CORN PRODUCERS´ RESPONSE TO THE 2001 NITROGEN FERTILIZER PRICE INCREASE

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Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Denver, Colorado, July 1-4, 2004

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ABSTRACT

During the past few years, nitrogen fertilizer prices and price volatility have increased. Producers of nitrogen-intensive crops, such as corn, who are faced with increased nitrogen prices or price volatility, can adopt either cost-reducing or price variability-reducing strategies. Using a behavioral model in the logit specification and data from a 2001 national survey of U.S. corn producers, we found that the probability of forward pricing nitrogen fertilizer and the probability of using nitrogen more efficiently were linked to operator occupation, farm size, yield goal, and farm location.

INTRODUCTION

During the past few years, nitrogen fertilizer price levels and price volatility have increased. Among the major crops grown in the U.S., corn producers are the most vulnerable to nitrogen fertilizer price movements. At the same time, the nitrogen fertilizer industry is dependent on corn producers for much of its revenue. About 4.5 million tons of nitrogen fertilizer was used in corn production in 2001, which represents nearly 40 percent of all nitrogen fertilizer consumed in the agricultural sector (U.S. Department of Agriculture, National Agricultural Statistics Service, 2002). Furthermore, nitrogen is a large part of the cost of all fertilizer used in corn production, varying from 25-30% of all cash costs depending on the year (U.S. Department of Agriculture, Economic Research Service). Hence, volatile nitrogen fertilizer markets have economic implications for both fertilizer suppliers and corn producers. From a corn producer's perspective, forward contracting of nitrogen fertilizer and/or adjusting nitrogen use are among the strategies available to deal with nitrogen price increases and volatility.

OBJECTIVE

The objectives of this paper are to estimate a behavioral model which identifies the farm and operator characteristics associated with 2001 corn producers´ decision to: 1) forward contract nitrogen fertilizer and 2) change nitrogen management practices, given that a producer did not forward contract. Past studies have shown that the decisions to adopt production practices, new technologies, or price risk strategies are often influenced by such factors as operator risk preferences and demographic characteristics as well as by farm attributes, such as size and extent of specialization (Sherrick, et al.; Fernandez, et al.). Identifying the factors influencing the decision to adopt price risk or production management strategies helps to identify what farms are most at risk from input price variations and to target policies that may be used to help these farms manage risk.

MOTIVATION

Other studies have found that producers who aggressively manage production costs consistently have higher returns relative to those producers who concentrate on commodity marketing to improve farm income (Dhuyvetter, et al.). For example, McBride and Johnson found that forward purchasing of inputs and negotiating lower input prices improved farm financial performance on cash grain farms. Given that corn is a nitrogen intensive crop, corn producers who are intently managing production expenses would likely pursue strategies to reduce the costs of nitrogen fertilizer such as by minimizing prices, reducing use, improving efficiency, or seeking substitutes while attempting to maintain or increase net revenue.

Nitrogen Fertilizer Price Volatility

Since 1990, the wholesale price of nitrogen fertilizer, as well as the price for the key ingredient to nitrogen fertilizer, natural gas, exhibited periods of stability but in recent years all prices have experienced increased volatility (fig. 1). Wholesale anhydrous ammonia prices (Gulf) were very stable during the early 1990's, but demonstrated a clear seasonal fluctuation—lower in the late summer or early fall and higher in the spring. From 1994 through 1997, ammonia prices more than doubled, especially in 1995, relative to the early 1990's but fell back to earlier levels from 1998 through 2000. The most volatile ammonia prices have occurred since 2000, with wholesale ammonia prices moving from about $100/ton to $240 in 2001, back to $100 in 2002, and again reaching well over $200 in 2003. According to a GAO report, even though the price of natural gas was very stable from 1990 through 2000, the recent nitrogen fertilizer price volatility is caused by large shifts in the price of natural gas, which accounts for 70-80% of the cost of producing nitrogen fertilizer (fig. 1). Furthermore, recent forecasts of natural gas markets project even higher prices and more volatility (U.S. Department of Energy, Energy Information Division).

