Are Farmers Using Too Much Fertilizer? Evidence from Missouri Corn Farmers

Feng Xu and Tony Prato

Center for Agricultural, Resource and Environmental Systems
College of Agriculture, Food and Natural Resources
University of Missouri-Columbia
Columbia, MO 65211

Research Report No. 3

August 1992

Are Farmers Using Too Much Fertilizer? Evidence from Missouri Corn Farmers

Feng Xu and Tony Prato[1]

Introduction

Farmers use fertilizers in production to increase productivity. However, recent water quality concerns have generated pressure on agriculture to reduce fertilizer use. Many advocates for sustainable agriculture believe that fertilizer use can be reduced without decreasing farmers' profitability based on belief that farmers tend to overuse fertilizers in their production. There is little evidence to support this belief. If it can be shown that reduction in fertilizer use is more profitable for farmers, they might be willing to reduce fertilizer use to enhance profitability. At the same time water quality could be enhanced. This is a win-win situation. It is also important to know whether or not reduction in fertilizer use decreases profitability. Estimates of effects of reducing fertilizer use on profitability can help to assess the impacts of potential regulatory policies on fertilizer use and farm profits.

Reduction in use of chemicals decrease yield. Smith et al. projected that average corn yield would decline 53 percent from 122 bushels per acre under current practice to 58 bushels per acre under no chemical scenario in the United States, and decline 48 percent from 127 bushels per acre to 66 bushels per acre in the Corn Belt. Nehring and Somwaru found that some medium and high input users of fertilizer and chemicals,

[1] Feng Xu is a Research Assistant Professor and Tony Prato is a Professor at the Department of Agricultural Economics, University of Missouri. A version of this paper was presented on a poster session at the 1992 AAEA Annual Meeting, August 9-12, Baltimore, Maryland. Authors thank Gerry Ehlmann for preparing data.

particularly among corn farmers, are over-utilizing fertilizers and chemicals and may not be maximizing profit.

Missouri is a major corn production State in the Corn Belt. Farmers use more fertilizer in the production of corn than in the production of any other crop. Vroomen and Larson have found that fertilizer elasticity of demand is low (for example nitrogen demand elasticity ranges from 0.23 to 0.85 in five Corn Belt states) and becomes less responsive to price over time, indicating that a policy of taxing fertilizers will not be very effective and will be less effective over time.

This paper analyzes the potential effects of reducing the quantity of fertilizer use in corn production in Missouri. Based on an estimated production relationship between yield and fertilizer expenses, effects of reducing fertilizer use in corn production are examined for selected Missouri farmers.

Data

The data were collected from the Management Information Record (MIR) in Missouri. The objectives of the MIR program are to provide information that is useful in managing farm businesses, and to provide current farm data to support research and teaching efforts in farm management. Cooperative farmers provide information which might not normally included in their own records. MIR data cannot be considered as representative of an average Missouri corn farm because farmer participation is voluntary. However, the data show what can reasonably be expected on commercial farms in Missouri (Hein).

Cooperative farmers are required to report their expenses on different inputs such as fertilizer, labor, machinery and seed, yield, and acres in corn. Among farmers participating the 1989 MIR, there were 251 farmers who had corn production ranging from 15 to 1362 acres in their operation. Data were screened and processed and one observation was deleted due to lack of information.

Procedures

Differences in corn yield among farmers are accounted for by differences in quantities of various inputs. Major input categories in corn production include land, labor, machinery, seed, pesticides and fertilizer (Vroomen and Larson). Denote corn yield as Y, and input vector as X. The production function can be written as:

(1) $Y = f(X)$

It is reasonable to assume that farmers face identical technologies and input prices in their production of corn and that inputs are homogeneous in a given year. Let r be a vector of input prices. Then production function (1) can be rewritten as:

(2) $Y = f(r^{-1}rX)$

That is, corn yields can be expressed as a function of expenses on inputs. Using the MIR data in 1989, the following statistical model of corn production function is specified:

(3) $Y = f(FERT, CHEM, LAB, MACH, SEED, INS, SIZE) + e$

where:

Y = corn yield per acre

FERT = fertilizer expenses per acre,

CHEM = chemical expenses per acre,

LAB = labor expenses per acre,

MACH = machinery expenses per acre,

SEED = seed expenses per acre,

INS = insurance expenses per acre,

SIZE = number of acres in corn, and

e = error terms that are statistically independent and identically distributed with zero mean and positive finite variance.

