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Effects of Natural Gas Decontrol on Farming Costs and Income

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ABSTRACT

Natural gas decontrol will likely have only a small effect on agriculture unless accompanied by renewed growth in crude oil prices or fertilizer import restrictions. Rising natural gas prices directly affect agricultural production by increasing costs for crop drying and irrigation. However, the largest effects will occur indirectly through increases in fertilizer prices where natural gas comprises 50 to 60 percent of domestic fertilizer production costs. An economic model of agricultural production is developed where profits are maximized subject to the quantity of a quasi-fixed production factor. Factor demand functions and an aggregate supply function are derived from this simple representation to evaluate alternative gas price impacts. Alternative fertilizer price trajectories are used to simulate effects on input demand, production costs, and income for 1981 through 1990.

Keywords: Natural gas decontrol, fertilizer, variable profit function.

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SUMMARY

Natural gas decontrol will likely have only a small effect on agriculture unless accompanied by renewed growth in crude oil prices or fertilizer import restrictions. Although natural gas prices directly affect agricultural production by increasing costs for crop drying and irrigation, the largest effects will occur indirectly through increases in fertilizer prices where natural gas comprises 50 to 60 percent of domestic fertilizer production costs. Increases in fertilizer prices caused by natural gas decontrol are offset by agriculture's ability to substitute other inputs in production. To the extent that input substitution is limited, increases in fertilizer prices cause higher production costs.

The effects on agricultural input demand, costs of production, and income are simulated under varying assumptions about future fertilizer prices and capital availability. The alternative fertilizer price simulations generate widely different fertilizer demand. When fertilizer prices increase 2.5 percent per year, fertilizer demand decreases a total of 10 percent from 1980 through 1990. A 1-percent-per-year decrease in fertilizer prices causes fertilizer demand to increase by 13 percent during the same period.

The level of capital is an important determinant of fertilizer demand. Even when fertilizer prices and output prices are constant, the demand for fertilizer increases 13 percent. Increased fertilizer demand is caused by the dynamic expansion of capital (11 percent from 1980 through 1990). When fertilizer prices increase by 2.5 percent per year beginning in 1981 and output price is constant, fertilizer demand does not decrease until 1984. Variables which affect investment, such as farmers' access to financial capital and interest rates, have important indirect implications for fertilizer demand and agricultural production.

INTRODUCTION

About 50 percent of natural gas production will be decontrolled in 1985 under the provisions of the Natural Gas Policy Act of 1978 (NGPA). Whether natural gas is decontrolled under NGPA provisions or new decontrol legislation is enacted, real natural gas prices are likely to increase during the next few years. Rising natural gas prices will directly affect agriculture by increasing crop drying and irrigation costs. However, the largest effects will occur indirectly through increases in nitrogenous fertilizer prices where natural gas comprises 50 to 60 percent of fertilizer production costs (Lutton and Andrilenas, 1983). Because farm production expenses have increased nearly $100 billion from 1970 through 1981 (U.S. Department of Agriculture, 1982) and real farm income has decreased 70 percent during the same period, the decontrol of natural gas is a concern of the agricultural community.

This analysis determines the effect of alternative natural gas prices, and consequently alternative fertilizer prices, on input demand, production costs, and agricultural income. Although other studies have examined the effects of natural gas decontrol on agriculture (Tyner, 1982; Reisner, 1982), they have not presented a theoretically consistent framework from which to conduct the analysis nor have they adequately accounted for input substitution in agricultural production. A variable profit function is used to derive input demand functions and an aggregate supply function for agricultural output. From these relationships the effects of alternative fertilizer prices on input use, production costs, and farm income are determined. Four fertilizer price paths, representing a broad range of potential natural gas prices, are used to examine agricultural impacts.

REGULATORY POLICIES

The wellhead price of natural gas has been regulated since the 1954 Supreme Court ruling in the case of Phillips Petroleum Co. vs. Wisconsin. Between 1954 and 1978, two separate markets for natural gas developed: A regulated interstate and an unregulated intrastate market. The price of natural gas was higher in the interstate market prior to 1970. After 1970, prices in the unregulated intrastate markets increased faster than the interstate market so that by 1974 intrastate prices were almost four times greater. Most new gas discoveries were sold on intrastate markets causing shortages, curtailments, and the prohibition of new gas hookups in many States without access to intrastate gas supplies.

Congress passed the 1978 NGPA to reduce supply problems by phasing out regulation of many categories of natural gas. A price decontrol schedule was established whereby the price of newly discovered natural gas was allowed to rise to the oil equivalent price during 1979 through 1985. The deregulation schedule was pegged to 1978 oil prices of $14/bbl.

Although NGPA initiated phased deregulation of natural gas prices, inherent limitations of the law, certain provisions of long-term contracts, and decreasing demand have led to disarray in natural gas markets. Natural gas resources are not being developed in the most economically efficient manner, significant price disparities and distortions exist among various categories of gas, and take-or-pay clauses in contracts between gas producers and distributors contribute to rapid growth in prices despite the presence of large levels of shut-in gas supplies. In 1981, for example, wellhead prices ranged from $1 per thousand cubic feet (MCF) gas to $10/MCF, far exceeding the oil equivalent price of about $5.50/MCF.

Concerns of consumers and producers over natural gas availability and prices have led to many legislative proposals to modify current laws and regulatory policies. In early 1983, the Reagan administration proposed the Natural Gas Consumer Regulatory Reform Amendments which would deregulate all gas by January 1986. Alternative measures include freezing wellhead prices for two years, modifying NGPA, voiding take-or-pay contracts, limiting price pass-throughs from gas distributors, and early decontrol of natural gas prices. Any solution to the present natural gas policy problem will include a combination of the elements suggested by these competing proposals.

