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ECONOMIC INCENTIVES TO REDUCE THE QUANTITY OF CHEMICALS USED IN COMMERCIAL AGRICULTURE*

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In recent years, considerable national attention has focused on the use of chemicals by the agriculture sector. Recent descriptive analyses have addressed the problem of attempting to determine, or to describe, some of the social "costs" of chemicals used in agriculture which later move to non-agricultural areas [8, 14]. The primary effect of the attention on chemical use in agriculture has been legislative action relative to specific pesticides such as DDT and 2,4,5-T. These actions have made national news along with reports of measured residues of these pesticides in wildlife, fish and other forms of foodstuffs.

The watchful eye of the public does not limit its vision strictly to pesticide uses. Commercial fertilizers are also under scrutiny due to the increasing public awareness of nitrates and phosphates in rivers and water supplies. While the total effect of commercial fertilizer has not been specifically delineated, continual pressure to reduce pesticides, nitrates and phosphates introduced into the ecosystem by agriculture can be expected. Society may, in some cases, effect a reduction in the use of particular pesticides through a legislative ban on their use.

Assuming adjustments in certain agricultural inputs are socially desirable, there are possible alternatives which need to be examined. The discussion in this paper is limited to the concept of chemical use taxation (a method of expressing social costs in the primary cost function) and a marketing quota governmental farm program. A ban on the use of an agricultural chemical or cancellation of the use of a chemical is not included in the following analysis since the effect on quantity of the chemical used is predetermined. Also, the authors do not digress to a

social welfare function in which the optimal level of chemical use in agriculture is derived. Functions of this nature, as expressed in several recent papers, include many variables which cannot currently be quantified [5, 6].

The major emphasis of this paper concerns the response of chemical use in agriculture to an agricultural chemical tax and a marketing quota farm program. The theoretical implications are briefly considered. In addition, empirical estimates obtained in a linear programming analysis of the two alternative policies for a study area are discussed.

THEORETICAL IMPLICATION

An important assumption underlying this paper is that of profit maximization. This suggests that production economics, or theory of the firm, is an applicable analytical tool. The following discussion relates to the theoretical effect of a specific pesticide tax and marketing quota farm program under conditions of profit maximization.

A tax on a specific agricultural chemical, such as the organochlorines or on a single herbicide such as 2,4-D, is similar to Langham's social costs that are added to the farmer's cost of acquiring that input [7]. The effects of a tax are analyzed because a tax could be implemented without requiring a direct measurement of social costs. Of course, the tax becomes a proxy for the social costs of a chemical used in agriculture.¹

From textbook theory, a tax on a specific chemical (say chemical X) would be expected to reduce the use of the chemical. Rather than belabor the point using iso-product curves, marginal value

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¹There are also benefits that accrue to society due to chemicals used in agriculture. It can be argued that the appropriate tax on a chemical is only that amount of social costs that exceed social benefits or net social costs.

product curves, industry supply and aggregate demand curves; the increased farm price for Chemical X would likely result in a degree of substitution of other inputs for chemical X. Thus, the use of chemical X could be expected to be less than without the tax.²

This discussion does not include the use of chemicals in non-farm sectors. The authors speculate that the demand in sectors other than commercial agriculture is very inelastic and the effect of a tax on the quantity of chemicals used would be minimal.

As indicated above, a per unit tax on specific chemicals would be useful in reducing their use in commercial agriculture. However, a marketing quota farm program rather than acreage allotments could be expected to reduce the use of practically all chemicals per acre of cropped land. To pursue the above hypothesis, the discussion can begin by examining the incentives of past farm programs. That is, commodity acreage allotments and price supports with no limitation on the quantity that may be sold.

