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How Sensitive are Crop Yields to Price Changes and Farm Programs?

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Abstract

A two-stage approach is used to estimate sensitivity of corn, wheat, and soybean yields to changes in prices and land idled. Estimated elasticity of demand for fertilizer per acre with respect to expected output price equals 0.47, 0.10, and 0.82 for corn, wheat, and soybeans. Upper estimates of the elasticity of yield with respect to fertilizer equals +0.58, +0.29, and +0.16 for corn, wheat, and soybeans. Yields are found to be quite insensitive to price changes. Fertilizer demands and yields are insensitive to land idled under farm programs.

Key Words: corn, farm programs, fertilizer demands, soybeans, wheat, yields

In a paper published nearly 15 years ago, Houck and Gallagher noted that the sensitivity of crop yields to price changes was a relatively neglected topic. Why this was true then and continues to be true now is difficult to understand. A supply elasticity, the sum of acreage- and yield-response elasticities, is of basic importance to price and farm program analysis. Even so, most of the work on supply has centered on acreage-response elasticities. Although several writers have estimated the demands for fertilizer (Griliches and Roberts and Heady) while others have estimated the purely physical relationship between yields and inputs (Ash and Lin, Butell and Naive, Berck and Helfand, and Paris and Knapp), these two lines of work have rarely been joined to assess the sensitivity of yields to prices.[1] In an important exception, Houck and Gallagher, using time series for 1951-72, estimate that corn yield elasticity with respect to corn price is in the neighborhood of 0.24 to 0.76. They conclude that equating the corn supply elasticity with the acreage response elasticity would be an egregious error. More recently, Menz and Pardey updated the Houck-Gallagher study, using time series data for 1951-80 and a similar research method. They find that a significant corn yield response to corn price changes can no longer be detected.

The main objective of this paper is to investigate the sensitivity of corn, wheat, and soybean yields to price changes using time series for 1964-1988. An important secondary objective is to assess the yield effects of acreage idled under farm programs. Our research strategy, based on a simple recursive model, involves two stages. The first centers on the demands for fertilizer use per acre planted; the second centers on the effects of fertilizer applications on crop yields. In both stages, acres idled under farm programs is treated as an exogenous or predetermined variable measuring the extent of government intervention. The elasticity of yield response with respect to crop price is estimated as the product of fertilizer demand elasticities and yield-fertilizer elasticities. (Our debt to previous researchers is substantial as will become apparent at various points in what follows.) What we find is this. Corn, wheat, and soybean yields likely respond positively to increases in expected output prices, as one might expect, but the effects

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appear to be very small. This is especially true in the case of wheat. We also find little evidence to support the widely held view (see, e.g., Ericksen and Collins) that farm programs tend to increase the demand for fertilizer per acre planted or to increase significantly the quality of land planted to farm program crops.

I. Theoretical Considerations

We assume that the representative farmer seeks to maximize expected profit as follows:[2]

$$E_t(\pi_{t+1}) = E_t(P_{t+1})\, E_t(Y_{t+1} \mid a_t, f_t)\, a_t - R_t a_t - V_t f_t a_t - TFC \qquad (1)$$

where E is the expectation operator and where π equals profit; P equals crop price; a equals acres planted; f equals pounds of fertilizer per acre; TFC equals total fixed cost; and Y equals yield, which is a function of acreage planted, fertilizer per acre, and a random variable measuring the weather. The variables V and R equal, respectively, the price of fertilizer and the nonfertilizer cost per acre of renting and planting land. The subscript t indicates period t. The expected yield is conditional on the levels of planted acreage and fertilizer. We assume the farmer ignores any covariance that might exist between his (her) yield and price and that $y(.)$ is decreasing in a_t but increasing in f_t. Optimization implies that (1) the expected marginal value product of land equals the cost per acre of renting, planting, and fertilizing; and (2) the price of fertilizer equals its expected marginal value product. Assuming the production function is strictly concave, we solve for the first order conditions for the choice variables, which yields the farmer's demand functions for a_t and f_t. These two functions together with the physical relationship for yield are given by:

$$a_t = a[R_t, V_t, E_t(P_{t+1})]$$

$$f_t = f[R_t, V_t, E_t(P_{t+1})] \qquad (2)$$

$$y_{t+1} = y(a_t, f_t, w_{t+1})$$

where w measures random weather. Standard theory predicts that the level of an input is a downward sloping function of its own price and, providing the input in question is normal, an upward sloping function of the expected output price. The cross-price term will be of little interest in what follows. On the basis of System (2), we postulate the following empirical model for the ith crop:

$$FERT_i = F_i\,(PRRA_i, DIVA_i, TREND, e_{1i}) \qquad (3)$$

$$YIELD_i = Y_i(FERT_i, ACP_i, DIVA_i, WETH_i, TREND, e_{2i})$$

where $FERT_i$ equals the fertilizer per acre planted to the ith crop, for corn, wheat, and soybeans in the United States; $YIELD_i$ equals yield per planted acre; $PRRA_i$ equals the ratio of an index of fertilizer prices (1977 = 100) to an index of futures prices for crops, explained in more detail below; $DIVA_i$ equals millions of acres idled under the farm program for the ith crop, including acreage reduction, paid diversion, and 50/92 and 0/92 idled acreage (excludes conservation reserve program); $TREND$ equals 1, 2, ..., 24; ACP_i equals acres planted to the ith crop; $WETH_i$ equals a vector of weather variables; and e_{1i} and e_{2i} are error terms, independently, normally distributed with zero means. Returning to $PRRA_i$, we note that for corn the denominator is an index of the mean futures price for the 15th and last days of March for December delivery. The denominator for soybeans is calculated as for corn except the delivery month is November. The futures price for wheat is the mean price for the 15th and last day of September for delivery in July of the following year. (More than 70 percent of the nation's wheat is winter wheat.) $WETH_i$ for corn equals the deviation from the mean acreage weighted July precipitation for 5 major Corn Belt States (see Butell and Naive). For soybeans, $WETH_i$ is calculated in the same way as for corn except for both July and August. For wheat, $WETH_i$ is a vector with $WETH1$ equaling the deviation from mean acreage weighted April temperature for the Southern Plains States; with $WETH2$ equaling the deviation from mean weighted June temperature for the Northern Plains States; and with $WETH3$ the same as $WETH2$ except for July (see Ash and Ash and Lin).

Some further explanation of System (3) is appropriate. Perhaps the first thing to be said is that aggregate planted acreage equations corresponding to the first equation of (2) have been excluded. The reason for this is that farm programs with land idling provisions greatly complicate estimation of acreage response functions. (See, e.g., the recent work of Burt and Worthington.) Partly for this reason our research objective was limited to fertilizer decisions and yield response, where we believe government intervention is less disruptive of the market mechanism.

Even so, we propose to include land idled under farm programs as an exogenous variable in both the fertilizer demand and yield-fertilizer response functions. Roberts and Heady also included idled acres as fertilizer demand shifters, arguing that (p. 267), "...farmers would apply on their remaining acreage some of the resources they might have used on their diverted land. Also, with the program comes a greater degree of certainty about the product price." They hypothesize that the ceteris paribus relationship between fertilizer use and idled acres is positive. If true, this would be a source of slippage where slippage is defined as the difference between the percentage reductions in acreage and expected production. Idled acreage is also included in the yield-fertilizer relationship on the argument that farmers tend to idle land of the poorest quality subject more-or-less to the provisions of farm programs (see Love and Foster). We will have more to say about this issue later on.

Following previous research, acreage planted is included as a predetermined variable in the yield-fertilizer equation. The argument is that as acreage expands, land of varying quality may be brought into production with uncertain effects on yield. (See, e.g., Butell and Naive and Houck and Gallagher.) Also, it may be noted that the variable $FERT_i$ could be eliminated from the second equation using the first equation of System (3). The remaining equation then becomes similar to that used by Houck and Gallagher and by Menz and Pardey. We choose to estimate System (3) because the added structure allows for greater clarification of economic effects. In this regard, we note that assuming zero covariance between e_{1i} and e_{2i} converts (3) into a recursive system such that, absent the familiar specification errors, single equation *OLS* yields unbiased estimates.

II. Econometric Results

The econometric results of our analysis are given in tables 1, 2, and 3. Several comments are in order. The estimated coefficients for the ratio of fertilizer price to expected crop price, $PRRA_i$, appearing in the equations reported in table 1, have the expected signs and they are significant at the 1 percent level. Entering the indexes of fertilizer prices and crop prices as separate variables in the fertilizer demands rather than in ratio form gave results that were essentially the same as those given in table 1. This was true whether or not the indexes were corrected for price level changes.