According to USDA (U.S. Department of Agriculture, National Agricultural Statistics Service. 2003a.), prices paid by farmers for anhydrous ammonia in the spring of each year have followed the wholesale market. With the exception of 1995, anhydrous ammonia prices were fairly stable between 1990 and 2000 ranging from about $200 and $300 per ton. But in 2001 and 2003, prices rose to $399 and $373, respectively. Spot prices paid by farmers during the spring of 2004 were also well above the average level during the 1990's, reaching $379 per ton. Clearly, price volatility has also increased in recent years at the farm level —ammonia prices rose 76% and 49% over year earlier levels in both 2001 and 2003, respectively, the largest year-over-year price increases during the last 14 years.

Managing Nitrogen Fertilizer Price Risk

If producers anticipate that fertilizer prices will increase in the future and want to reduce input price variability, forward contracting for fertilizer may be an option (Dhuyvetter, et al.; Haydu, et al.). Farmers often participate in forward contracting with a fertilizer distributor because they can lock in a certain nitrogen price and quantity early in the production cycle, such as in the fall before planting, rather than accepting the spot price in the spring[1]. Contracting may also reduce the risks surrounding the timeliness of fertilizer deliveries. Typically these contracts require a substantial advance payment but farmers receive a discount below the spot price prevailing at the time of contracting. However, Haydu, et al. point out that (p. 146) "Once the contract is finalized, an increase in the market price implies an *ex post* gain to farmers whereas a price decline implies an *ex post* loss." In essence, the contract allows the producer to share the price risk with the fertilizer distributor.

Historically, nitrogen fertilizer prices fluctuated seasonally—prices tended to peak in the spring and reached their low point in the fall which may have offered producers some price management opportunities. Nitrogen fertilizer price movements are closely related to the

[1] Farmers also often pre-pay for farm supplies to be used during the following year for income tax management purposes. This analysis does not address the use of contracting for tax purposes.

seasonal consumption of nitrogen fertilizer. In 2000, 24 percent of the total nitrogen applied to corn was applied in the fall, 50 percent in the spring before planting, 8 percent at planting, and 18 percent after planting (Huang and Magleby). While the seasonal nature of fertilizer prices was not nearly as predictable in recent years as in the early 1990's, producers may be able to purchase nitrogen fertilizer in the fall and either store the product until spring or apply it in the fall[2]. However, producers bear costs either way: through increased inventory costs or through the potential leaching of nitrate during the winter[3]. Alternatively, the increasing volatility of the nitrogen market may encourage producers to use forward contracts to reduce input price risk.

Managing Nitrogen Use

Even if a producer does not forward contract for nitrogen fertilizer, he/she has other options for managing fertilizer costs when faced with rising spot prices in the spring. These options include: 1) switching from a nitrogen intensive crop, such as corn, to soybeans which require very little nitrogen fertilizer[4] and/or 2) adjusting nitrogen use or the timing of nitrogen fertilizer application. Once the decision to plant corn is made, producers can respond to increased nitrogen prices by reducing nitrogen application rates and/or adopting enhanced nutrient management practices such as soil testing, splitting application rates (e.g., applying nitrogen at and after planting), and using manure as a substitute for commercial fertilizer. However, these strategies can increase costs (e.g., soil or manure testing and multiple fertilizer applications) or increase production risks. For example, delaying nitrogen application until after planting

[2] Another factor that may encourage fall fertilizer purchases and application is the relatively low opportunity cost of labor in the fall compared to the spring.
[3] For some soils, applying nitrogen in the fall when soil temperatures are low may minimize or eliminate such leaching losses.
[4] This analysis is restricted to producers who planted corn in 2001. No data were available for producers who opted to switch from corn to soybeans in response to higher nitrogen fertilizer prices.

increases the likelihood that nitrogen cannot be applied in a timely manner due to excessive rainfall.