Data on FERT, CHEM, LAB, MACH and SEED are available in the MIR database. The directional effects of these variables on corn yield are expected to be positive. However, the possibility of negative effect exists for expenses on fertilizers above a certain level since applying more than is required would reduce corn yield. A quadratic form of the production function is used to examine this possibility.

Variable INS is used to represent a farmer's yield expectation for the coming year. Rates vary inversely with expected yield, holding coverage constant. It is hypothesized that farmers who had purchased and paid higher premiums for crop insurance tend to receive a lower yield, as they had expected. Variable SIZE is used to represent the size effect on corn yield. It is hypothesized that large corn farms are more efficient in using inputs than small farms, that is, there exists economics of size in corn production.

An econometric model is estimated for corn yield responses to inputs and other variables. MIR data on 251 farmers in Missouri who grow corn in 1989 were used. These data included corn yield, expenses on fertilizers, chemicals, labor, machinery, seed and insurance, and acres in corn. Various functional forms were tested and the following was chosen based on plausibility, goodness of fit and statistical significance. The coefficient on SEED was found to be insignificant for several forms chosen in different models and was dropped from the final model. The final model used in the analysis is:

$$(4) \quad Y = a_0 + a_1 FERT + a_2 FERT^2 + a_3 CHEM + a_4 LAB + a_5 MACH + a_6 (LAB)(MACH) + a_7 INS + a_8 \ln(SIZE) + e$$

Results and Analyses

The mean and standard deviation for the variables used in the econometric model are provided in Table 1. If farmers participating in the MIR program are representative, the data can be interpreted as for an average corn farmer. A corn farmer who spent $47.62 on fertilizer, $19.69 on chemicals, $24.74 on labor, $34.92 on machinery and $3.40 on crop insurance would expect a yield of 100.27 bushels of corn per acre on a 187-acre farm in 1989. Estimated results for model (4) are provided in Table 2. The estimated model has a goodness of fit measured by R^2 of 13.76 percent. All estimated coefficients are statistically significant at the 5 percent level.

Table 1. Varaible mean and standard deviation for 250 corn farmers in 1989 MIR data

Variable	Unit	Mean	Standard Deviation
YIELD	Bu/Ac	100.27	26.96
FERT	$/Ac	47.62	18.42
CHEM	$/Ac	19.69	10.78
LAB	$/Ac	24.74	9.27
MACH	$/Ac	34.92	17.12
INS	$/Ac	3.40	5.29
SIZE	Acre	186.82	175.19

Table 2. Estimated results for corn yield model

Parameter	Variable	Estimated Coefficient	Standard Error	|T| Ratio	Prob > |T|
a_0	INTER	40.1406	15.4528	2.60	0.0100
a_1	FERT	0.9488	0.2534	3.74	0.0002
a_2	$FERT^2$	-0.0058	0.0020	2.87	0.0044
a_3	CHEM	-0.4170	0.1572	2.65	0.0085
a_4	LAB	0.7772	0.3669	2.12	0.0352
a_5	MACH	0.5658	0.2750	2.06	0.0407
a_6	LAB*MACH	-0.0180	0.0088	2.37	0.0414
a_7	INS	-0.7510	0.3168	2.05	0.0186
a_8	ln(SIZE)	3.7031	1.8628	1.99	0.0480

