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The Demand for Pesticide Use: The Effect of Farm Programs

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There is a long history of studies that have sought to quantify the productivity of agricultural pesticides and thereby explain the long term growth in pesticide demand. Findings indicate that returns to a one dollar pesticide expenditure vary by crop, but in general have resulted in positive profits (Headley, Hawkins et al., Campbell, Miranowski, Duffy and Hanthorn). The value thus created has sustained the growth in demand for pesticide products and has maintained agricultural pesticide use levels at about 850 million pounds of active ingredients per year during the 1980's. An exception was 1983, the Payment-In-Kind (PIK) year, when total agricultural sector pesticide usage dropped to 733 million pounds, the lowest figure since 1977 (Environmental Protection Agency). The effect of the PIK program was to decrease pesticide use by approximately 17 percent from the previous years' total.

The effect of the PIK program on input use was highly predictable. In-Kind subsidy payment stipulations assured lessened demand in input markets in general due to decreased planted acreage (Erikson and Collins). More problematic are the effects of farmer compliance stipulations for subsidy eligibility of the periodic Farm Bill renewals. Acreage under programs such as Acreage Reduction (ARP), Conservation Reserve (CRP), and Paid Land Diversion (PLD) which set aside land previously in production for up to ten years in the case of the CRP, have no or minimal inputs applied. Input use could be expected to decline as a greater number of acres are enrolled. However land is generally substitutable by other inputs in the production process. To maintain production levels after set-aside compliance, farmers could be expected to use the remaining inputs more intensively. Under that reasoning pesticide use, while not increasing, may remain relatively stable as idled acreage is increased.

This paper investigates that assumption by employing an econometric model that seeks to explain pesticide use. Basically its arguments include the real price of pesticides, acreage planted in principal crops, and indices that provide a measure of aggregate pesticide prices relative to other substitutable inputs and aggregate output prices. The model is expressed as a simultaneous equation system with acreage planted as an argument of the pesticide demand equation, while factors such as aggregate product prices, and the "target-to-market" price ratio affecting acreage planted.

A brief overview of pesticide use patterns and productivity issues as well as arguments outlining the impact of farm programs on pesticide use follows this section. Next the econometric model is specified in greater detail along with a priori hypotheses regarding factors affecting the demand for agricultural pesticides. Results of the estimation procedure follow. A concluding section offers policy implications for better management of set aside programs to achieve the multiple social goals of supply control and preventing environmental degradation.

USDA/ERS

Pesticide Use Patterns

Comprehensive yearly pesticide use estimates are available from the Environmental Protection Agency (EPA). For the period 1964 through 1982 agricultural pesticide use increased from 320 million pounds of active ingredient (a.i.) to 880 million pounds. Use declined to 733 million pounds in the 1983 PIK year, but then returned to pre-PIK year levels in 1984 and 1985. Figures for 1986 and 1987 were estimated to be 820 and 815 million pounds. These EPA estimates compare favorably with U.S. Department of Agriculture (USDA) estimates obtained through actual farm surveys in 1964, 1966, 1971, and 1976. A USDA pesticide survey in 1982 sampled only a limited number of states and commodities, and therefor differs significantly from EPA estimates which encompass the nation as a whole. We relied on EPA estimates in our aggregate analysis and USDA survey data in reporting disaggregated trends.

The steady growth in agricultural pesticide use since 1964 can be attributed to the increasing popularity of chemical herbicide use for weed control in major field crop production. USDA data (which allow disaggregation by pesticide type) indicate that herbicide use increased from 71 million pounds a.i. in 1964 to 456 million pounds in 1982 (Osteen and Szmedra). Insecticide use has historically coincided with the severity of infestation but more recently is a result of the changing composition of the compounds used. Use of insecticides increased from 117 million pounds of a.i. in 1964 to 129 million pounds in 1971 and 130 million pounds in 1976. Use then dropped to 71 million pounds in 1982. Organophosphates, carbamates, and pyrethroids have displaced the organochlorine insecticides which lost their effectiveness due to insect resistance, and subsequently their markets with the discovery of their persistence in the environment. The development of synthetic pyrethroids is especially significant as these products are applied at much lower rates than older products which afforded a comparable level of pest damage control. Pyrethroids are used widely in cotton production to control the Heliothis spp. complex. Cotton production requires relatively heavy insecticide use because of the plants' characteristically long fruiting season. The substitution of pyrethroid products has decreased per acre insecticide use in cotton from 5 to 6 pounds a.i. prior to 1977, to about 1.6 pounds a.i. after 1977. The use of fungicide and other pesticide products has been relatively stable between 1964 and 1982 ranging from 31 to 43 million pounds of a.i. during the period (Osteen and Szmedra).