Acreage allotments for alternative crops are an effective means of regulating the amount of land used in the production of each crop. However, typically, the objective of the farm operator is to maximize net returns on the allotted acres based on the assurance of receiving no less than the government support price. This means that other variable inputs are used until their marginal value product is equal to their respective prices and in many instances may be at relatively large per acre output levels. This does not yield a least-cost combination of land and other inputs for the commodity produced on the allotment.³

However, if the farm operator was free to use all of his cropland (no set aside) but permitted to sell only a specified quantity of output such as the quantity produced on the previously allotted acres, the incentive would be to minimize the cost of producing the specified quantity of output.⁴

To obtain a least-cost combination of inputs to produce a specified level of output, some substitution

of land for variable inputs could be anticipated. The expected result of a marketing quota program is, therefore, a reduction in the quantity of chemicals applied, at least a reduction in the quantity applied per acre of cropped land.

A recent study estimated the marginal rate of substitution of land for insecticides [13, pp. 80-89]. The results for the United States indicate that a one acre increase in cropped land reduced the quantity of insecticides applied by 13.24 ounces. In the Southern Plains of the United States one acre of additional land reduced level of insecticides applied by 547.17 ounces [13, p. 85]. This empirical evidence suggests that a marketing quota farm program would provide incentives to reduce the level of inputs applied in agricultural production.

AN EXAMPLE

A five county area in the Northern High Plains of Texas was selected as a study area to evaluate the effect of a tax and marketing quota farm program on level of chemicals used in a specific agricultural region.⁵ The primary agricultural crops of the area are grain sorghum and wheat. Irrigation has been established by pumping water from an underlying aquifer. On the land that is irrigated, the quantity of nitrogen applied per acre is larger than for dryland production.

To control weeds in wheat and grain sorghum, herbicides, especially 2,4-D, are utilized. Farm management specialists in the area estimate that 2,4-d is applied to 50 percent of dryland grain sorghum, 85 percent of irrigated grain sorghum, 5 percent of dryland wheat and 30 percent of irrigated wheat acreage.

Data on land utilization for 1969 are used as a basis for this analysis. In addition, only the wheat and grain sorghum acreages grown under the government farm program and diverted acres are included. In 1969, wheat program participation acres were 602,506 with another 104,053 acres diverted and grain sorghum participation acres were 267,355 with

² Several interesting theoretical implications of a tax on chemical X can be pursued including shifts in (1) the industry supply function, (2) the aggregate demand function and (3) the firm marginal value product function.

³ The reader should recognize that with an open market system of no allotments or price supports, land is typically the most limiting resource, and other variable inputs are again added to the point where their price per unit is equated to their marginal value product. In the absence of price supports, a lower bound on commodity price is not established; hence, the marginal value product of variable resources will reflect market price rather than the support price.

⁴ For the marketing quota farm program to operate as indicated, it is expected all agricultural products or a total farm would have to be subject to the program. In the absence of a program that includes all products or the total farm and only one crop, say wheat, were put under a marketing allotment program but another crop, say grain sorghum was not, the farmer would be inclined to produce the wheat quota on as small an acreage as possible, thereby, releasing maximum acreage for the production of grain sorghum.

⁵ The counties selected were Hartley, Hansford, Hutchinson, Moore and Sherman.

another 85,480 acres diverted [10]. Of these acres, 202,442 acres of wheat were irrigated and 204,259 acres of grain sorghum were irrigated [11,12].

A linear programming model for the five county region was constructed using the above basic land resources. The dryland and irrigated activities for grain sorghum and wheat were based on crop enterprise budgets for the area [3, 4, 9]. Weed control beyond normal tillage operations was included based on the estimated acreages sprayed as reported above. For example, for every acre of dryland grain sorghum produced, additional weed control is needed on one half acre; for every irrigated acre of grain sorghum produced, additional weed control is required on 0.85 of an acre. This weed control requirement was included in the model in one of three ways: (1) use of 2,4-D, (2) use of 2,4-D and dicamba, and (3) use of dicamba, other chemicals and additional tillage operations. Each of the three weed control alternatives was included as separate activities, by crop. The substitutes for 2,4-D to control weeds were based on data reported in the USDA publication "Restricting the Use of Phenoxy Herbicides" [2].⁶ Dicamba was assumed to substitute for about one half of the acres where 2,4-D is presently being used, with other controls including chemicals and tillage operations required on the other half [2].

