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# TARGET PRICE INCENTIVES TO REDUCE NITROGEN USE IN AGRICULTURE - FIRST ROUND IMPACTS[1]

by

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## Target Price Incentives to Reduce Nitrogen Use in Agriculture - First Round Impacts

### Issue

In the past decade the environmental consequences of nitrogen use in agriculture on groundwater quality have received accelerated attention. Nitrate levels near or above the EPA 10 part-per-million drinking water limit have been documented in a number of states. This has led to various approaches to reducing the potential for nitrogen to leach into groundwater.

One approach is that of significantly reducing or completely eliminating commercial fertilizer applications by the use of crop rotations and livestock wastes. Generally this approach has focused on rotations which include forage legumes. This approach has had its policy focus in the interest and development of commodity programs which provide for greater crop flexibility for producers. This approach can result in a lower proportion of acreage in nitrogen intensive higher valued crops. Further, questions remain regarding the environmental consequences of high levels of soil nitrogen provided by legumes or livestock wastes.

Another approach has been more narrowly focused and directed toward the levels of commercial nitrogen applied in conventional cropping systems. It is frequently suggested that with better management, current levels of nitrogen applications can be continued without threatening groundwater quality. Generally, however, this perspective is that with somewhat reduced levels of nitrogen, better management will enable crop yields to be maintained. In some cases it is suggested that reduced nitrogen applications might be actually yield enhancing. While this latter potential is possible for particular farms it is not likely as a general rule unless there are other considerations such as risk which currently cause farmers to use nitrogen at greater than the yield maximizing level.

This analysis is directed toward the second general emphasis, the direct reduction of nitrogen use within conventional cropping systems. In this analysis the profit penalty to a farm of

22199



sequentially reduced nitrogen use is estimated and translated into a "bribe" calculation. That is, what economic incentive is necessary for farmers to reduce nitrogen application by 10 percent, 20 percent, etc. while remaining equally well off financially? Here, that incentive payment is placed in terms of a target price incentive and the analysis is examined under current commodity program alternatives. Both an individual farmer and an aggregate analysis (widespread farmer participation) are examined. To the degree that such a program is not mandatory nor originating from a regulatory context, the program analyzed here can be termed voluntary.

It should be pointed out that while current agricultural commodity programs are assumed here, a growing awareness of the impacts of commodity programs on the environment is occurring. This emphasis could almost be termed a third approach to reducing environmental consequences of current agricultural practices. This approach suggests that there are three basic features of current programs which result in a resource imbalance in agriculture. These are 1) the use of target prices on certain crops, 2) land retirement in set-aside (ACR) and cropland retirement (CRP), and 3) the past and continuing use of program bushel bases used in determining deficiency payments. The first two forces impact incentives for a) the types of crops grown and associated fertilizer demand, b) overall output levels, and c) substitution of fertilizer and chemicals for other resources. For the third feature (program yields), while these bases can no longer be increased, it is unclear how strong the motivation is to maintain a high farm yield history should future programs change.

The general approach of this study can be visualized in terms of a normal nitrogen production function. It is generally recognized that given current low real nitrogen prices, optimum current production is at the nearly "flat" point of the function. The incremental benefits of marginal nitrogen increases at this point may be negligible. Thus, the necessary incentive payment to decrease nitrogen use may need to be very small. As further nitrogen reductions occur, that cost to compensate producers is expected to rise because the elasticity of the production function continues to increase.

Currently there is considerable interest in programs and educational efforts directed at reducing fertilizer use in agriculture. The 1990 Agricultural Act created a program in which incentive payments can be made to producers who enter a three to five year agreement to reduce chemical use. Further, there is considerable research and educational efforts for farmers to voluntarily reduce chemical applications. In some cases this current interest in reduced chemical use may be the result of fear of potential regulation of use.

## Theoretical Framework

The approach of this study originates from a discrete nitrogen production function such as that shown in Figure 1. In the analysis the function is estimated, but in Figure 1 a representative function is shown. It has the characteristics of production elasticity of less than one. Assume, for the present, constant land and other inputs with nitrogen as a variable input. It results in a marginal cost (supply) function which is segmented and upward sloping as well as an average cost function which is also upward sloping and lies below the supply function.