A quadratic form in fertilizer expenses (FERT) implies that there exists a level of fertilizer expenses at which yield reaches a maximum. Below this level, the marginal effect of fertilizer is positive and above this level the marginal effect will be negative. Specifically, this level is estimated to be $81.12. According to USDA data for 1990, expenses on N-P-K is $51.93 per acre in Missouri (using $.25, $.23 and $.15 for three component prices, respectively). Average lime expense is $4.00 per acre. Total expenses on fertilizers is $55.93, which is $25.19 below the estimated threshold level, indicating that, on average, farmers in Missouri do not seek maximum yield in making their decisions on fertilizer expenses. Note that 5 percent of total farmers in the data set (13 out of 250) had fertilizer expenses higher than this maximum level.

Optimum level of fertilizer expense is defined as a level that would bring $1.00 return from $1.00 expense on fertilizer. This level is estimated to be at $43.72, which is about half of the maximum level and only $3.90 below the average level, indicating that farmers in Missouri, on average, spend a little more than the optimum level on fertilizer. Maybe yields or prices were not as expected. Farmers may set a yield goal higher than the optimum yield goal and therefore use more fertilizer, or they may expect to have a higher corn price.

Corn price affects farmer's decisions on fertilizer quantity and expenses. Mean corn price is $2.29 per bushel and the standard error is $0.17. It is assumed that corn price varies within 3 standard errors with $0.17 increments. This assumption allows for an analysis of how sensitive fertilizer quantity or expense (assume a constant fertilizer price) is to the price of corn. Optimum fertilizer expenses are $32.83, $37.10, $40.68, $43.72, $46.34, $48.61, and $50.60, respectively, for variations in corn price within three standard errors of the mean. If corn farmers' price expectation was between $2.63 and $2.80 per bushel in 1989, their fertilizer expenses were consistent with profit-maximization behavior.

These results show that Missouri farmers can increase their profits and reduce the risk of water contamination by decreasing fertilizer expenses by about 8.2 percent. Reduction beyond 8.2 percent would reduce farm profits. Incentive policies could be used to compensate farmers if water quality protection is required to further reduce fertilizer uses.

Since prices are constant in a given year, percentage change in fertilizer expenses and percentage change in fertilizer use are the same. Results indicate that farmers spent only slightly more on fertilizer for corn than the optimum amount in 1989, which is inconsistent with the belief by some advocates of sustainable agriculture that farmers tend to use more fertilizer than needed. Arguments that farmers use more fertilizer than needed by advocates of sustainable agriculture is probably based more on crop requirements than on maximizing profits. Therefore, fertilizer use cannot be greatly reduced without decreasing farm profits. If water quality protection requires reducing fertilizer use below the profitable level, farmers should be provided with some incentives to do so.

The substitution between machinery and labor is found to be significant. For each $1.00 decrease in labor expense, $1.17 increase in machinery is required. This is probably due to the low wage rate used to calculate labor expenses, or opportunity cost of labor is low. Crop insurance expenses (INS) were negatively correlated with yield, indicating that corn farmers in general were correct in making decisions on purchasing crop insurance. Those who spent one more dollar purchasing crop insurance experienced a yield reduction of 0.75 bushels per acre.

Effect of farm operation size is found to significant in corn production. Large farms tend to have high yields and therefore more profit than small farms by spending same levels of inputs on a per acre basis. This result is as expected. Large farms are more efficient in their use of machinery, seed, fertilizer and labor. For example, a 300-acre corn farm has a 4 bushel higher yield than a 100-acre farm, ceteris paribus.