The herbicide, 2,4-D was assumed to be applied at a rate of one-half pound per acre with the price 52 cents per pound compared to an application rate of one-fourth pound per acre for dicamba with the price assumed to be \$1.85 a pound. The assumed price, excluding government payments, for wheat was \$1.25 per bushel and for grain sorghum \$1.95 per hundredweight. No government payments were included for either crop but amounted to \$16.6 million in 1969. With this basic input data, the effect of a tax on quantity of chemical use on wheat and grain sorghum for the five county area was estimated.

A Tax

For illustrative purposes, the response of quantity used of the phenoxy herbicide 2,4-D to changes in the price of 2,4-D was investigated.⁷ The price of 2,4-D was increased by increments, using parametric programming, from 52 cents per pound to \$100.00 per pound. The L.P. model indicated the quantity of 2,4-D that could be expected to be applied to the five county study area. The tax on 2,4-D would be the difference between 52 cents and

the farmer or program price; i.e., at 96 cents per pound of 2,4-D, the tax would be 44 cents.

The solid line on Figure 1 indicates the quantity of 2,4-D used at alternative prices of 2,4-D given that 1969 diverted acreages are maintained. At the normal 52 cents per pound, use of 142,800 pounds of 2,4-D would be expected with net returns from the sale of grain sorghum and wheat an estimated \$18.8 million. This solution provides a basis for comparison. If the price of 2,4-D is increased to 92.5 cents per pound, the use of 2,4-D decreases to 101,132 pounds (a decline of 41,668 pounds) and net returns decline only \$17 thousand. In this case, the use of dicamba goes from zero to 20,834 pounds, (i.e., dicamba is substituted for 2,4-D on irrigated grain sorghum). At a price of \$2.26 per pound for 2,4-D, 74,256 pounds would be applied (this implies a tax of \$1.74 per pound on 2,4-D). With the 2,4-D price increased to \$26.92 per pound, 15,790 pounds are still in the solution, but net returns have been reduced to less than \$18 million. The price of 2,4-D was increased to \$37.44 per pound before the herbicide was forced completely out of solution. This provides some indication of the response of 2,4-D use to a price change.

Marketing Quota Program

Extending the analysis to a marketing quota program, the initial solution obtained with diverted acres and a price of 52 cents for 2,4-D was selected as the basis. The solution with acreage allotments and, alternatively, a marketing quota program, given 2,4-D is 52 cents a pound is shown in Table 1. The production for the five county area was 14,836,052 hundredweight of grain sorghum and 17,044,441 bushels of wheat. For a marketing quota program, these output levels for grain sorghum and wheat were entered into the model as an upper limit on quantity that could be sold from the five county area. In addition, all allotments were removed as restrictions and diverted acres released for production.

As indicated in Table 1, the effect of a marketing quota farm program compared to acreage allotments for the study area is: (1) net returns increased from \$18.8 million to \$19.9 million, (2) the diverted acres along with some irrigated wheat acres were used to produce dryland wheat (dryland wheat production increased from 394,009 acres to 622,943 acres) and (3) no change in grain sorghum acreages. Regarding inputs, the marketing quota farm program used

⁶The simplex tableau and any specific input data or additional explanation are available from the authors.