Again, assuming no change in other inputs, the supply function resulting from alternative nitrogen use is presented in Figure 2 along with a demand for a crop for which nitrogen is an input. For simplicity the segmented supply function is modified to linear as is represented as S. If land currently idled under ARP and CRP programs were brought back into production, the resulting supply curve would be the right of S.

Equilibrium output is determined by the intersection of the target price ($TP_1$) and the supply function at $Q_1$. The market price resulting from that output is the intersection of $Q_1$ and the demand function (D) at $MP_1$. To the producer, returns are composed of two parts. One is market returns which is $Q_1$ multiplied by $MP_1$. The second component is the deficiency payment which is a program farm yield ($Q_*$) multiplied by $TP_1$ minus $MP_1$.

Suppose now producers, in aggregate, are willing to reduce nitrogen use by some amount. That incentive to reduce supply may be assumed to result from a program to reward producers through a target price incentive. That new target price ($TP_2$) intersects the supply function S' (reduced from nitrogen) at $Q_2$. $Q_2$ in association with the demand function increases the market price to $MP_2$. Market returns are now $Q_2$ multiplied by $MP_2$ and the change in those returns depend upon the product demand elasticity. A demand elasticity of -1 would result in market returns being unaffected. Should the demand elasticity be infinite (such as to a producer acting alone) market price is unaffected. Thus, in this case, market returns must decline resulting from a reduction in nitrogen use. Given these potential changes in market returns, that target price $TP_2$ can be estimated such that it will make the producer as well off as before the nitrogen reduction because of its deficiency payment compensation to the market value change.

In this analysis three demand elasticities are examined (-1, -.5, and $-\infty$), the last for a producer acting alone. Also, $Q_*$ is 1) held constant as a base for deficiency payments and 2) reduced as nitrogen and yields are reduced. The analysis estimates necessary target prices $TP_2$ as well as resulting government cost. It should be recognized that because market price increases in response to reduced output, the necessary target prices may actually decline from the current level of $2.75 per bushel because of fertilizer savings.

It is important to stress the theoretical limitations of the study. The use of a farm model to represent necessary adjustment payments does not take into account aggregate resource demand changes nor output supply adjustments in response to these first-round changes. This issue is not important where only a few firms participate in nitrogen reductions but under widespread participation there will be significant second round impacts. For example, as the demand for nitrogen is reduced, its price will be reduced. Further, demands for other inputs will change (p. 99 Gardner). The supply function is reduced and output prices rise. These forces result in eventual new equilibriums in the resource and output markets. These aspects are not considered here, hence this analysis must be considered to be first-round except for the situation of a producer acting alone ($-\infty$ demand elasticity).

In addition to these secondary impacts, it is assumed that output price changes in feedgrains vs. soybeans do not occur resulting from those output changes in corn analyzed here. Also, at the farm level it is assumed for simplicity that reduced corn output does not involve production cost savings.

## Procedure

To arrive at the analytical objective of the study an appropriate farm decision model was required. Its construction and the analysis process resulted in six steps:

1) The development of the base farm. A representative eastern Nebraska farm with a feedgrain base of 400 acres was selected. The relevant cropping system alternatives were chosen to represent the diversity currently existing.
2) For each cropping system involving corn, production functions for anhydrous ammonia ($NH_3$) were estimated from experimental data for each cropping system. 0, 20, 40, 60, 80, 100, and 110 lb.
3) A linear programming matrix was constructed including the discrete $NH_3$ related cropping system activities. Also, the appropriate rows and activities for the four current alternative commodity program alternatives (1990 program) were included.
4) Optimum solutions were determined for each commodity program alternative.
5) For each of the four program alternatives, the matrices were modified to include accounting rows to determine the necessary target price to place the farm at the same income as before a reduction in fertilizer use. This was done sequentially

reducing the fertilizer level from the optimum found in (4) for two program base assumptions and three demand elasticities. The first program production base assumption held the base constant while the second assumed a reduction corresponding to the yield reduction found in the analysis.

6) Government cost (deficiency payments) of each fertilizer reduction-target price solution was calculated.

