the Pesticide Problem

The first commercial pesticide appeared in 1867 with the use of Paris Green to control the Colorado beetles. The use of pesticides was expensive and time-consuming, and was confined primarily to high-value crops such as fruits, vegetables, and cotton until the wide spread use of DDT in 1945 [5].

To date pesticides fall into three primary groups: the organochlorine or chlorinated hydrocarbons, the organic phosphates, and the carbomates. Dichloro-diphenyl-trichloroethane(DDT), chordane, aldrin, endrin, toxaphene, methoxychlorins, and heptachlorine are members of the chlorinated hydrocarbon group. The chlorinated hydrocarbons have very desirable characteristics in pest control—high acute and chronic toxicity to insects and persistence. The quality of persistence, while highly desirable in attacking various pest populations, is extremely undesirable from a broader environmental aspect.

The organic phosphates are represented by parathion, malathion, tetra-ethyl pyrophosphate(TEPP), and others. The primary advantage of the organophosphates lies in their varied properties. TEPP hydrolizes and leaves no residues after use, while other members are systemic in growing plants and animals[3]. In some organophosphates such as parathion the lack of persistence is accompanied by high toxic effects on those who handle these materials.

The third class of pesticides, carbomates, were developed because of the ability of insect populations to become resistent to the organochlorine and organophosphate chemicals. Resistence is a continual problem, and the process is accelerated when chemicals are highly acute.

A buildup of agricultural chemicals, primarily organochlorine insecticides, occurs in various insect species through the natural processes of the food chain[6]. However, the biological impact of pesticides is highly variable, even in a sensitive species[7]. Several studies[8, 9, 10] have found strong probabilistic relationships between pesticides and harmful effects to birds and other wildlives. The exact mode of action of chlorinated hydrocarbons is unknown so it is presently impossible to develop a complete cause-and-effect relationship between biological malfunctions and chlorinated hydrocarbons that have been found in the affected organisms.

## III. Effects of Agricultulal Pesticide Usage

### 1. On Human Health

On the one hand the primary benefits of pesticides to human health result from the control of insects, weeds, and other pests during the process of food production and storage. This increases the quality of foods as well as their quantities, while usually lowering their prices[3]. However, these benefits are reflected through the consumer's demand function for the food and thus enter into the production decision of the agricultural sector.

The use of agricultually developed chemicals for disease control by the public health servies does represent an positive externality[2]. Benefits accrue to individuals who avoid exposure to diseases. The fact that the service is provided by the public sector and not undertaken by a firm or individual basis is evidence of the public good aspect of the consumption of the benefits from this type of pesticide use. The services, once provided, are available to everyone. No one can be excluded from enjoying them. Generally, since private market institutions would fail to provide the services, some type of group action is required for this provision[5].

On the other hand there are negative externalities to consider as well, since most agricultural chemicals are toxic to humans. Organic chemicals can enter the body by ingestion, dermal absorption, or inhalation. Ingestion involves both accidental poisoning and involuntary ingestion of toxic residues on or in fish.

Most exposures of the general public to pesticides, especially dielin and DDT, come through residues on food[11]. However, residues in excess of officially set tolerance levels have only rarely been recorded following the use of pesticides in accordance with recommended practices as to the amount and timing of the application.

Synergistic effects through the combination of various chemicals have not been and probably cannot be completely evaluated. Uncertainty about these types of effects will always be represented as new chemical mix with others in the environment[3].

### 2. On Fish and Wildlife

Agriculturally developed pesticides have been used in the management of fish and wildlife and their habitats. Harmful or undesirable insects, fish, rodents, and predatory animals have been controlled in order to decrease animal diseases and maintain a necessary balance in the system. However, rarely do benefits to fish and wildlife appear to result from the use of agricultural chemicals where the primary purpose is to increase agricultural production.

Species vary in their sensitivity to pesticides. Crustaccenas, fish, reptiles, birds, and mammals are the accepted order of sensitivities for most chemicals, with crustaceans being the most sensitive. However, a resistant species can accumulate concentrations that would be harmful to its predators [6].

Potentially far-reaching ecological effects due to pesticide use are expected to result from persistence and biological magnifications of pesticides. It would seem desirable to remove chemicals having these characteristics from use since it is presently possible to use alternative chemicals for certain pests.

DDT, while still the widely used insecticide, continues to decrease in volume produced. The primary reasons for the reduction are the development of resistance to DDT by many insect pests, the introduction of more effective replacement insecticides, and environmental concern over the use of persistent chemicals.

Cole [13] suggests that while the need for chemicals will never be removed, their use can be drastically reduce by observing ecological principles in agricultural practices:

> First, the chemical should not be used routinely but only when needed to halt an outbreak of pests, and it should not have a residual effect, but should quickly break down into harmless substances and disappear from the environment. Under these conditions the chemical will be absent from the environment most of the time; there will not be a selective pressure for the pests to evolve resistant strains, and the land will not become the sort of toxic environment that favors the presence of huge populations of a few tolerant species.
> Second, the chemical pesticide should be as highly specific as possible for the one particular pest that is under attack. This feature will preserve species diversity and avoid incidents of failure such as have occurred in the past when a pest was made more, rather than less, abundant, because the chemical was more effective in eliminating predators and parasites than in reducing the pest. Specificity will also help to avoid the difficulty of suppressing one pest only to have it replaced by another as a result of eliminating predators and parasites.