NATURAL GAS USE

Natural gas is the most important domestic energy source. Domestic natural gas production exceeds production of domestic crude oil by about 20 percent and coal by about 25 percent, on an energy equivalent basis (U.S. Department of Energy, 1982). It accounts for over 30 percent of total U.S. energy consumption.

The direct use of natural gas in agriculture totalled just under 100 billion cubic feet in 1981 (Torgerson, 1983) or only about 0.5 percent of total agricultural energy consumption. Natural gas expenditures accounted for 3.5 percent of energy expenditures and less than 0.3 percent of total farm production expenses. About 67 billion cubic feet of natural gas were used to irrigate crops in 1981 and 12.7 billion cubic feet were used to dry crops.

About four times more natural gas is used in fertilizer production than is used directly in agriculture (Gardner, 1981). Therefore, the major effect of natural gas decontrol on agriculture will be transmitted through changes in fertilizer prices. Fertilizer use in agriculture increased dramatically during the last 15 years. From 1967 through 1982, agricultural fertilizer use grew from 14 to 21.5 million nutrient tons (U.S. Department of Agriculture, 1982). Expenditures during the same period increased over 300 percent. In 1981, farmers spent about $10 billion on fertilizer, 7 percent of total farm production costs (U.S. Department of Agriculture, 1982).

Natural gas is the primary feedstock for the production of anhydrous ammonia, the basis for nearly all domestically produced fertilizer. One ton of ammonia requires between 36,000 to 38,000 cubic feet of natural gas. About 21,000 cubic feet of natural gas are used as raw material for the ammonia and another 15,000 to 17,000 cubic feet are used to provide heat for the production process. Fertilizer producers paid an average price of $2.30/MCF for natural gas in 1981. However, contract prices varied from $0.25/MCF to $4.60/MCF. Natural gas price increases for fertilizer producers will exceed average increases to other industrial users because fertilizer producers currently pay less for natural gas. These lower prices result from price provisions in long-term contracts signed between fertilizer producers and gas distributors in the 1960s and early 1970s and pricing exemptions granted to agriculturally related firms under the auspices of NGPA. In addition, all fertilizer producers will not be affected equally by deregulation because a wide variation in plant efficiency, natural gas prices, and plant location exists among fertilizer producers.

Substantial uncertainty surrounds the future price of natural gas and the price of fertilizer. The uncertainty is generated by the energy market where the price of natural gas is linked to crude oil prices and by the fertilizer market itself. Domestic fertilizer prices are affected by production costs, level of agricultural output, and competition from lower cost fertilizer imports. A 10-percent increase in natural gas prices has been shown to increase aggregate fertilizer prices by only 2 percent (LeBlanc, 1983).

The presence of lower cost nitrogen imports moderates the ability of fertilizer producers to pass natural gas price increases on to domestic agriculture. The United States was a net exporter of nitrogen fertilizers during the 1970's. By 1982, however, exports and imports were about equal. As low-priced natural gas contracts expire, U.S. fertilizer producers are hampered in their competition for international markets. Five million tons of U.S. ammonia production capacity was closed in 1982, representing 25 percent of total capacity. At the same time, ammonia was imported into the United States at less than $115/ton which is $40 to $50 below operating costs for some domestic producers (Lutton and Andrilenas, 1983).

Countries with large supplies of low-priced natural gas and rapidly developing nitrogen production capacity (Canada, Mexico, Nigeria, Indonesia, and the USSR) are in a position to increase their share of the U.S. fertilizer market. Their comparative advantage will rise as domestic fertilizer production costs and prices increase in response to higher natural gas prices. Greater ammonia imports contribute to the cost-price squeeze experienced by domestic manufacturers while moderating fertilizer prices paid by farmers.

PROFIT FUNCTION, FACTOR DEMAND FUNCTIONS, AND CAPITAL

The effect of increasing input prices on agricultural production and income depends on the elasticity of supply for each input, the elasticity of demand for output, and the elasticity of substitution among inputs. This analysis focuses on the farm's production process and treats input and output prices as exogenous data. An economic model is developed whereby profits are maximized subject to the quantity of a quasi-fixed production factor. Factor demand functions and an aggregate supply function are derived from this simple representation. The system is completed by describing how the quasi-fixed factor, capital, changes through time.

Theoretical Structure

The restricted profit function expresses the maximized profit of a firm as a function of output price, input prices, and the quantity of a fixed factor (Lau, 1978). If competitive behavior and a regular technology are assumed, then there exists a one-to-one correspondence between technology and its dual transformation, the profit function. That is, there is a one-to-one correspondence between the set of concave production functions and the set of convex profit functions. The use of a profit function allows the analyst to examine the structure of production without explicitly specifying and estimating the firm's production function. All relevant information about production can be derived from the profit function.

The restricted profit function is derivable from neoclassical concepts. A firm's production function exhibiting the usual neoclassical properties is

$$Q = F(X_1, X_2, \ldots, X_n, K_1, \ldots, K_m) \quad (1)$$

where Q is output, X's are variable inputs, and K's are fixed capital inputs. Because fixed costs do not affect optimal input use, profit is

$$\Pi' = PF(X_1, X_2, \ldots, X_n, K_1, K_2, \ldots, K_m) - \sum_{i=1}^{n} W_i' X_i \quad (2)$$

where Π' is profit, P is the unit price of output, and W_i' is the unit price of the ith variable input. Profits equal current revenue less current cost.

Marginal productivity conditions of the firm

$$P\, \partial F(X,K)/\partial X_i = W_i' \qquad i=1,2,\ldots,n \quad (3)$$

are obtained by maximizing profits for a given technology and capital endowment. The model is simplified by using the output price as a numeraire and defining $W_i \equiv W_i'/P$ as the normalized price of the ith input (Lau and Yotopolous, 1971). The marginal productivity conditions become

$$\partial F(X,K)/\partial X_i = W_i \qquad i=1,2,\ldots,n. \quad (4)$$

Profits are rewritten as

$$\Pi = \Pi'/P = F(X_1,X_2,\ldots,X_n,K_1,K_2,\ldots,K_m) - \sum_{i=1}^{n} W_i X_i \tag{5}$$

where Π is the Unit-Output-Price (UOP) profit.