The estimated coefficients for idled acres, *DIVA*, under the corn and wheat programs are insignificant. (See table 1.) Aside from the possible indirect effects of price changes, it does not appear that farm programs have an impact on the demands for fertilizer per acre planted. Because farm programs undergo significant alterations through time, we decided to use idled acreage as the best indicator of the extent to which government programs alter farmers' production decisions.[3]

The results given in table 2 suggest, as expected, that fertilizer exerts a positive effect on crop yields. The estimated coefficients for *FERT*, although generally significant, are almost certainly biased upward because the estimated equations fail to separate out the effects of technological change. The standard though somewhat crude method for taking technological change into account is to insert trend as an independent variable (Menz and Pardey). We learned from experimentation, however, that including both *TREND* and *FERT* in any one of several alternative specifications plays havoc with the statistical results. (For similar findings see Love and Foster.) Including *TREND* in the equations given in table 2 gave rise in all cases to negative coefficients for fertilizer. (Parenthetically, the resulting positive yield-trend elasticity for corn was much larger than for wheat and soybeans.) The high degree of multicollinearity between fertilizer applications and technological change poses a major problem for those interested in measuring the separate influence of each. Returning to table 2, we argue that the coefficients for fertilizer should be viewed as measuring an upper bound effect of

Table 1. Estimates of Fertilizer Demand Functions for Corn, Wheat, and Soybeans Based on Time Series for 1964-1988[a]

	Independent Variables and R^2				
Crop	*CONST*	*PRRA*	*DIVA*	*TREND*	R^2
Corn	124.14	-44.489 (4.877)	0.211 (1.419)	2.975 (10.373)	0.84
Wheat	17.002	-3.034 (2.102)	-0.021 (0.516)	1.041 (20.402)	0.95
Soybeans	22.118	-9.594 (6.320)	NA	0.573 (11.835)	0.87

[a] Estimates were obtained using seemingly unrelated regression (*SUR*). The dependent variable is pounds of commercial fertilizer per acre planted. Numbers in parentheses are t-ratios. NA means not applicable. (See text for definitions of independent variables.)

Table 2. Estimates of Yield-Fertilizer Relationships for Corn, Wheat, and Soybeans Based on Time Series for 1964-1988[a]

	Independent Variables and R^2							
Crop	*CONST*	*FERT*	*ACP*	*DIVA*	*WETH1*	*WETH2*	*WETH3*	R^2
Corn								
(1)	-16.802	0.370 (2.796)	0.712 (0.747)	0.182 (0.279)	6.028 (3.069)	NA	NA	0.65
(2)	37.170	0.412 (3.467)	NA	-0.279 (1.353)	6.250 (3.254)	NA	NA	0.64
Wheat								
(3)	16.489	0.146 (1.024)	0.096 (1.111)	0.104 (1.399)	-0.336 (2.277)	-0.159 (0.865)	-0.408 (2.015)	0.75
(4)	19.639	0.282 (5.141)	NA	0.038 (0.845)	-0.304 (2.090)	-0.285 (1.945)	-0.361 (1.932)	0.73
Soybeans								
	23.209	0.265 (2.674)	NA	NA	0.789 (2.921)			0.53

[a] Estimates were obtained using seemingly unrelated regression (*SUR*). Yield per planted acre is the dependent variable. Numbers in parentheses are t-ratios. NA means not applicable. (See text for definitions of independent variables.)

fertilizer use. Also, the estimated coefficients for the weather variables were significant in all cases except for *WETH2*, reflecting June temperature for the Northern Plain States in equation (3) for wheat.

The amount of planted acreage may have an effect on crop yields. This is because a higher relative expected price of a crop would attract additional acreage that might be of either higher or lower quality than initial acreage. Examination of the data indicated that the primary cause of variation in acreage planted is land idled under farm programs. We experimented with formulations in which total land planted to a crop or acreage idled or both were included as independent variables. The main results are given in table 2. None of the estimated coefficients for planted and idled acreage is significant. Deleting acreage planted did little to improve the results for idled acres. (Deleting idled acres but maintaining planted acreage also failed to improve the results.)