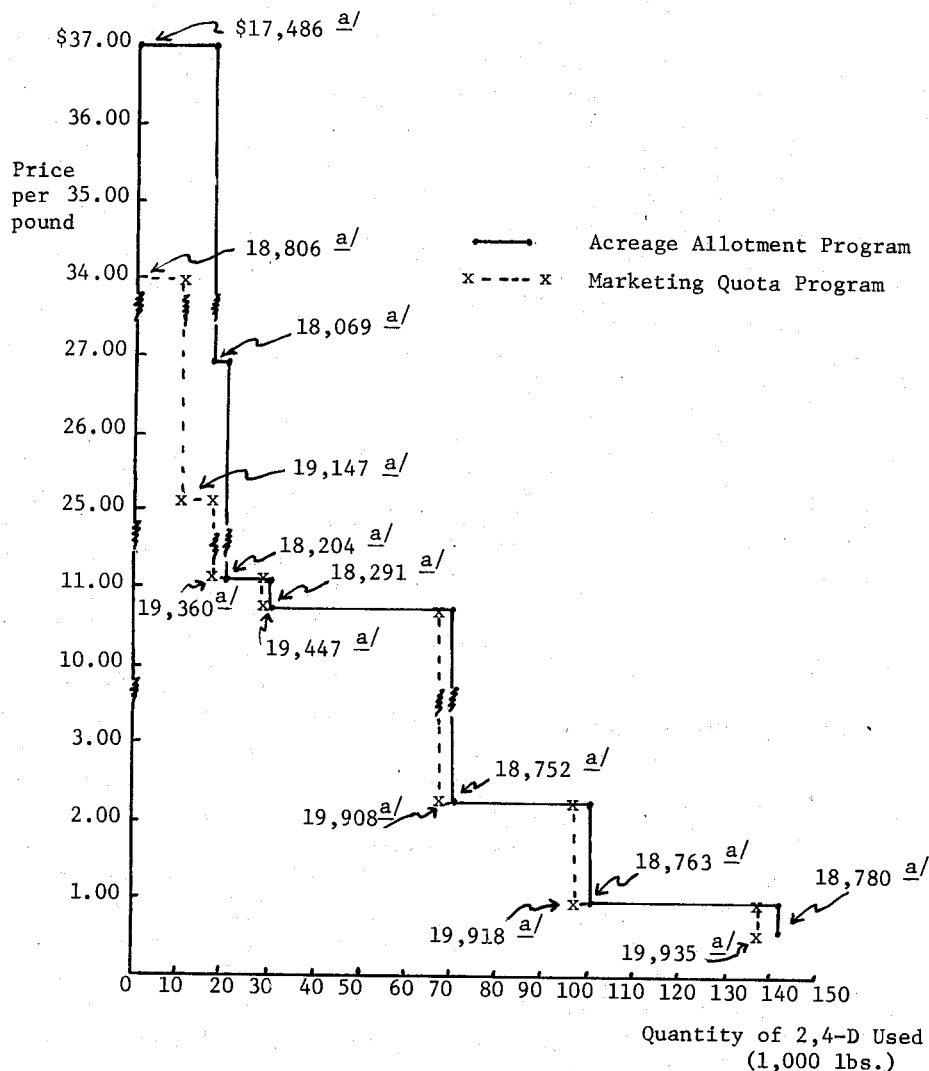
⁷The herbicide 2,4-D was selected principally because data for such an analysis were available. No reflections on this herbicide are intended.

40,003,000 pounds of nitrogen compared to 48,804,000 for an acreage allotment program (8,801,000 pound decrease) and use of 2,4-D declined over 4,000 pounds.

The broken line in Figure 1 illustrates the effect of a marketing quota farm program used in conjunction with a 2,4-D tax on the quantity of 2,4-D applied. This can be compared to the acreage

allotment program. The difference in 2,4-D use rates is not dramatic, but at each given price of 2,4-D, the marketing quota farm program is characterized by less 2,4-D being used as well as a higher net return value being derived for the five county area. The increased level of net returns is the result of substituting idle dryland for irrigated cropland under a marketing quota program.⁸

Figure 1. RESPONSE OF QUANTITY OF 2,4-D USED IN A FIVE COUNTY AREA OF THE NORTHERN TEXAS HIGH PLAINS TO ALTERNATIVE 2,4-D PRICES ASSUMING A GOVERNMENT FARM PROGRAM OF ACREAGE ALLOTMENTS AND ALTERNATIVELY A MARKETING QUOTA PROGRAM



^aFive County area net returns in thousands of dollars assuming \$1.25 @ bushel for wheat and \$1.95 @ cwt. for grain sorghum.

⁸Returns above production costs per bushel of wheat produced are larger for dryland as compared to irrigated production, but, as expected, per acre yields are larger for the irrigated land. Therefore, with a specified level of wheat that can be produced and idle acreage available, total area net returns are increased by substituting additional dryland wheat production for irrigated production until all acres are utilized to satisfy the specified level of output.