DATA

Data used in this study come from the 2001 Agricultural Resource Management Survey (ARMS) of U.S. corn producers. Each farm in the ARMS sample represents a known number of farms with similar attributes so that weighting the data for each farm by the number of farms it represents provides a basis for calculating estimates for the target population. The ARMS annually collects data about farm income and expenses, farm assets and debt, and farm and operator characteristics, as well as information about the farm household. The corn version of the 2001 ARMS included this information, plus a detailed accounting of the practices, input use, and costs associated with producing corn. The corn sample targeted farm operations planting one or more acres of corn. Corn producers were surveyed in 19 states covering 93 percent of U.S. corn acreage planted in 2001 (U.S. Department of Agriculture, National Agricultural Statistics Service, 2003b.).

The 2001 ARMS also asked corn producers how they altered the amount applied and management of commercial fertilizer in response to the higher nitrogen fertilizer prices that were observed during the spring of 2001 (table 1). About a third of corn producers reported that most of their nitrogen fertilizer was pre-purchased at a pre-determined price set prior to January 1, 2001, and thus were not affected by the sharp rise in fertilizer prices early in 2001. These producers were larger than corn farms in the other categories, averaging 329 acres of corn, and had higher average rates of nitrogen applied at 133 pounds per acre. Eleven percent of corn producers reported adjusting nitrogen rates and/or practices in response to higher prices. About 80 percent of these producers reduced nitrogen by an average of 22 percent. More than half of all corn producers, 56 percent, reported no response to higher nitrogen prices[5]. These producers were among the smallest corn farms, averaging 149 corn acres, and applied the least amount of nitrogen.

The analysis in this study was limited to the set of farms that planted corn with the intention of harvesting the corn for grain, as opposed to silage or seed. This included 1,560 farms in the ARMS data representing a population of about 184,000 farms across the nation. The analysis examined differences between three groups of farmers--those that 1) pre-purchased nitrogen fertilizer prior to January 1, 2001; 2) adjusted nitrogen application rates for the 2001 corn crop; and 3) did nothing differnt in response to the higher nitrogen prices. Among the 1,560 farms, 596 reporting pre-purchasing N fertilizer, 181 adjusted nitrogen rates in response to the price increase, and 783 did nothing.

EMPIRICAL APPROACH

The response of corn producers to the rise in nitrogen fertilizer prices is examined with reference to two decision points. First, producers could have decided to forward purchase nitrogen fertilizer prior to January 1, 2001. These producers were not affected by the price increase early in 2001. Among producers that chose not to forward purchase nitrogen, the relevant decision was whether or not to reduce the nitrogen application rate in response to the price increase. Consequently, corn producers self-select themselves into a group based on their decisions instead of being randomly selected from the survey respondents. This presents a problem of self-

[5] Other research has documented that fertilizer demand is very inelastic (e.g., Denbaly and Vrooman).

selection. If the self-selection problem is left uncorrected, results from the analysis could be biased.

To illustrate how this situation is modeled, consider the following equation:

$$y_p = X_p\beta_p + \varepsilon_p \tag{1}$$

where y_p denotes the decision to pre-purchase nitrogen, equal to 1 if yes and zero otherwise, X_p is a matrix containing farmer economic and demographic variables which influence the pre-purchase decision, β_p is a vector of parameters to be estimated, and ε_p is an error term. Because of the sequential nature of the decisions, the second decision, whether to adjust the nitrogen rate, is conditional on the first and can be expressed as:

$$y_{a|p} = X_a\beta_a + \varepsilon_a \tag{2}$$

where $y_{a|p}$ indicates the decision to adjust the nitrogen rate, given that nitrogen was not pre-purchased, X_a is a matrix of variables influencing the nitrogen adjustment decision, while β_a and ε_a are defined as above.