Since there are only six observations for the nonprogram years in the case of corn and eight such observations for wheat in our time sample, a Chow test procedure is used to examine structural difference in the determination of crop yields between program and nonprogram years. The null hypothesis that the nonprogram years obey the same relation as the program years is not rejected at the 1 percent level of significance.[4]

Our results are inconsistent with conventional wisdom, which asserts that when a farmer chooses to participate in a land idling program, he or she will tend to idle the least productive acres. We do not reject the plausibility of this argument as far as it goes, but there are other considerations. There is evidence that some land idled by farmers would not have been planted to program crops even if the farmers did not participate in programs. We refer specifically to the so-called "phantom" acres. Between 1972 and 1973, acres idled under the wheat and corn programs fell by over 31 million acres. The total acres planted to wheat and corn increased by 9 million acres. Also, farmers who rent or own phantom acreage, in areas where enforcement of program provisions is lax, will be more inclined to participate in farm programs than those who do not. Of likely greater importance, however, is the land allocation decisions of farmers who do not participate in farm programs. These farmers may be expected to bring additional land into production, land that may be of relatively low quality. High levels of participation in feedgrain programs on the part of the Corn Belt farmers, for example, encourage farmers in the fringe areas such as Wisconsin and South Dakota to plant more corn. We agree that a tendency may exist for the quality of land planted to program crops to rise with increases in idled acres but if the effect is large we would have expected it to show up in our regression equations. The fact that it doesn't suggests the effect may be of negligible importance.

Turning to table 3, elasticity estimates are evaluated at the means. The demand elasticities, given in the first column, are with respect to the ratios of fertilizer to crop prices. As shown by Houck and Gallagher, if prices enter as a ratio, then the elasticity of demand with respect to expected crop price equals minus one times the elasticity with respect to fertilizer price. Farmers increase fertilizer in response to increases in the price of output but the effect is inelastic, particularly in regard to wheat. A 10 percent increase in the price of fertilizer lowers the application of fertilizer per acre of planted corn, for example, by 4.7 percent. The elasticities of yield response to changes in fertilizer applications are given in the second column of table 3. A 10 percent increase in fertilizer per acre causes corn yield to rise, for example, by 5.8 percent. For reasons already noted, these elasticity estimates should be viewed as upper bound estimates, since they are based on estimated slope coefficients that are biased upward. Even so, the yield responses are quite inelastic, particularly for soybeans. The last column of table 3 gives the estimated elasticities of crop yield with respect to expected crop price. They are found by multiplying the product of the entries in the first two columns times minus one. According to the estimate for corn, for example, a 10 percent increase in the price of corn increases corn yield by 2.7 percent. These estimates should also be viewed as upper bound estimates.

III. Conclusions

The above findings coupled with previous findings and theoretical arguments lead us to

Table 3. Elasticities of Fertilizer Demands, Yield-Fertilizer Relationships, and Yield Response to Price Changes for Corn, Wheat, and Soybeans[a]

	Elasticity of		
Crop	Demand	Yield to Fertilizer	Yield to Product Price
Corn	-0.47	+0.58	+0.27
Wheat	-0.10	+0.29	+0.03
Soybeans	-0.82	+0.16	+0.13

[a] Demand elasticity is with respect to the price of fertilizer. Because the estimates are based on price ratios, the demand elasticity with respect to the expected crop price equals -1.0 times that for fertilizer. The elasticities in the second column are for yields with respect to fertilizer use, based on Equation (2) for corn and Equation (4) for wheat, both from Table 2. The elasticities in the third column are found by multiplying the product of the elasticities in the first two columns times -1.0.

conceptualize the yield-price response as follows: at planting time farmers increase fertilizer applications per acre in response to increases in expected output prices but the percentage increases for fertilizer tend to be much less than for prices. The response is inelastic. Idled land considerations under farm programs are largely irrelevant aside from possible indirect effects that arise out of the impacts of farm programs on farm prices.

Increased fertilizer applications increase crop yields but the effects may be small in comparison with those of many disturbing influences. (Adding trend to the equations reported in table 2 still leaves the R^2 values less than 0.85.) Measuring the separate effects of fertilizer poses a difficult statistical problem because fertilizer use has trended upward and is highly correlated with trend, the latter typically used as a proxy for technological change.