The marginal productivity conditions are solved for the optimal level of variable inputs, X_i^*, as a function of normalized input prices and the quantity of capital. The optimal levels of variable inputs can be substituted into equation (2) to form

$$\Pi' = PF(X_1^*,X_2^*,\ldots,X_n^*,K_1,K_2,\ldots,K_m) - \sum_{i=1}^{n} W_i' X_i^* \tag{6}$$

or

$$\Pi' = P[F(X_1^*,X_2^*,\ldots,X_n^*,K_1,K_2,\ldots,K_m) - \sum_{i=1}^{n} W_i X_i^*]. \tag{7}$$

Because the term inside the brackets is a function only of W and K it is rewritten

$$\Pi = \Pi'/P = G(W,K) \tag{8}$$

which is the restricted UOP profit function. The profit function, equation (6), is nondecreasing in P and nonincreasing in W', convex in P and W', and continuous in P and W' (Varian, 1978). Therefore, the UOP profit function is decreasing and convex in the normalized prices of variable inputs. In addition, it is increasing in the quantity of capital and the price of output.

The profit function's power rests on a set of dual relationships connecting it with the firm's production function. According to Hotelling's Lemma, the firm's input demand functions are derived by differentiating the profit function with respect to input prices

$$X_i^* = -\partial G(W,K)/\partial W_i \qquad i=1,2,\ldots,n \tag{9}$$

and the supply function is derived by differentiating the profit function with respect to output price

$$S = \partial G(W,K)/\partial P. \tag{10}$$

Hotelling's Lemma makes it possible to derive the factor demand functions and supply function without explicitly specifying and estimating the corresponding production functions. Furthermore, variable profits, supply, and input demand are functions of variables typically considered to be exogenous to a firm's production decisions.

The level of the quasi-fixed factor, capital, is determined outside the current period's profit maximization framework. It is assumed that changes in the level of capital in the current period do not affect production decisions until next period. Profit maximization in this period depends on the level of capital existing at the beginning of the period. Changes in the endowment of capital affect production decisions recursively.

Empirical Model

The modeling system used for simulating the effects of alternative natural gas prices is composed of two submodels. The first submodel is associated with the optimizing behavior of the firm and includes the UOP profit function and factor demand equations. The second is a prediction-oriented submodel which estimates the level of capital. The overall system can be conceptualized as a sequential model where variable profits are maximized subject to capital investment decisions made last period. The UOP profit function is specified and estimated as a quadratic function of normalized variable input prices and the level of capital available at the beginning of the current period

$$\Pi = b + \sum_{i=1}^{n} b_i W_i + b_k K + 0.5\left(\sum_{i=1}^{4} b_{ii} W_i^2 + b_{kk} K^2\right) + \sum_{i=1}^{4} \sum_{j=1}^{4} b_{ij} W_i W_j + \sum_{i=1}^{4} b_{ik} W_i K \qquad (11)$$

where b's are parameters, W's are normalized input prices, and K is the exogenous level of capital. Four variable inputs are considered; fertilizer, labor, energy, and feed-seed. The quasi-fixed factor capital is a Divisia index composed of durable equipment, land, buildings, livestock, and inventories. The input demand equations asociated with the profit function have the form

$$- X_i^* = b_i + \sum_{j=1}^{4} b_{ij} W_j + b_{ik} K \qquad i=1,2,3,4 \qquad (12)$$

where X*'s are optimal input demand quantities.

A quadratic UOP profit function is used because its structure facilitates simulating and estimating the model without placing *a priori* restrictions on the elasticities of substitution. Any equation that gives a second-order Taylor series approximation to an arbitrary functional form is termed flexible. A flexible form is sufficient to guarantee that no arbitrary restrictions on input choice exists (Fuss, McFadden, Mundlak, 1978). The quadratic structure generates linear input demand functions and simple expressions for demand and substitution elasticities. A quadratic normalized profit function is self-dual. That is, if the profit function is quadratic, the technology is also. The UOP profit function and the input demand equations contain all the information necessary to derive the supply function. Symmetric cross-price effects, suggested by neoclassical theory, are applied in both the profit function and the input demand equations.

The quasi-fixed factor, capital, is represented as single variable in the UOP profit function and input demand functions. Because the focus of the analysis is on fertilizer use, production costs, and income, capital is aggregated to reduce the number of parameters entering the estimation procedure. The Divisia aggregator function (approximated in a discrete form by a Tornquist index) is composed of three input categories: durable farm equipment, land and buildings, and farm produced durables. While the Divisia index has many desirable properties, it is not exact for the normalized quadratic form (Diewert, 1976).

The Divisia quantity index requires estimates of the quantity to compute the cost share for each capital input category. The quantity of each capital category is specified as a simple linear function

$$K_i = c_i + \sum_{j=1}^{5} c_{ij}W_j + c_{ki}K_i(-1) \qquad i=1,2,3 \qquad (13)$$

where K_i is the quantity of the ith capital input, c's are parameters, and $K_i(-1)$ is the lagged quantity of the ith capital input.

Data on input and output prices and quantities are required to estimate the models. This analysis uses aggregate time series data for the years 1947 through 1980. A detailed description of data is available in Ball (1984). The data was aggregated using a discrete Tornquist approximation to a Divisia index. Tornquist price indices are computed first, and then implicit quantity indices are computed by dividing value (revenue or expenditures) by the Tornquist price index.