## Commodity Programs

In this section the four commodity program alternatives are briefly outlined. In addition, there were some differences in assumption regarding what proportion of fertilized acreage was reduced in the development of incentive payments.

FLEX CORN signifies the program in which a farmer who grows corn on the allowable 77.5 percent (155 acres) of the base acres, plants corn on the 15 percent (30 acres) flex acres, and allows 7.5 percent (15 acres) for acreage conservation reserve (ACR). The fertilizer incentive payment under this scenario is for the entire fertilizer level used to grow corn on this farm. This includes the fertilizer originally used on the flex acres. Hence, the return sacrifice of fertilizer in this scenario is greater than the others and is represented by the need for a higher target price incentive. For this alternative as well as the following two, the program base production is 15,810 bushels.

FLEX CORN ALTERNATIVE TWO signifies the program for a farmer who grows corn on the allowable 77.5 percent (155 acres) of the base acres, plants corn on the 15 percent (30 acres) flex acres, and allows 7.5 percent (15 acres) for acreage conservation reserve (ACR). The fertilizer incentive payment under this scenario is for the fertilizer used to grow corn on the allowable 77.5 percent of the base acres. The reduction does not affect the fertilizer usage of the corn planted on the 15 percent flex acres. Overall, the output reduction will be slightly less than that of the FLEX CORN program, which would impact the market price slightly less and require a target price that is slightly higher than that of the FLEX CORN option.

FLEX BEAN signifies the program where corn is grown on the allowable 77.5 percent (155 acres) of the base acres, plants soybeans on the 15 percent (30 acres) flex acres, and allows 7.5 percent (15 acres) for acreage conservation reserve (ACR). The fertilizer incentive payment under this scenario is for the fertilizer used to grow corn on the allowable 77.5 percent of the base acres. The payment does not affect the fertilizer usage of the soybeans planted on the 15 percent flex acres, because soybeans do not require any anhydrous fertilizer.

The ADDITIONAL FLEX BEAN is the program where a farmer grows corn on the allowable 67.5 percent (135 acres) of the base acres, plants soybeans on the 25 percent (60 acres) flex acres, and allows 7.5 percent (15 acres) for acreage conservation reserve (ACR). Notice that the flex acres were expanded by ten percent and the percent of corn on the base acres was reduced by ten percent. Since any decreases in the amount of corn bushels produced would have a similar percent of total bushel change as the FLEX BEAN option, the target prices required for each option is nearly the same for each nitrogen cutback level. The program base production is 13,770 bushels.

## Results

The results of the analysis related to corn production, market prices, and adjusted target prices are shown in Table 1. Initially the optimum $NH_3$ level for corn was found to be 110 lb. per acre resulting in 23,558 bu. of corn produced in the first two program alternatives, 19, 738 bu. in the FLEX BEANS alternative, and 17,191 bu. in the ADDITIONAL FLEX BEAN program. The five discrete $NH_3$ reductions are 10, 20, 20, 20, and 40 lb. Except for FLEX CORN ALTERNATIVE TWO (as explained in the commodity program section) these $NH_3$ reductions are 9, 27, 45, 64, and 100 percent of current optimum (110 lb./acre).

The market price response for a demand elasticity of -∞ is unchanged from the $1.97 per bushel assumed in the analysis. For demand elasticities of -1 and -.5 market prices increase as expected. For example, for the FLEX CORN alternative when $NH_3$ use is eliminated, corresponding market prices increase from $1.97/bu. to $2.41 and $2.85 for demand elasticities of -1 and -.5 respectively.

The target price adjustments from the current $2.75 per bushel resulting from $NH_3$ reductions are downward for all program alternatives at demand elasticities of -1 and -.5 except under the second program yield assumption with a demand elasticity of -l. In that case target prices must be raised above $2.75. Otherwise, for these two elasticity assumptions target prices can be reduced. Market prices increase in these cases either maintaining market returns in the case of demand elasticity of -1 or increasing market returns in the case of demand elasticity of -.5. With increased market prices, deficiency payments are reduced reducing necessary target prices because of fertilizer savings. Where the farm program yield base declines, target prices must be increased to compensate that decline at higher reductions in $NH_3$ where the demand elasticity is -1.