Pesticide Productivity

The steady growth in aggregate pesticide use is often attributed to cost-effectiveness relative to other pest control methods. The use of herbicides reduces the need to mechanically cultivate for weed control reducing labor, fuel and machinery costs, and significantly reducing the time necessary for task completion. In addition, many pesticide products can be applied during other operations such as planting or tillage, again resulting in time savings at critical junctures of the production season, and allowing a single farmer to manage a larger operation.

The demand for agricultural pesticides is therefore related to the cost of substitutable inputs, output price, and planted acreage. Declines in pesticide prices relative to the prices of crops and other inputs increases the relative marginal net return of pesticide products and encourages substitution of pesticides for less efficient substitutable inputs. This relative marginal advantage contributes to the overuse of some pesticide products; many farmers applying prophylactic pesticide treatments as a type of crop insurance against pest damage. Miranowski et al. have shown that agricultural chemicals (both pesticides and fertilizers) are substitutable to some degree for labor, capital, and land. Therefore increasing wage rates, and the cost of capital and land provide a plausible explanation for the strong growth in pesticide use levels.

Farm Program Effects on Pesticide Use

A number of researchers have suggested that the combination of price support and acreage diversion programs have encouraged farmers to substitute pesticides and fertilizers for land (Carlson and Castle, Farris and Sprott, Headley). Miranowski described four ways in which farm program participation could effect pesticide use. These include: a) price effects in which higher prices caused by acreage controls or inventory programs, or price guarantees through target prices or loan rates, increase the marginal return of pesticide products and thereby encourage greater per acre use; b) acreage effects whereby acreage set-aside and reserve programs would decrease pesticide use; c) location effects whereby crop production becomes feasible under price and income supports in regions where pest infestations had prevented profitable production in the past, resulting in increased pesticide use; and d) crop mix effect in which acreage in crops that are more susceptible to pest damage increases to take advantage of the relatively inexpensive pesticide input.

The economic threshold concept dictates the application of pesticides until the marginal cost of application and the marginal benefits equilibrate. Farm programs create higher marginal benefits than "free" agricultural markets if: a) target prices or loan rates exceed market prices, and program payment yields are a function of past production (affecting only program participants); and b) acreage diversions or crop storage programs encourage higher market prices than "free" agricultural markets. Higher realized marginal returns could encourage higher application rates per acre, more treatments per acre, and/or a greater percent of acres treated, as well as the location and crop mix effects described by Miranowski. Farm programs' ability to maintain marginal returns at levels greater than market prices, would lower economic thresholds for pest populations in program crops. With acreage limited under set-aside and reserve stipulations, more intensive pesticide use may result. Similarly, supply control measures leading to higher program commodity prices would encourage pesticide use.

The Model

The model is specified as a simultaneous equation system:

$$1.\ QP_t = \beta_o + \beta_1 AP_t + \beta_2 PPI_t + \beta_3 PCR_t + \beta_4 PWR_t + e_1$$
$$2.\ AP_t = \tau_o + \tau_1 ACI_{t-1} + \tau_2 CIM_t + e_2$$

where in the first equation QP_t is the total pounds of a.i. used in agricultural production in year t; AP_t is the acreage planted in principal crops in year t; PPI_t is an aggregate agricultural pesticide price index weighted by quantity of a.i. used; PCR_t is the ratio of pesticide prices to aggregate crop output prices; PWR_t is the ratio of the pesticide prices index to aggregate wage rates applicable to the agricultural sector; and e_1 is a random error term.

The second equation describes the factors affecting acreage planted in principal crops. These are assumed to include ACI_{t-1} which is an aggregate price index of all crops lagged one period, in this case one year, and CIM_t is the corn target-to-market price ratio in year t, here used as a proxy for the differences between target and market prices for all program crops in a given year, and e_2 is a random error term.

Based on the arguments presented earlier, a priori assumptions regarding the effect of total planted acreage on quantities of pesticides used may be taken two ways. The most obvious assumes a direct relationship. That is, as acreage decreases (increases) pesticide use would decrease (increase). This assumption implies that the intensity of pesticide use would not increase as acreage is withdrawn from production to comply with reserve or set-aside programs. If this assumption is substantiated by the data then it would argue against the implication that pesticides are good substitutes for land in the production process. If, on the other hand, decreases in acreage planted result in greater pesticide use, the pesticide for land substitution argument may indeed hold.