The overall system is estimated in its decomposed form: optimizing model and capital quantity model. The two equation systems were estimated using maximum likelihood methods. Neither the optimizing model's equations (profit function and demand equations) nor the equations associated with capital quantities present any unusual estimation problems.

Model Estimates

The estimated form for the profit function and input demand equations are given by equations (11) and (12), respectively. The quantities of capital inputs are given by equation (13). Parameter estimates and their associated asymptotic t-Statistics are presented in table 1. The single equation R^2 statistics are: equipment 0.98, land 0.70, and farm-produced durables 0.93 for the capital quantity model and variable profit 0.37, fertilizer 0.92, labor 0.89, energy 0.95, and feed/seed 0.87 for the variable profits and input demand model.

The parameter estimates produce plausible model results. Own-price effects have the correct sign and are associated with large asymptotic t-Statistics. In fact, the large magnitude of some of the t-Statistics in the profit function and input demand system is surprising. Part of the explanation lies in ascribing asymptotic properties to parameters estimated from only a

Table 1--Parameter estimates for profit function, input demand, and capital quantity systems

Profit function and input demand system			Capital quantity system		
Parameter	Estimate	t-Statistic	Parameter	Estimate	t-Statistic
b	580876.0	139.10	cg	3173.24	96.39
bf	-1328.04	-8.76	ct	11564.40	235.60
be	2062.8	15.19	cv	1861.91	24.35
bl	-37142.9	-815.29	cgg	-2545.35	-37.31
bs	-11894.3	-110.17	ctt	-1358.55	-8.53
bk	-26.886	-148.72	cvv	454.52	4.04
bff	4156.47	80.01	cgf	-1065.37	-5.93
bee	1603.17	24.31	cge	1436.02	3.27
bll	2498.8	13.11	cgl	312.08	2.28
bss	7479.85	51.65	cgs	869.46	19.19
bkk	0.00072	87.43	ctf	-111.59	-1.06
bfe	234.77	3.95	cte	1068.2	16.87
bfl	-2436.32	-34.49	ctl	-129.22	-1.17
bfs	-1714.49	45.21	cts	-663.06	-5.25
bfk	-0.1150	-37.07	cvf	-913.76	-8.98
bel	-1372.5	-29.93	cve	1051.55	8.26
bes	207.46	0.73	cvl	-72.19	-0.76
bek	-0.1325	-32.54	cvs	712.36	4.13
bls	-3558.56	-189.09	cgk	0.82	24.12
blk	0.6418	73.59	ctk	0.58	35.96
bsk	-0.3991	-49.32	cvk	0.68	13.81

Notation: bi and ci are constants for the ith equation, bij and cij are coefficients associated with the ith equation, and the jth input price, bik and cik are coefficients associated with the ith equation and aggregate capital stock. Also, bij = bji and f = fertilizer, e = energy, l = labor, s = feed/seed, k = aggregate capital, t = land, and v = farm-produced durables.

moderate-sized sample. Kmenta and Gilbert (1968) suggest most of the maximum likelihood estimator's properties tend to be present in small samples. However, this analysis suggests caution when relating statistical significance to maximum likelihood parameter estimates for at least some applications.

Given the estimated parameters for the profit function and the input demand system, input demand price elasticities can be calculated (table 2). Each own-price elasticity has the theoretically correct negative sign. Fertilizer has the largest own-price effect and feed-seed has the lowest. The cross-price relationships are generally small except for the substitution relationship between fertilizer and labor. An increase (decrease) in fertilizer price significantly decreases (increases) fertilizer demand and increases (decreases) labor.

SIMULATION RESULTS

Eight simulation experiments are conducted for 1981 through 1990. Given the great uncertainty surrounding future crude oil prices, ammonia imports, and natural gas regulatory policy, no attempt is made to predict domestic fertilizer prices. Instead, four alternative price paths representing a broad range of price possibilities are exogenously specified and used to simulate the effects on agricultural production. The cases considered are sufficiently diverse to capture any reasonable projection of natural gas prices (U.S. Department of Energy, 1983). The four cases range from a 1-percent per year real decrease (representing falling oil prices and continued growth in fertilizer imports) to a 5-percent per year increase in the price of fertilizer (representing significant oil price increases and fertilizer import restrictions). Other cases hold fertilizer prices constant and increase prices 2.5 percent per year.

Effects of these alternative fertilizer prices are examined under two different assumptions of output price and capital availability. In the first case, the level of capital is determined within the modeling system and output price is held constant at the 1980 level. In the second case, output price and capital are both constant at 1980 levels. All other input prices are constant at 1980 values for each simulation. Identical

Table 2--Input demand elasticities*

Input	Fertilizer	Labor	Energy	Feed-seed
Fertilizer	-1.10	1.05	-0.04	-0.36
Labor	0.24	-0.40	0.10	0.28
Energy	-0.06	0.57	-0.29	-0.04
Feed/seed	-0.07	0.25	-0.01	-0.26

*Computed at mean values.

simulations can be generated by either varying output price and holding input prices constant or by holding output price constant and varying input prices. Only the relative input-output prices are important.