For demand elasticities of -∞ which is the case of a producer acting alone without widespread participation, target prices must always be increased. Those increases, however, are minor for small and moderate reductions in $NH_3$. For example, for FLEX CORN and Program Yield 1, target price increases of 1, 3, 10, 20, and 42 cents per bushel are necessary to accompany reductions of 9, 27, 45, 64, and 100 percent of current optimum $NH_3$ applications. Among program alternatives little difference occurs, however the program yield assumption makes a significant impact.

The government cost (or savings) of the incentive payments depend upon the program base production multiplied by the a) target price previously determined less b) the market price.

Thus, consistent with the previous discussion the government accrues savings by fertilizer reductions for demand elasticities of -1 and -.5 under both program base assumptions and all program alternatives (excepting only demand elasticity of -1 under Program Yield 2 at higher $NH_3$ reductions. For demand elasticities of -∞ (an individual producer acting along) total government cost for the two producer base assumptions are the same (because target price incentives differ). Space does not permit a listing of these savings or costs. In the former case, the governmental savings per farm for FLEX CORN and production base 1 for a demand elasticity of -1 is \$236, \$678, \$1024, \$1171, and \$1385 for the five respective steps. These are cumulative savings. For demand elasticity of -∞ the additional government cost per farm (compared to the current program cost of \$12,332) is \$76, \$601, \$1628, \$3156, and \$6656 respectively for the five steps (again cumulative).

Consumer costs dependent upon corn will be affected by changes in market prices of corn. For demand elasticities of -1 and -.5 (widespread participation), these costs will rise while, of course, for a demand elasticity of -∞ costs are unchanged.

## Conclusions

Under the assumptions of the analysis, a program to reduce anhydrous ammonia use in agriculture was found to require minimum cost. In fact, under widespread participation output reductions lead to increased market prices thereby reducing necessary target prices and government cost. Even without widespread participation affecting market prices, the compensation for a 64 percent reduction in $NH_3$ required only a range of 17-31 cents per bushel depending upon program.

Again it must be stressed that the effects estimated here are only first round and only are derived from one production region. Under widespread participation (demand elasticities other than -∞), output supply functions for feedgrains are significantly impacted yet there may be also minor impacts on other crops formerly using more residual nitrogen. Demand functions for other inputs will shift depending upon the nature of their complementarity or substitutability with $NH_3$. Together, the changed output market and input market will impact equilibria output and input prices.

It is not clear whether the substitution of other inputs for $NH_3$ would be greater than the substitution of other inputs for land under current land retirement programs. Allowing current retired cropland to be used in production under a program of $NH_3$ reductions would be a useful additional analysis.

It may be suggested that an active program (eligibility to receive deficiency payments) of $NH_3$ reductions would be difficult to administer. Whether this observation is correct is unclear. What is important is that this analysis has shown that a direct focus on nitrogen use on current production systems is possible, and such an approach may attain more social goals than other indirect approaches such as the development of incentives to increase the use of long term forage based rotations.