The model to be estimated is given in (1) and (2) except that the issue of self-selection has yet to be addressed. The nitrogen adjustment decision is conditional on the decision not to pre-purchase nitrogen. That is, responding to the higher nitrogen prices is relevant only to those producers who did not pre-purchase nitrogen, and thus face higher spot prices. In terms of the estimation equations, this means that y_a=1 only if y_p=0. Assuming the error terms in (1) and (2) are jointly distributed as bivariate normal, i.e., $(\varepsilon_p,\varepsilon_a)\sim BNV(0,0,1,1,\rho)$ and $\rho=cov(\varepsilon_p,\varepsilon_a)$, the conditional probability of adjusting nitrogen rates is given by:

(3) $$\text{prob}(y_a = 1 | y_p = 0) = \Phi(X_a\beta_a) + \rho\lambda_p(\alpha_p)$$

where $\alpha_p = -X_p\beta_p$, $\lambda_p = \varphi(\alpha)/1-\Phi(\alpha)$, and Φ and φ denote the cumulative distribution function (cdf) and probability density function (pdf) of a univariate normal distribution, respectively.

Equation (3) suggests that direct estimation of (2) would lead to an omitted variable bias because the last term on the right-hand side of (3) would be omitted. This problem is overcome by augmenting (2) such that:

(4) $$y_{a|p} = X_a\beta_a + \lambda_p\theta_p + \varepsilon_a$$

where λ_p is estimated from the results of (1) and θ_p is the parameter to be estimated. The model to be estimated is given in (1) and (4), while the presence of selection bias is indicated if the estimated parameter θ_p is statistically significant.

MODEL SPECIFICATION AND ESTIMATION

A multi-stage logit approach was used to specify the model used in this study. The decision to pre-purchase nitrogen fertilizer was modeled in the first-stage and the results were used to correct for potential self-selection bias in a second-stage equation about the decision to adjust nitrogen rates. The dependent variable of the first-stage equation was specified as binary, equal to 1 if most of the commercial nitrogen applied was pre-purchased prior to January 1, 2001, and zero otherwise. Only the sample of farmers who did not pre-purchase nitrogen fertilizer was included in the second-stage. The dependent variable of the second-stage equation was also a binary variable, equal to 1 if nitrogen fertilizer rates were adjusted in response to the price increase, zero otherwise.

Independent variables specified in the model, including farm and operator variables, are presented for each group in table 2. Size was measured as total planted corn acres (*CORNAC*), and was specified with a quadratic term (*CORNAC2*). Specialization in corn production was specified as the percent of total farm value of production that was attributed to corn (*SPECIAL*). Operator age was measured in years (*OPAGE*). Operator education was the number of years of formal education including high-school, college, and any post-graduate work (*OPEDUC*). The major occupation of the operator was specified with a binary variable indicating whether the operator's major occupation was farming or something else based on a self-assessment by the survey respondent (*OPOCUP*). Yield goal for the corn enterprise, measured in bushels per acre, was included because farmers with higher target yields would be less likely to reduce nitrogen use (*YLDGOAL*). Variables for geographic location were also included in the model to account for the impact that differences in soil, climate, and the availability of fertilizer vendors willing to forward contract, would have on operator decisions (*HL, NC, NP, PG, EU, SS,* and *OR*).

A measure of risk preference was also included in both nitrogen fertilizer decision equations. Farmers were asked to assess their preference toward risk based on a scale from 0 to 10, with 0 indicating farmers who avoid risk as much as possible and 10 indicating farmers who take as much risk as possible (*RISK*). The expectation was that farmers who indicate risk adverse preferences are more likely to pre-purchase nitrogen to avoid price risk. Also, more risk adverse farmers are expected to be less likely to adjust nitrogen rates in response to price changes.