Demand

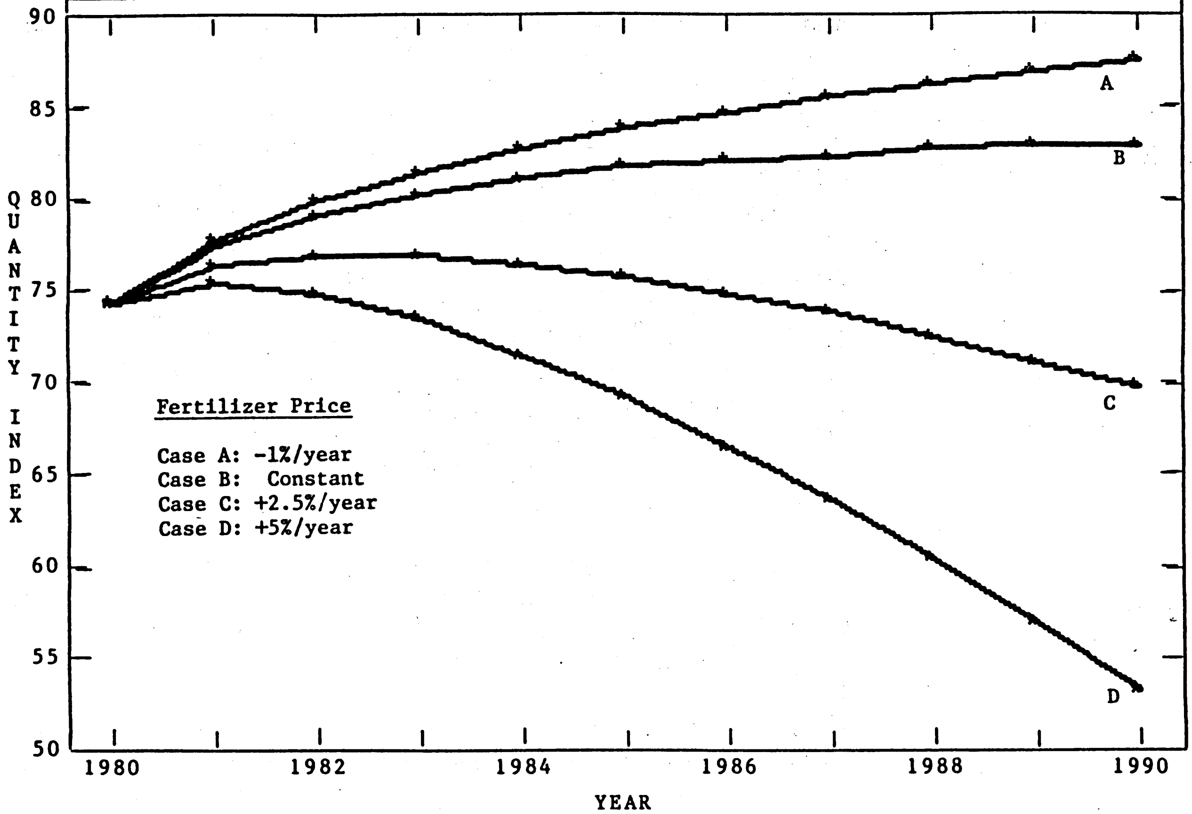
Changes in fertilizer prices have a significant effect on fertilizer demand (table 3). If fertilizer prices increase 5 percent per year, fertilizer demand decreases by 31 percent when output price is constant during 1981 through 1990. A 1-percent per year decrease in prices causes fertilizer demand to increase by 13 percent during the same period. The large changes in fertilizer demand are not surprising given an own-price elasticity of -1.10. When output price is held constant, changes in fertilizer demand are caused by changes in fertilizer prices and changes in the level of capital. Both these factors affect input substitution and output supply. The four fertilizer price simulations generate widely differing fertilizer demands (fig. 1).

The level of capital is also an important determinant of fertilizer demand. This importance is evident when simulations which hold only output price constant are compared with simulations where both output price and the level of capital are constant. The latter set of simulations change fertilizer demand by 3, 0, -15, and -34 percent from 1980 to 1990 under the respective fertilizer assumptions. Holding the level of capital constant reduces the output effects of decreases in fertilizer prices and reinforces increases in fertilizer prices. A constant level of

Table 3--Simulated variable input quantities: 1985 and 1990

Input	Base	Annual percentage change in fertilizer prices							
		-1.0		Constant		+2.5		+5.0	
	1980	1985	1990	1985	1990	1985	1990	1985	1990
Fertilizer:									
P constant	7424	8378	8751	8156	8291	7561	6959	6909	5317
P and K constant	7424	7934	8126	7732	7732	7189	6576	6591	5136
Energy:									
P constant	5438	6315	6534	6281	6438	6190	6169	6094	5854
P and K constant	5438	5804	5815	5792	5792	5762	5727	5728	5646
Labor:									
P constant	7534	3222	2103	3453	2693	4061	4355	4715	6330
P and K constant	7534	5700	5587	5819	5819	6137	6496	6487	7340
Feed/seed:									
P constant	3139	3408	3479	3393	3440	3352	3331	3309	3201
P and K constant	3139	3254	3262	3246	3246	3223	3198	3199	3139
Capital:									
P constant	5007	5438	5569	5413	5504	5350	5325	5285	5115
P and K constant	5007	5007	5007	5007	5007	5007	5007	5007	5007