## Reference

1. Garner, B.L. The Economics of Agricultural Policies. Macmillan, New York, N.Y., 1987.

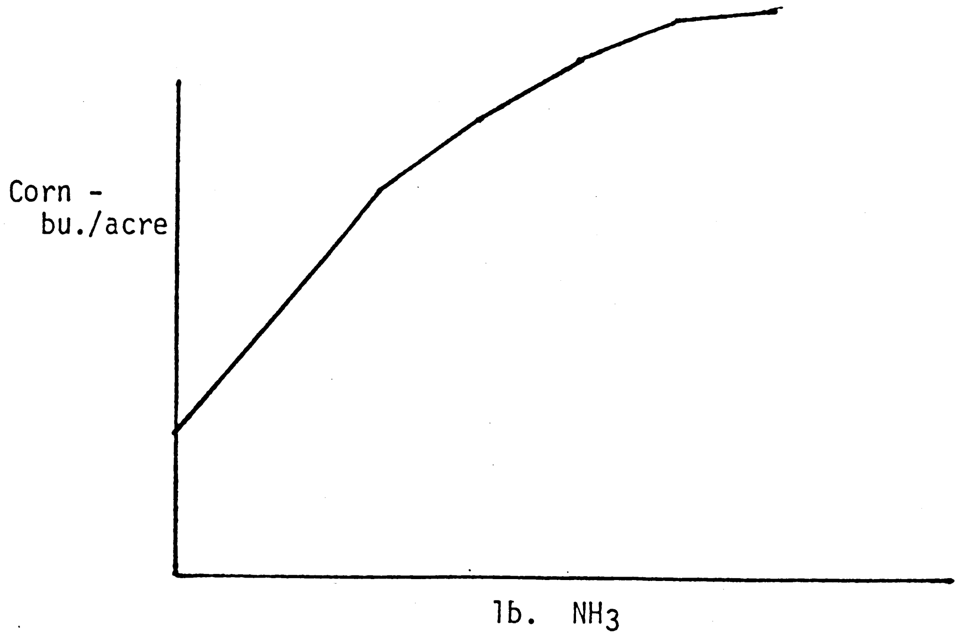


Figure 1. Discrete Production Function for Corn and $NH_3$.

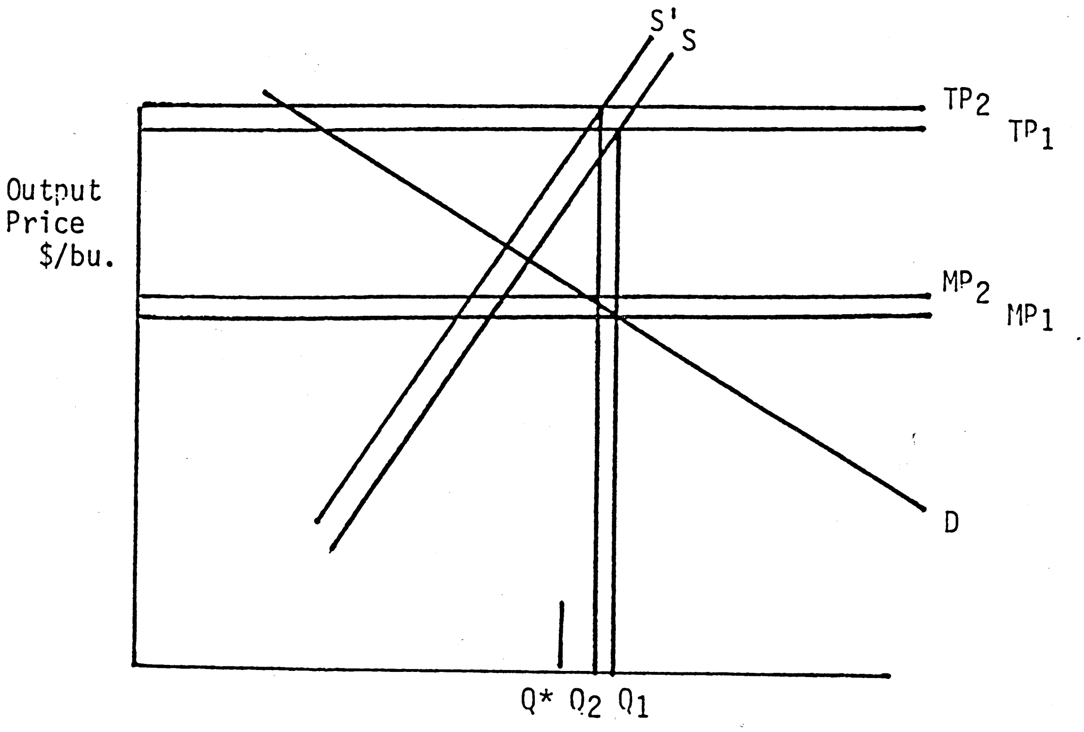


Figure 2. Supply-Demand Equilibria Relationships for Corn Under Current Commodity Program.