Since pesticides having all of these desirable properties are not presently available, several countries (i.e. U.S.A.) are developing integrated pest management technologies (IPM) which are based on the natural balancing forces in ecological system.

## IV. Economic Evaluation of Environmental Costs

Adverse effects on the quality of surface and ground water, soil, air, wildlife, and man have been cited as externalities associated with the application of certain types of agricultural technologies. Thus the owners or users of all these resources will bear costs as a result of agricultural production. Some of the these costs are well defined and, with engineering knowledge and market prices can be readily computed. These include increases in industrial, municipal, and agricultural water treatment cost as well as increased capital investments and maintenance costs for power generation, navigation, and irrigation. Other costs, while market related, are harder to determine.

These external costs are difficult to estimate when their incidence is very widespread. Certain effects on aquatic life, wild populations, and human health are examples.

One way to evaluate the external costs is based on recreational demand functions [14]. The primary difficulty in measurement of recreational values stems from the fact that recreational services are generally provided as extramarket commodities. Some simulation of market behavior has most frequently been relied upon deriving demand functions for outdoor recreational services. These demand functions are then used to derive estimates of social values.

The estimation of such demand functions has become possible after Hotelling's suggestion to define concentric zones around the recreational site and to use travel costs to the site as a proxy for the prices of utilizing its services. This idea was first utilized by Clawson [15] and has since been refined in a number of important ways. The methodology of primary interest have been how to reflect the impact of a possible deterioration in the physical attributes of the recreational sites in the estimates of existing recreational resource values.

To make an economic evaluation of Yaquina Bay dispute, demand functions for the various sports fisheries, utilizing Hotelling-Clawson techniques, were estimated by Stevens [16]. This empirical relationships were based on available time series and cross-sectional data derived from responses to the questions about hypothetical situations posed by fishermen in mail questionaires. But this approach requires great care in formulating the questions. Although this exploratory effort fails to include many of the quality-related characteristics of an outdoor recreational experience, it does provide a consistent economic framework for estimating at least a portion of the real welfare losses associated with variations in residual concentrations.

Another important study [17] focused on the changes in the economic value of the recreational use of the Delaware estuary. This study was done in a benefit-cost framework designed to guide decisions on the optimal level of water quality for the estuary. It yielded estimates of the extent of economic losses now and in future years attributable to the low water quality of the estuary.

Some other studies evaluated the damage of pesticides to human health. Muskin and Collings [22] suggest two categories of costs of disease and injury that might apply to social costs. The first category is costs of resource use, covering the use of resources for the prevention, diagnosis, and the treatment and rehabilitation of persons infected or injured. The second category of resource loss includes death and disability, but the concept is not necessarily limited to human resources. However, Ridker restricts himself to six categories of diseases. He defines four types of costs: those due to premature death, those associated with morbidity, treatment costs, and prevention or avoidance costs. Because of data limitations he considers neither the prevention nor the psychic costs associated with illness and death. He thus believes the measures of costs to be underestimates. There are two important steps in the estimation of pollution damage. The first is the attribution of given effects to a certain level of pollution and the second is the placing of an economic value on these estimated effects [18]. The Ridker's approach is to estimate the total costs of a specific disease and then to attribute some percentage of these costs to air pollution. There are two problems with this type of damage estimation, both of which are due to a lack of data and information. It seems to be difficult to judge what percentage of these costs has to be assigned to other particular situation of air pollution. This approach might be applicable to the estimating of agricultural pesticide effects of damage on human health.

In agricultural production an enforced reduction of pesticide use may generate economic costs, largely in the form of reduction in agricultural output. Estimation of these costs have been made by J. C. Headley, using 1964 data from a random sample of 393 counties [19]. Estimating national and regional production function, Headley evaluated the contribution of pesticides to agricultural output. This contribution will be the cost which society will have to bear if pesticide use is curtailed.

To ascertain if the external, non-market damage from pesticides is sufficiently large to warrant enforced curtailment of pesticides, Edwards et al. [20] attempted to measure the damage for a region in Florida and to incorporate them into a measure of social welfare. Two types of pesticides were evaluated and compared in an analysis of alternative policies for pesticide use. The two pesticides evaluated were acutely toxic to human but non-persistent chlorinated hydrocarbons. In their effort to measure the extent of external environmental damage, the researchers aimed at relating a dollor measure of the social costs of externalities to the amount of a pesticide being used.

All the above suggests that the externalities associated with agricultural pesticides could pose serious ecological, social, and economic problems, but measurement techniques to provide accurate data and useful information are not readily available.

## V. Possibility of a Solution

Many economists agree that the existence of technological externalities can necessitate modifications to claims of the unregulated market mechanism's efficiency. It must be true that the problems created by technological externalities are most perplexing. In fact, there is no simple, universally acceptable solution to the problems. Perhaps, at least for the foreseeable future, our society seems to have no alternative but to seek pragamtic solutions to the problems.