Measures indicating whether a fall application of nitrogen fertilizer was made and farm credit availability were included in the decision equation for pre-purchasing nitrogen fertilizer. The variable indicating a fall application of nitrogen fertilizer (*FALLAP*) was included because farms using this practice are more likely to be pre-purchasing most of their nitrogen fertilizer. A variable indicating maximum borrowing capacity (*CREDCAP*) was included to examine whether the capital required for pre-purchasing inputs prevented farmers from using this practice (Ryan). These variables were not added to the nitrogen rate adjustment equation because they were believed to have an important influence on the pre-purchasing decision, but not on the rate adjustment decision.

The model indicated by the equations in (1) and (4) was estimated using Heckman's multi-stage approach. Parameters of each equation were estimated using the ARMS survey weights in a weighted least squares version of the maximum likelihood method. Due to the complex design of the ARMS sample, standard errors were estimated using a jackknife replication approach (Dubman).

RESULTS

The multivariate logit regression model is useful for simultaneously assessing the impacts of specific variables on the probability of a farm operator belonging to a given group, while accounting for the impact of other variables. In the case of farm operators choosing to pre-purchase nitrogen fertilizer, few operator characteristics affected the decision[6]. Corn farmers with a primary occupation as farming, instead of retirement or non-farm occupations, were more

[6] Note that this group includes a small group of producers who pre-purchased AND applied all of their nitrogen in the fall prior to Jan. 1, 2001and thus did not utilize forward contracting.

likely to pre-purchase nitrogen, but variables for operator age and education were not statistically significant (table 3). Farmers with larger farms were more likely to pre-purchase nitrogen. Likewise, farmers with a higher corn yield goal more often pre-purchased nitrogen. Farmers with a higher target corn yield can be expected to use more nitrogen and may be more concerned about securing nitrogen fertilizer supplies at a reasonable price.

Measures of farmer risk attitude and credit constraint were not statistically significant in the equation for pre-purchasing nitrogen. Risk aversion was not associated with nitrogen pre-purchasing, suggesting that most farmers may not have had expectations of higher nitrogen prices during the spring growing season or, perhaps, that the self-reported measure was not a clear indicator or risk aversion. The variable indicating a nitrogen fertilizer application in the fall was positively associated with pre-purchasing nitrogen, as expected. Location in the Heartland region, compared to the Northern Crescent, Eastern Uplands, and Southern Seaboard regions, was associated with a greater likelihood of pre-purchasing nitrogen. Corn farmers in the Heartland may have greater access to input pre-purchasing programs because of the concentration of corn production in this region.

Among farmers who did not pre-purchase nitrogen, a primary occupation of farming was associated with a greater likelihood of adjusting nitrogen application rates in response to the higher prices. The decision to adjust nitrogen rates was also associated with larger farms, as was the pre-purchasing decision. No other operator characteristics were found to be associated with the decision to adjust nitrogen application rates.

Regional factors were important to the nitrogen adjustment decision, as corn farmers in the Heartland were more likely to adjust nitrogen rates than were corn farmers in nearly all other regions. Farmers in regions with lower average corn yields, most notable the Eastern Uplands and Southern Seaboard, were the least responsive to the nitrogen price increase when compared to farmers in the Heartland. Soils characteristics in the Eastern Uplands and Southern Seaboard are not as conducive to corn production as in the Heartland. Lower soil fertility may mean that the impact on corn yield from adjusting nitrogen rates in response to the price increase may have been more severe in these regions. Also, the coefficient on the self-selection variable was statistically significant, suggesting that self-selection would have been a problem had it not been corrected.

CONCLUSIONS

Nitrogen fertilizer price volatility has become a significant source of price risk for farmers during recent years. Corn farmers are particularly vulnerable to this price risk because nitrogen fertilizer can have a large impact on corn yields, and because nitrogen fertilizer expenses comprise a large share of overall corn production costs. This means that controlling costs associated with nitrogen fertilizer, through such means as pre-purchasing nitrogen or adjusting rates in response to prices, can have a major impact on the returns to corn production.

Results of this study indicate that larger farms, farms with an operator whose primary occupation was farming, and those located in the major corn production region were more likely to undertake practices that reduce the price risk associated with nitrogen fertilizers. Farms with these characteristics likely have a significant human and financial resource investment in corn production, and thus are more likely to manage this enterprise more intensively than other farms.