FIGURE 1. SIMULATED FERTILIZER DEMAND, 1980-1990: CONSTANT OUTPUT PRICE

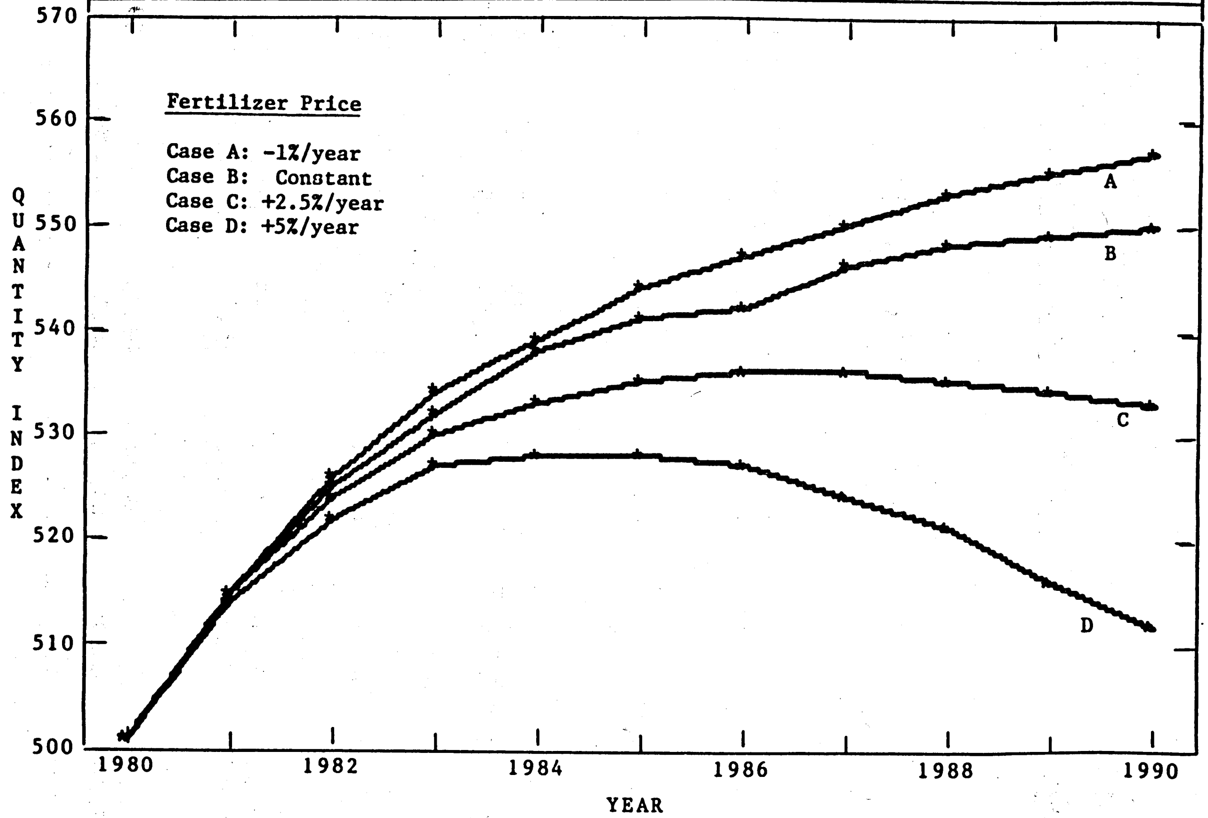


capital affects fertilizer demand by limiting input substitution and restricting output supply. For example, when only output price is constant and fertilizer prices decrease 1 percent per year, output supply increases 70 percent from 1980 to 1990. If both output price and the level of capital are constant, output increases about 18 percent. Increases in the level of capital account for over 50 percent of the growth in output.

The importance of capital in determining fertilizer demand is observable in two instances. First, when fertilizer and output prices are constant, the demand for fertilizer increases by 13 percent. The expansion of capital during this time period (11 percent from 1980 through 1990) causes a continual increase in profits and decrease in costs (fig. 2). Increased profitability results in the expansion of output and an increased demand for fertilizer. Second, even when fertilizer prices increase by 2.5 percent per year and output price is constant, fertilizer demand does not decrease until 1984. From 1980 through 1983, fertilizer demand actually increases by 3 percent. It is not until 1984 that increasing fertilizer costs exceed the effects of capital on total production costs. Capital increases by 6 percent from 1980 through 1983 when fertilizer prices are increasing 2.5 percent per year and output prices are constant.

Increases in fertilizer prices have a small negative effect on energy and feed-seed, but a relatively large positive effect

FIGURE 2. SIMULATED CAPITAL QUANTITY, 1980-1990: CONSTANT OUTPUT PRICE



on the demand for labor. This is expected since the cross-price elasticities are -0.06, -0.07, and 0.24 for energy, feed-seed, and labor, respectively. When output price is constant and fertilizer prices increase 5 percent per year, energy demand increases only by 1 percent and feed-seed demand decreases by 1 percent from 1980 through 1990. The demand for labor under similar assumptions increases nearly 9 percent. Of course, the level of capital is an extremely important determinant of the demand for labor. When capital and output price are constant, the demand for labor increases (capital and labor are substitutes) by 26 percent during 1980 through 1990. Under the same conditions, the demand for energy declines by about 3 percent.

Costs

The derivation of input demand and supply functions using Hotelling's Lemma enables the simulation of input demand and the calculation of production costs and profitability measures (table 4). Fertilizer costs are greater in 1990 than the 1980 base of $10.6 billion for nearly every simulation. Only when output price and capital are constant and fertilizer prices decrease are fertilizer costs lower. A 1-percent per year decrease in fertilizer prices, holding output price constant, results in a 2-percent increase in fertilizer costs by 1990. Otherwise, fertilizer use and costs increase due to expanding output and input substitution.

Table 4--Simulated costs and profits: 1985 and 1990

Input	Base	Annual percentage change in fertilizer prices							
		-1.0		Constant		+2.5		+5.0	
	1980	1985	1990	1985	1990	1985	1990	1985	1990
	Billion dollars								
Fertilizer cost:									
P constant	10.18	10.92	10.85	11.18	11.37	11.73	12.22	12.09	11.88
P and K constant	10.18	10.35	10.08	10.60	10.60	11.51	11.54	11.53	11.47
Variable cost:									
P constant	66.05	81.03	78.03	81.90	80.11	84.07	85.36	86.17	90.25
P and K constant	66.05	86.92	86.35	87.50	87.50	88.91	90.27	90.24	92.48
Capital cost:									
P constant	91.78	71.98	73.71	71.99	72.86	70.81	70.49	69.92	67.71
P and K constant	91.78	66.27	66.27	66.27	66.27	66.27	66.27	66.27	66.27
Total cost:									
P constant	157.83	153.01	151.74	153.56	152.97	154.88	155.85	156.09	157.96
P and K constant	157.83	153.20	152.62	153.77	153.77	155.18	156.55	156.51	158.76
Revenue:									
P constant	166.18	253.69	280.98	250.83	271.06	243.54	246.98	236.04	217.67
P and K constant	166.18	196.80	196.74	196.85	196.85	196.85	196.87	196.87	196.29
Variable profit:									
P constant	100.13	172.66	202.95	250.83	271.06	243.54	246.98	236.04	217.67
P and K constant	100.13	109.87	110.39	196.85	196.85	196.92	196.87	196.87	196.29
Total profit:									
P constant	8.35	100.68	129.24	97.27	118.10	88.66	89.30	79.95	59.71
P and K constant	8.35	43.60	44.11	43.07	43.07	41.73	40.33	40.36	37.53