Seneca, Headley, Davis et al., respectively, examined some proposed solutions. Their analyses can be largely divided into six cataegories:

### 1. Solution by Pohibition

When one is convinced that collective action is necessary to correct the abuses caused by a technological externalities, the first impulse is to simply prohibit the action giving rise to it. After all, if creation of the externality is prohibited, will the market system then bring the economy to a Pareto optimal position? As a matter of fact, it is not difficult to realize that simple prohibition of activities that create technological externalities is a poor approach. In fact, optimality does not call for the complete elimination of externalities. Instead, optimality requires that externalities be present in the right amount. Strict prohibition of whatever causes a technological externalities is alsmot certain to prevent attainment of Pareto optimality. An appropriate level of externality, not necessarily equal to zero, is needed.

### 2. Solution by Voluntary Action

Some argue that collective action is not needed to correct the market solution where there are technological externalities. It has often been pointed out that there is motivation for private parties to act to correct the situation by a variety of methods.

However, two methods frequently discussed are bribes and merger. The bribe method of avoiding a divergence between private and social costs is purely voluntary and leads, when bargaining is perfect, to a Pareto optimal allocation of resources. Unfortunately, bargaining is not perfect. Another voluntary scheme for internalizing technological externalities, free of the implementation difficulties, is the merger of the involved entities whenever merger is a feasible possibility. However, two difficulties with the merger solution can be pointed out. The first is the practical consideration that the entities have to be firms. The second is that merger is feasible only when the member of entities envolved is small.

### 3. Solution by Directive

There are several difficulties with this procedure. First, there is the problem of determining just how much of the externality is desirable. This question is related to the problem of determining the overall quality standard. In principle this could be done by careful weighing of costs and benefits. Second, the marginal effectiveness of dollars spent for treating pollutants can not be accurately calculated for any given polluters. Third, implimentation of the procedure is even more difficult. The overall standard should still be determined by weighing and comparing the benefits and the costs of different alternatives. The procedure also involves administrative costs of policing the directives, which can not be ignored in its evaluation.

**4. Solution by Taxes and Subsidies**

If voluntary arrangement among the entities by technological externalities are impractical or not forthcoming, governmental action might be justified. The difficulty is in the immense informational requirements necessary for the implementation of this scheme. The amount of information required also depends on the productive technologies involved.

Despite the difficulty, an attempt to achieve optimal resource allocation by taxes and subsides might be justified if the losses to society from the presence of technological externalities are large enough. In essence, what has to be balanced in this case is the cost of acquiring the needed information against the losses to society if nothing is done or another imperfect policy is followed.

**5. Solution by Regulation**

Regulation also has implementation difficulties. The administrative costs of enforcing the regulations do matter so they can not be overlooked. A more basic problem with government regulations is incapability of bringing the system to a Pareto optimal solution for many externalities, because regulations are inherently inflexible.

**6. Solution by Payment**

One of the obvious ways of trying to accommodate the market system to the presence of technological externalities is to provide a financial incentive for the desired actions to be taken. However, because each entity does not bear the full costs of its own contribution to pollution, none has enough incentive to remedy the problem. A possible remedial policy is to provide the proper incentive.

The major drawback of this policy is its crudeness. It does not easily provide proper coordination for all of the relevant units in the system.

As in the above, there are many potential policies which can be formed to deal with the problems associated with technological externalities. In the context of pesticide problems, it seems to be true that regulation and monitoring of residue levels is only one but perhaps not the most important line of defense against the side effects of pesticide use. Proper labeling of containers and the education of pesticide users concerning proper methods, quantities, and time of application may well be a higher order of requirement.

## VI. Research Needs

Seitz [1] characterizes policy making in the context of environment as a continuing process of assessment of conditions, identification of policy alternatives and analysis of their impacts, policy change, and a reassesment of conditions. Research can play an important role in each phase because the physical, economic phenomena involved are complex and not adequately understood.

One of the major changes needed may be the utilization of interdisciplinary research teams rather than relying on the aggregation of results from separate, smaller research activities.

## VII. Summary and Conclusions

– The first part of this paper attempted to summarize some of the available information of external effects of agricultural pesticides on environment and natural resources; much of this is sparse and inconclusive.

– Some empirical studies discussed are indicative of the difficulties involved in extending information of physical-biological effects to parameters that are more amenable to social evaluation.

– Even though the data limitations are substantial as are estimates of the relevant physical relationships, sensitivity tests in the context of a benefit-cost framework can provide important information for decision makers.

– A more intensive monitoring system seems to be needed which can provide numerical data from the chemical-physical measurements with sufficient accuracy and reproducibility for subsequent mathematical or statistical analysis.

– At present none of the policies which can be formed to deal with externalities appears to be perfect.

– There are research needs for identification and measurement of problems, development of alternative policies, analysis of the alternatives, development of efficient responses to policy inititives, and assessment of policy performance. One of the important changes needed is the utilization of interdisciplinary research teams.

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