Conversely, small farms, farms with operators whose primary occupation is something other than farming, and those located where corn production is a less common farm enterprise are less likely to undertake these practices. These farms are more vulnerable to the price risk associated with nitrogen fertilizers. Improving awareness and/or access to flexible input purchasing programs, and providing information about responding to changing input prices might assist these producers cope with the increasing risk associated with nitrogen fertilizer prices.

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Table 1. Reported response of corn producers to higher nitrogen prices in the spring of 2001[1]

Item	Pre-purchased N[2]	Adjusted N amount or practice	No change
Percent of farms	33	11	56
Corn acres per farm	329	206	149
Nitrogen applied (lbs. per acre)	133	113	104
Adjusted N by: (percent of farms[3])			
Reducing rate[4]	na	80	na
Increasing manure/organic sources	na	13	na
Changing type of product	na	14	na
Managing more carefully	na	57	na

[1]Includes farms planting corn for all purposes including silage and seed.
[2]Pre-purchased most of their nitrogen at a pre-determined price set prior to January 1, 2001.
[3]Total will not add to 100 percent because some producers made more than one adjustment.
[4]Reduced N rate by an average of 22 percent.
na=not applicable.

Table 2. Description and mean values of variables used in the decision model of producer response to higher nitrogen fertilizer prices, 2001[1]

Variable	Pre-purchased N[2]	Adjusted N rate	No change
CORNAC (100 corn acres planted)	3.42	2.14	1.48
SPECIAL (corn as percent of total farm value of production)	38.17	32.30	28.16
OPAGE (operator age in years)	51.74	53.12	52.48
OPEDUC (operator education in years)	13.03	12.93	12.83
OPOCUP (proportion with farm occupation)	0.87	0.79	0.68
YLDGOAL (corn yield goal)	150.99	136.07	135.12
FALLAP (proportion with a fall N application)	0.25	0.07	0.10
RISK (risk preference scale 0-10)[3]	5.20	5.51	4.81
CREDCAP ($1,000 borrowing capacity)	321.76	244.26	213.10
HL (proportion in Heartland region)	0.70	0.63	0.49
NC (proportion in Northern Crescent region)	0.13	0.15	0.26
NP (proportion in Northern Plains region)	0.04	0.03	0.03
PG (proportion in Prairie Gateway region)	0.10	0.13	0.08
EU (proportion in Eastern Uplands region)	0.02	0.03	0.05
SS (proportion in Southern Seaboard region)	0.01	0.02	0.08
OR (proportion in other regions)	0.00[4]	0.00[4]	0.01
Sample size	596	181	783