The estimated yield-output price elasticity is close to zero for wheat and less than 0.13 for soybeans. The results for corn are problematic. Corn yields are almost certainly increased by increases in expected corn prices, contrary to the claim of Menz and Pardey. (How else can one explain why farmers apply more fertilizer when corn prices rise?) The yield-price elasticity is less than 0.27, however, and probably much less than suggested by Houck and Gallagher on the basis of earlier data. Although the estimate for corn is a good deal higher than for wheat and soybeans, technological change has almost certainly been a greater source of yield increases for corn over our time sample than for wheat and soybeans; the upward bias in our yield-fertilizer elasticity for corn likely exceeds that for wheat and soybeans.

Contrary to conventional wisdom and our own expectations, we find little evidence that land idling programs affect significantly crop yields. As explained above, phantom acres together with a tendency of nonparticipating farmers to bring relatively poor quality land into production, as participating farmers do just the opposite, may cause the yield-diversion effect to be small and difficult to detect using regression analysis.

References

Ash, M. S. "Predicting Yields of Wheat by Class." *Wheat Situation and Outlook.* WS282, USDA, ERS, August, 1988.

Ash, M. S. and W. Lin. "Wheat Yield Response: Policy Implications and Projections." *Wheat Situation and Outlook.* WS-275, USDA, ERS, May, 1986.

Berck, P. and Gloria Helfand. "Reconciling the von Liebig and Differentible Crop Production Functions." *Amer. J. Agr. Econ.* 72(1990):985-996.

Burt, O. R. and V. E. Worthington. "Wheat Acreage Supply Response in the United States." *W. J. Agr. Econ.* 13(1988):100-111.

Butell, R. and J. J. Naive. "Factors Affecting Corn Yields." *Feed Situation.* FdS-269, USDA, ERS, May 1978:14-15.

Ericksen, M.H. and Keith Collins. "Effectiveness of Acreage Reduction Programs." *Agricultural -Food Policy Review: Commodity Program Perspectives.* Agr. Econ. Report No. 530, USDA, ERS, July, 1985.

Griliches, Zvi. "Estimates of the Aggregate Agricultural Production from Cross-Sectional Data." *Amer. J. Agr. Econ.* 45(1963):419-432.

Houck, J. P. and P. W. Gallagher. "The Price Responsiveness of U.S. Corn Yields." *Amer. J. Agr. Econ.* 58(1976):731-34.

Love, H. A. and W. E. Foster. "Commodity Program Slippage Rates for Corn and Wheat." *W. J. Agr. Econ.* 15(1990):272-281.

Menz, K. M. and P. Pardey. "Technology and U. S. Corn Yields: Plateaus and Price Responsiveness." *Amer. J. Agr. Econ.* 65(1983):558-562.

Paris, Q. and K. Knapp. "Estimation of von Liebig Response Functions." *Amer. J. Agr. Econ.* 71(1989):178-86.

Roberts, R.K. and E.O. Heady. "Fertilizer Demand Functions for Specific Nutrients Applied to Three Major U.S. Crops." *W. J. Agr. Econ.* 7(1982):265-277.

Endnotes

[1]In a recent paper, Love and Foster are mainly concerned with estimating farm program slippage rates; they do not estimate yield-output price elasticities. Also, they assume fertilizer applications and yields are jointly dependent but we argue that in modeling the determination of actual as opposed to expected yields, fertilizer use must be viewed as a predetermined variable.

[2]This objective is usually based on the assumption of risk neutrality. Alternatively, it may be assumed that the farmer, though risk averse, has access to a costless banking system that allows complete stabilization of consumption expenditures even though profits vary from year to year.

[3]Inserting idled acreage as an independent variable risks simultaneous equations bias, but inserting variables to measure the changes in program parameters that have occurred through time in farm programs also risks specification error. We nevertheless explored alternative specifications in which support and target prices and acreage diversion percentages were included in the equations in place of idled acreage. The results supported the conclusion given in the text.

[4]The values of the F-statistic for corn using Equations (1) and (2) from table 2 are, respectively, 0.70 (6,15) and 0.79 (6,16). The F-values for wheat using equations (3) and (4) from table 2 are, respectively, 0.01 (8,11) and 0.06 (8,12).