Table 1. $NH_3$ Use, Corn Production, Market Prices, and Necessary Target Prices to Maintain Returns Under $NH_3$ Reductions.

| | $NH_3$ Applied[2/] lb. | Corn Produced bu. | E = -1 Market $/bu. | E = -.5 Market $/bu. | ----Program Yield 1[1/]---- E = -1 Target $/bu. | E = -.5 Target $/bu. | E = -∞ Target $/bu. | -----Program Yield 2----- E = -1 Target $/bu. | E = -.5 Target $/bu. | E = -∞ Target |
|---|---|---|---|---|---|---|---|---|---|---|
| FLEX | 20350 | 23558 | 1.97 | 1.97 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 |
| CORN | 18500 | 23399 | 1.98 | 2.00 | 2.74 | 2.72 | 2.76 | 2.74 | 2.72 | 2.76 |
| | 14800 | 22889 | 2.03 | 2.08 | 2.71 | 2.63 | 2.79 | 2.74 | 2.65 | 2.81 |
| | 11100 | 22124 | 2.09 | 2.21 | 2.69 | 2.52 | 2.85 | 2.73 | 2.55 | 2.91 |
| | 7400 | 21106 | 2.18 | 2.38 | 2.68 | 2.40 | 2.95 | 2.76 | 2.45 | 3.06 |
| | 0 | 18305 | 2.41 | 2.85 | 2.66 | 2.15 | 3.17 | 2.86 | 2.21 | 3.52 |
| FLEX | 20350 | 23558 | 1.97 | 1.97 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 |
| CORN | 18800 | 23425 | 1.98 | 1.99 | 2.74 | 2.72 | 2.75 | 2.74 | 2.73 | 2.76 |
| ALTERNATIVE | 15700 | 22997 | 2.02 | 2.06 | 2.71 | 2.65 | 2.78 | 2.73 | 2.66 | 2.80 |
| TWO | 12600 | 22357 | 2.07 | 2.17 | 2.69 | 2.55 | 2.84 | 2.73 | 2.58 | 2.88 |
| | 9500 | 21503 | 2.14 | 2.31 | 2.68 | 2.45 | 2.92 | 2.75 | 2.50 | 3.01 |
| | 3300 | 19157 | 2.34 | 2.71 | 2.66 | 2.21 | 3.10 | 2.82 | 2.27 | 3.36 |
| FLEX | 17050 | 19738 | 1.97 | 1.97 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 |
| BEANS | 15500 | 19604 | 1.98 | 2.00 | 2.74 | 2.72 | 2.76 | 2.74 | 2.73 | 2.76 |
| | 12400 | 19177 | 2.03 | 2.08 | 2.71 | 2.64 | 2.78 | 2.74 | 2.67 | 2.81 |
| | 9300 | 18537 | 2.09 | 2.21 | 2.70 | 2.56 | 2.84 | 2.76 | 2.59 | 2.89 |
| | 6200 | 17683 | 2.18 | 2.38 | 2.69 | 2.46 | 2.92 | 2.77 | 2.52 | 3.03 |
| | 0 | 15336 | 2.41 | 2.85 | 2.68 | 2.25 | 3.10 | 2.88 | 2.33 | 3.43 |
| ADDITIONAL | 14850 | 17191 | 1.97 | 1.97 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 |
| FLEX | 13500 | 17075 | 1.98 | 2.00 | 2.74 | 2.72 | 2.75 | 2.74 | 2.72 | 2.76 |
| BEANS | 10800 | 16703 | 2.03 | 2.08 | 2.71 | 2.65 | 2.78 | 2.74 | 2.67 | 2.81 |
| | 8100 | 16145 | 2.09 | 2.21 | 2.70 | 2.56 | 2.84 | 2.74 | 2.59 | 2.89 |
| | 5400 | 15401 | 2.18 | 2.38 | 2.69 | 2.46 | 2.92 | 2.77 | 2.52 | 3.03 |
| | 0 | 13357 | 2.41 | 2.85 | 2.68 | 2.25 | 3.10 | 2.88 | 2.33 | 3.43 |

1/ Program Yield 1 maintains the farm yield base as production decreases while Program Yield 2 reduces the base yield corresponding to yield decreases as fertilizer is reduced.

2/ The first level is 110 lb. per acre, and the remaining levels are 100, 80, 60, 40, and 0 respectively.