There are large differences in fertilizer costs between simulations which increase fertilizer prices and those which decrease fertilizer prices. However, there is little difference in total fertilizer costs by 1990 between simulations with fertilizer prices increasing by 2.5 percent per year and those with fertilizer prices increasing 5 percent per year. When output prices are constant, fertilizer costs are $10.9 billion in 1990 with an annual decline in fertilizer prices of 1 percent and are $12.2 billion with an annual increase in fertilizer prices of 2.5 percent. In the first case, fertilizer costs increase 3 percent and in the second they increase 15 percent. Fertilizer costs are greater in 1990 when fertilizer prices increase by 2.5 percent than when they increase by 5 percent per year. This results from decreases in output due to lower profits.

Fertilizer costs do not necessarily exhibit monotonic trends through time (fig. 3). These trends are caused by the complex interaction of changes in output supply and input substitution. When fertilizer prices increase 5 percent per year, maximum costs occur in 1987 at a little over $12.2 billion and decline to about $11.9 billion in 1990. Maximum fertilizer costs occur in 1986 at about $10.9 billion when fertilizer prices decline 1 percent per year.

Other variable costs exhibit trends similar to fertilizer costs. Variable costs are largest when capital costs are smallest. This occurs for simulations where capital is constant. For example, when fertilizer prices are constant, variable costs are nearly $8 billion greater than when both output price and capital are constant. Total costs generally follow the trend established by variable costs although offset somewhat by changes in capital costs.

Profits

Two profitability measures are presented in table 4: variable and total profits. While variable profit is the value maximized in the profit function, total profit is interesting because it captures the effects of capital costs. These two measures are highly correlated with one another.

The effects of natural gas deregulation and fertilizer price changes on the agricultural production system are summarized by a measure of total profit. In all cases where output price is constant, total profit is greater in 1990 than 1980 (fig. 4). Greater absolute profits are caused by the dynamics of capital. Even when fertilizer prices increase by 2.5 percent per year, the level of capital increases until 1987. A 5-percent growth rate in fertilizer prices turns capital downward by 1985. Profits likewise increase until 1985 with a 5-percent fertilizer price growth and 1987 with a 2.5-percent fertilizer price growth. The timepath of profits follow the same general path as capital.

The four fertilizer price paths generate widely different levels of total profit. If output prices are constant, a 1-percent decline in fertilizer prices increases total profits by $11 billion relative to a situation where fertilizer prices are constant.