Table 1 COMPARISON OF INPUTS, NET RETURNS AND ACREAGES ASSUMING FARM PROGRAM AND ALTERNATIVELY A MARKETING QUOTA FARM PROGRAM

Item	Unit	Acreage Allotment Program	Marketing Quota
Net returns ^a	dol.	18,780,000	19,953,000
Irrigated grain sorghum	acres	204,259	204,259
Dryland grain sorghum	acres	63,096	63,096
Irrigated wheat	acres	202,442	126,096
Dryland wheat	acres	394,009	662,943
Diverted	acres	189,533	0
Grain sorghum	cwt.	14,836,052	14,836,052
Wheat	bu.	17,044,441	17,044,441
Nitrogen	lb.	48,804,000	40,003,000
2,4-D	lb.	142,800	138,522

^aThe price of grain sorghum was set at \$1.95 per hundredweight and wheat at \$1.25 per hundredweight with no government payments included.

CONCLUSIONS

With public attention directed toward action to reduce pollution and clean up the environment; industry, municipalities and also agriculture can expect pressure to be brought forth which will reduce the wastes released into the ecosystem. It is appropriate to evaluate the alternatives available for reducing the quantity of chemicals used in agricultural production with an obvious shifting of society's environmental awareness.

A major contribution of this study is deriving empirical estimates of the response of 2,4-D using two alternative policies. Based on a linear programming model for a five county area in the Northern High Plains of Texas, a tax which increases the price of 2,4-D by 78 percent could be expected to result in a 30 percent decrease in its use. As the price of 2,4-D is increased from \$0.52 cents a pound to \$2.26 a pound, the reduction in use is significant (at \$2.26 per pound the quantity of 2,4-D used is one-half of that quantity used when 2,4-D is priced at \$0.52 per pound). Beyond \$10.00 per pound, the reduction in quantity of 2,4-D used is less responsive to increased price. This suggests a tax on 2,4-D equal to the present price of 2,4-D up to about 5 times the

present price would result in sharp reductions in the use of the herbicide.

The expected effect of a marketing quota program for the five county study area in which there are no diverted areas or allotments would be an 18 percent reduction in the level of nitrogen applied, a 4,300 pound reduction in use of 2,4-D and a \$1.2 million increase in net returns, not including any government payments. This implies a marketing quota program would have the greatest effect on fertilizer use while a tax could be instigated to affect the use of a particular pesticide. In many cases, it is expected that with a marketing program the use of pesticides would remain fairly constant per acre, and the result of the program in some areas could be an increase of the use of pesticides.

The authors suggest a tax on specific chemicals and a marketing quota farm program be considered not necessarily in the context of improving farm income (even though this may occur) but to reduce the level of chemical use in agriculture. The objective of these programs would, therefore, be to reduce agricultural related pollution and have the side benefit of minimizing the economic effect on the farmer.

This paper discusses some indications of the expected effect which selected government policies may have on agricultural use of chemicals and agricultural income. However, this study, as in most programming analyses, was confronted with the traditional data problems of price, appropriate coefficients and identifying and quantifying the alternatives. The authors acknowledge that there are substitutes for 2,4-D that can be considered for weed control other than those considered. Therefore, the 2,4-D prices, especially those greater than \$10.00 per pound, that designates a reduction in the use of 2,4-D may be over-estimated; i.e., substitution would occur at a lower 2,4-D price than that indicated.

The analysis of a tax and marketing quota farm program has been limited to a five county area in the

Northern High Plains. As a result, there are important implications not discussed. For example, regional shifts in production patterns and the effect on local economies of alternative policies need to be studied (i.e., an extension of the Farris and Sprott article [1]). In addition, there is a need to consider the manner in which time will effect expected quantities of chemicals used. That is, policies that bring about a quantity reduction in the present use of chemicals in agriculture may also permit increased weed and pest populations to survive. Therefore, after several years, effective control of weeds and insects may require an increasing annual quantity of chemicals used in agriculture. This paper represents a study of a small area and is intended to serve as a basis for more comprehensive analyses that consider the broader scope questions mentioned above.

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