The remaining variables in the first equation attempt to explain the relative attractiveness of agricultural pesticides when compared with the relative prices of other inputs and output. While the usual demand relation would require a negative relationship between pesticide price and use levels, pesticides are valued according to their prices relative to other inputs, and to the price of the crop on which a pesticide product is used. Hence PPI_t may not necessarily conform to the usual price-quantity demanded relation. Alternatively, PCR_t is expected to embody the relative attractiveness of using pesticides when compared with crop output price. As pesticides become relatively cheaper in terms of the value of the crop, more aggregate use is expected, and this variable should exhibit a negative sign. Similarly, as pesticide prices become cheaper relative to labor costs, we expect the amount of a.i.'s used to increase and for PWR_t to impact negatively on aggregate use.

The second equation describes the factors affecting acreage planted in principal crops. The expectation is that farmers make decisions about entering farm subsidy and mandatory set-aside programs based upon crop prices received the previous year, and expectations regarding the target price to market price ratio that will exist during marketing of the current crop. Therefore we expect a positive relationship between ACI_{t-1} and acreage planted, indicating the farmer's willingness to put more land into production, less into set-aside, if last years crop prices were favorable. Similarly if the market price is expected to be close to or surpass the target price in any year, then a larger number of acres will remain in production to take advantage of the expected price differential. A negative sign is expected for CTM. We use the historical target to market price ratio for corn as a proxy for all program crops.

The two equation simultaneous system was assumed to be linear in the variables and was estimated using three stage least squares. The linearity assumption accommodates the disaggregated yearly influences of insecticides, fungicides, and other pesticide products on total pesticide use. If modeling herbicide use was our primary objective, a log-linear or log-log functional form would be a better approximation. The linear specification provided the best overall fit to the data. The time series used spans the years 1964 through 1986.

Results

The results of the estimation procedure are provided in table 1 and generally coincide with a priori assumptions. All variables display the expected signs and are significant at the 95 percent significance level except for PCR_t, the ratio of pesticide price index to the aggregate index of output price, which is insignificant, and CTM_t which has the expected sign but is significant at only the 90 percent level. The positive sign on acreage planted indicates that pesticides may not be a good substitute for land taken out of production through federal set-aside and reserve programs. Aggregate pesticide use decreases as acreage declines. However, intensity of pesticide use, or use per acre, is not embodied in the measurement of this variable, and is strongly dependent on crop type and regional differences in pest problems. Investigation of the intensity of pesticide use by region and commodity remains on our research agenda. The positive sign on PPI_t, the pesticide price index, reinforces our argument that prices of pesticides relative to other inputs are what influence demand rather than simply nominal prices. The significance of PWR_t indicates this to be the case. Relative input prices outweigh the relationship between pesticide prices and the prices of commodities on which pesticides are used. The insignificance of PCR_t may reflect the necessity of protecting a crop through the season despite low realized market prices.

Estimation results for the second equation indicate that crop prices in the previous year have a strong impact on current planted acreage and thereby on acreage directed to set-aside programs. This result is consistent with the knowledge that some reserve programs contract for land to be retired from production for up to 10 years. The decision to place land in the CRP for instance, is based on the farmer's past financial experience with the land proposed for conservation purposes and his expectations of the future. The marginal effect of the previous years financial results is arguably the key decision criterion. Lastly, the negative sign for CTM_t reinforces the assumption that the expected target to market price differential for a program crop is another key factor in the farmer's decision to participate in farm subsidy and set-aside programs.

Summary and Policy Implications

These results indicate that the acreage restrictions stipulated by farm program participation significantly contribute to decreased pesticide use in the aggregate. For some crops and regions this may not be the case, with intensity of pesticide use possibly increasing as acreage is withdrawn from production. But in general these findings imply that pesticides are not used as an effective substitute for land in the same way that fertilizer and hi-bred seed may be. If decreased use of pesticides is judged to be a social goal due to the negative impact some chemical pesticides have on the environment, then larger set-aside requirements for farm program participation should be considered. Alternatively, increasing prices at which the government supports program crops would cause more land to be placed in land diversion and reserve programs by attracting more farmers into program participation. However this option may not be politically feasible considering the current mood of Congress and the Executive branch to phase out agricultural price support programs (Yuetter).

This paper only indirectly addressed the issue of pesticide use intensity. It may be the most cogent issue in terms of environmental degradation. Intensity of pesticide use probably has a direct relation with groundwater and soil contamination, and wildlife and human toxicity. The data currently available did not allow a comprehensive treatment of the issue. We hope to expand the present study to include farm program effects on the intensity of pesticide use to provide guidelines in defining future compliance requirements.

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