Effects of chemicals are different from that of fertilizer. Fertilizer is used to supplement soil's natural fertility. Chemicals are applied to control weeds, insects and diseases. For example, nearly 80 percent of the nitrogen and 99 percent of the phosphorus applied to corn in 1988 were applied at or before seeding (Taylor and Vroomen). Chemicals, especially pesticides, are typically applied to minimize loss rather than to increase yields. Even farmers have applied sufficient pesticides to control pest problems, yields may not be as high as without pest problems. Effects of CHEM are dependent on farmers' behaviors in choosing chemical uses, distribution of weed, pest and other diseases. It is not surprising that expenses on chemicals have a negative effect on corn yield. Berg et al. found that the marginal product for chemicals is significantly negative in 115 sustainable wheat and barley fields in Montana. Expenses on chemicals may be an indicator for severeness of weed, pest and diseases. In 1989, Missouri corn farmers who spent one more dollar on chemicals experienced 0.42 bushels per acre lower yield. Chemical use appears to be a proxy for yield effect of pests/weeds that had not been picked up in the model.

Summary and Concluding Comments

The objective of this study has been to examine the effect of reducing fertilizer use in corn production using farm-specific data. Results indicated that fertilizer use can be reduced from current level by 8.2 percent without decreasing farm profits. Further reduction in fertilizers would affect farm profits. This study showed that fertilizers had brought high returns to farmers in corn production. Without strong market incentives to corn farmers or regulation, fertilizer use is not expected to decrease by much.

While the average corn farmer makes fertilizer decisions that are consistent with profit-maximization behavior, some farmers were over-applying fertilizer. It would be economically sound to impose an upper limit on fertilizer use. Size of corn operation was found to have a positive effect on yield and large farms tended to be more efficient.

A major limitation of this analysis is the omission of other important variables affecting corn yield such as soil, crop rotation and weather. It is hoped that these effects cancel out among the 250 farms included in the analysis.

This paper does provide useful information regarding corn yield response to purchased inputs. Additional analysis should focus on estimating effects of reducing fertilizers and chemicals by examining yearly changes in input expenses and incorporating weather variables.

References

Ayer, Harry and Neilson Conklin. Economics of agricultural chemicals: flawed methodology and a conflict of interest quagmire. *Choices*, 4th Quarter 1990.

Berg, C., D. Dalenberg, J. Duffield, and K. Unger. Alternative agricultural production functions. Paper presented at the 28th annual meeting of Missouri Valley Economics Association, 1992.

Doering, Otto. Changing chemical use: the impact on producers and consumers. Annual Agricultural Outlook Conference, Washington, D.C., November 1990.

Hanson, Jams C., Dale M. Johnson, Steve, E. Peters, and Rhonda R. Janke. The profitability of sustainable agriculture on a representative grain farm in the Mid-Atlantic region, 1981-89. *Northeastern J. of Agricultural and Resource Economics*, 19(2):90-98, October 1990.

Hein, Norlin A. Missouri Farm Business Summary: 1990. University of Missouri-Columbia, Extension Division, FM 9190, 1991.

Knutson, Ronald D., C. Robert Taylor, John B. Penson, Jr., and Edward G. Smith. Economic impacts of reduced chemical use. *Choices*, 4th Quarter 1990.

Lambert, David K. Risk considerations in the reduction of nitrogen fertilizer use in agricultural production. *Western J. of Agricultural Economics*, 15(2):234-244, December 1990.

Nehring, Richard F. and Agapi Somwaru. Chemical use and profitability in the Corn Belt and Delta: and implications for policy. Paper presented in the 1990 SAEA meeting, February 1991.

Smith, Edward G., Ronald D. Knutson, C. Robert Taylor and John B. Penson. Impacts of chemical use reduction on crop yields and costs. Agricultural and Food Policy Center, Department of Agricultural Economics, Texas A&M University. 1990.

Taylor, H., and H. Vrooman. Timing of fertilizer applications. *Agricultural Resources*, AR-15:45-50, August 1989.

Vroomen, Harry and Bruce Larson. A direct approach for estimating nitrogen, phosphorus, and land demands at the regional level. ERS/USDA, TB No. 1786, 1991.

Zilberman, David, Andrew Schmitz, Gary Casterline, Erik Lichtenberg, Jerome B. Siebert. The economics of pesticide use and regulation. *Science*, 253:518-522, 2 August 1991.