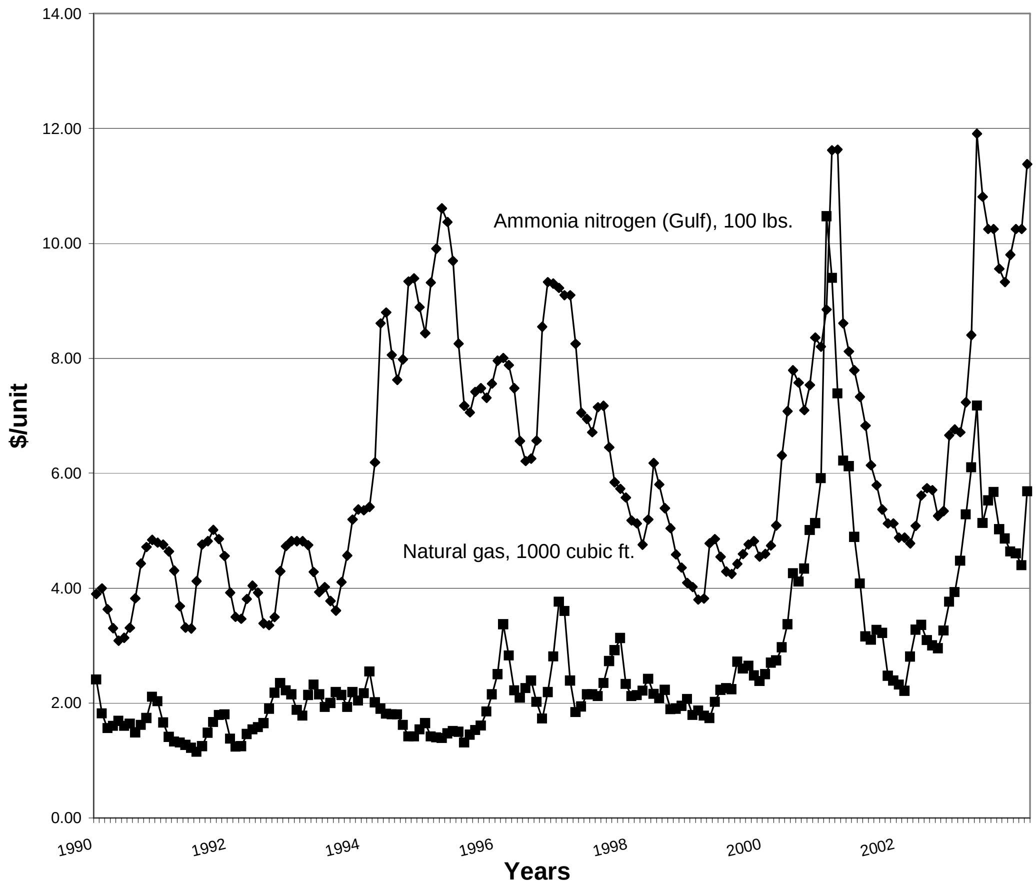
[1]Excludes farms producing corn for silage and seed.
[2]Pre-purchased most of their nitrogen at a pre-determined price set prior to January 1, 2001.
[3]Zero indicates farmer avoids risk as much as possible, while 10 indicates farmer taking risk as much as possible.
[4]Less than 0.01.

Table 3. Regression results for the response of corn farmers to the rise in nitrogen fertilizer prices, 2001

	Pre-purchased N		Adjusted N rate	
Variable	Parameter	Std. Error	Parameter	Std. Error
Intercept	-2.60051**	0.94419	-9.1177**	2.45903
CORNAC	0.16880**	0.06149	0.3704*	0.20506
CORNAC2	-0.00372	0.00221	-0.0129	0.01067
SPECIAL	0.00430	0.00362	0.0076	0.00663
OPAGE	-0.00470	0.00614	-0.0060	0.01403
OPEDUC	0.01197	0.05089	0.0461	0.03462
OPOCUP	0.92023**	0.21195	1.9211**	0.61478
YLDGOAL	0.00744**	0.00305	0.0074	0.00544
RISK	-0.02383	0.03312	0.0924	0.05480
FALLAP	0.57153**	0.22153	-	-
CREDCAP	0.00004	0.00016	-	-
NC	-0.46123**	0.18416	-1.4719**	0.62390
NP	0.07810	0.33465	-0.3474	0.61159
PG	-0.34846	0.23372	-0.5026	0.40544
EU	-0.74285*	0.43131	-1.8340**	0.80915
SS	-2.33369**	0.78377	-5.4314**	1.61447
OR	-0.38357	0.51205	-13.9725**	0.39587
λ_p	-	-	-3.4819**	1.42618
Samples w/ attribute	596		181	
Samples w/o attribute	964		783	
Total samples	1560		964	
Likelihood ratio	54,113		12,032	
McFadden R^2	0.14		0.07	

Notes: *HL* (Heartland) was the deleted region variable in the estimation. '*' indicates significant at 10 percent. '**' indicates significant at 5 percent.

Fgure 1. Monthly natural gas and ammmonia nitrogen prices, 1990-2003



Source: Huang and Magleby