FIGURE 3. SIMULATED FERTILIZER COST, 1980-1990:CONSTANT OUTPUT PRICE

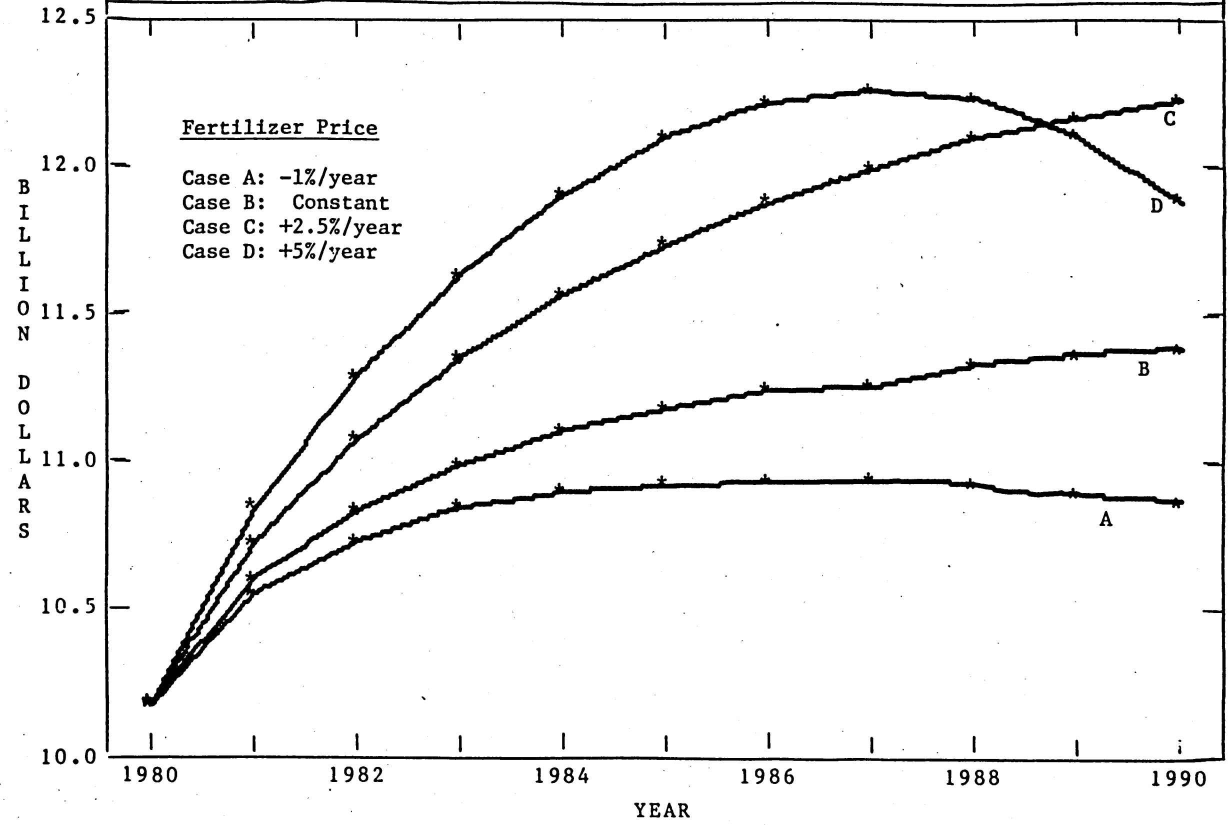
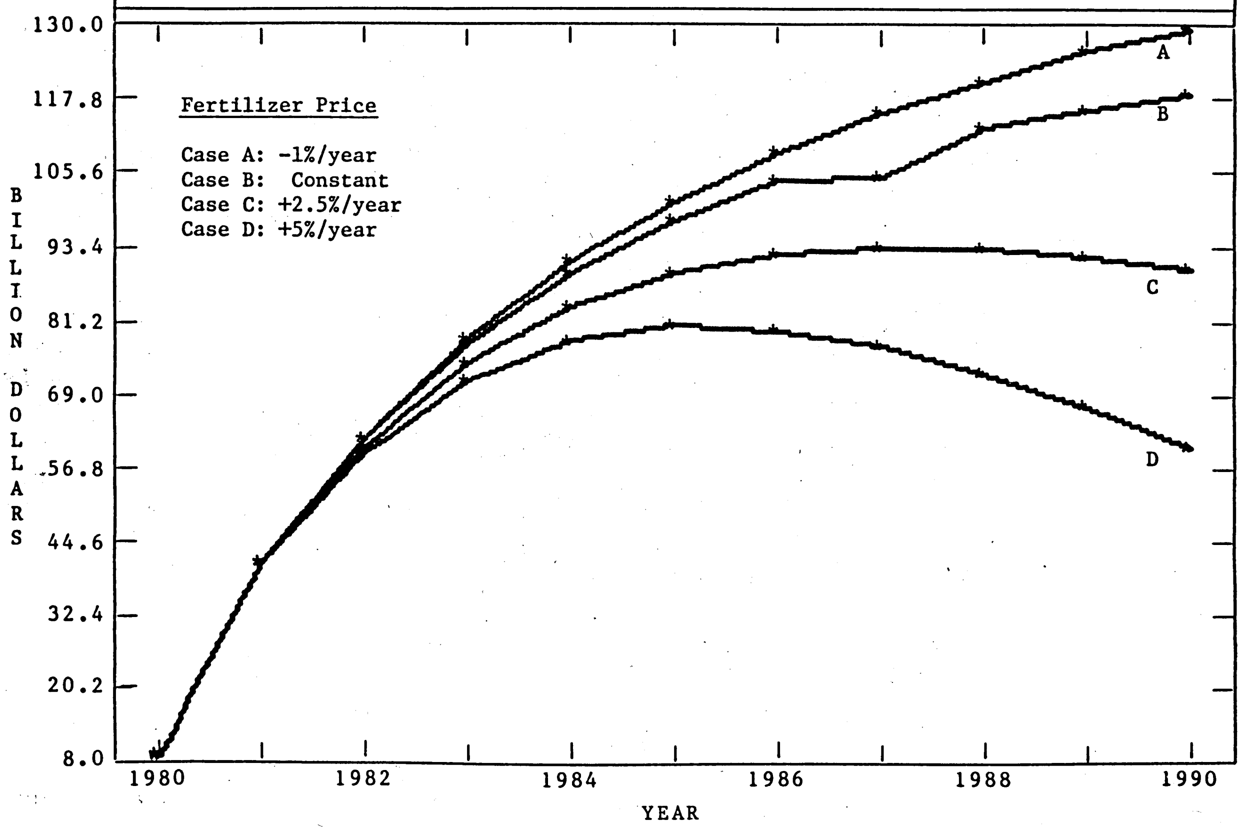


FIGURE 4. SIMULATED TOTAL PROFITS, 1981-1990: CONSTANT OUTPUT PRICE



A 2.5-percent fertilizer price growth rate reduces total profits by $29 billion and a 5-percent rate of growth reduces profits by nearly $60 billion.

CONCLUSIONS

This analysis uses a simple, aggregate, and theoretically consistent representation of agricultural production to examine effects of changes in fertilizer prices on farming costs and income. Results suggest fertilizer is responsive to changes in fertilizer price and is a substitute for labor. Fertilizer price increases have a small negative effect on energy and feed/seed, but a relatively large positive effect on the demand for labor. The different fertilizer price growth rates produced large differences between cost and profits.

The quantity of capital is an important determinant of fertilizer demand, output, costs, and profits. Capital is the fundamental transmission mechanism through which production is adjusted. Results indicate the importance of farmers' access to financial capital and highlight the relationship between agriculture and the macroeconomy through changes in the interest rate and the level of capital.

Natural gas deregulation will affect farming costs and income. The absolute magnitude of the effect depends on the structure of agricultural production and the level of output prices. Although constant and decreasing fertilizer price paths are analyzed, it is highly probable that deregulation will result in higher natural gas prices. Fertilizer price increases of 2.5 percent per year imply natural gas price increases of about 12 percent per year. Such a high rate of price growth might be difficult to sustain over a decade. If real fertilizer price increases average only 1 percent per year and output prices are constant, then farm profits might fall by 10 percent. Real output prices will increase, however, as aggregate supply adjusts to higher input costs thereby moderating the assault on farm income. The determination of equilibrium output, price, and income is, unfortunately, beyond the scope of this analysis.

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