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Does Information Matter?
Assessing the Role of Information and Prices in the Nitrogen Fertilizer Management Decision

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Nutrients from Agricultural Production Continue to Enter the Environment

Intense chemical use in modern agriculture contributes greatly to the degradation of surface and ground water. The U.S. Environmental Protection Agency (EPA) reports nonpoint source pollution (NPS) from agriculture as the primary source of pollution for 48 percent of streams and rivers that have been listed as impaired. The two predominant stressors from agricultural production are nitrogen (N) and phosphorous, but other pollutants, such as sediment, pathogens, and metals, also originate from agriculture (EPA 2002).

> In 2008, over 350,000 metric tons of N, dissolved nitrite plus nitrate, were deposited into the Gulf of Mexico.

> The deposited nutrient load contributed to over 20,000 square kilometers of bottom-water hypoxia (USGS 2009).

Understanding how information influences the farmer's nutrient application decision is important when developing strategies for N load mitigation. This research assesses the value of information farmers receive from several common sources, including nitrogen soil (N-soil) testing and price signals from markets, and makes several important innovations to the existing literature. I account for farmer heterogeneity and endogenous N-soil testing by proposing an instrumental variables approach that overcomes identification issues when estimating N application rates at the field level. Notably, this research incorporates N prices using 2 years of cross-sectional data by exploiting exogenous ammonia production capacity and farm location as instruments for N price.

Data

This analysis relied on data from the USDA's Agricultural Resource Management Survey (ARMS). ARMS collects data via a series of interviews with farm operators on a wide range of topics, such as agricultural production practices, costs of production, farm income and finances, and other farm business and household characteristics. Because the research focused on N application, data from 2001 and 2005 were used because they focused on corn production—agriculture's heaviest N user.

The Researcher's Age-old Dilemma

Several issues make it difficult to estimate the impact of prices and information, like N-soil testing, on applied N using survey data.

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1. I cannot observe test-recommended N levels for farmers who do not test the soil, nor do I know why two observationally similar farmers make different choices about whether to test or not.

2. Heterogeneous manager characteristics can cause otherwise similar farmers to make different decisions about the amount of fertilizer to use once they have conducted a test. Such differences, unknown to the researcher, can potentially bias estimates.

3. The classic error-in-variables problem that may come from using a price variable created from nitrogen's relative share of total expenditures for fertilizer. Along with the component's relative size of the total expenditure, I use total applied acres to calculate the dollars per pound of nutrients applied.

4. Farmers may receive quantity discounts when purchasing N fertilizer where more fertilizer is purchased and the unit price falls. If the application rate is correlated with the farmer's total N demand, failing to account for this may result in a bias.

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Endogenous Variables, Plausibly Exogenous Instruments

N-Soil Testing Farmers who conduct the test may do so because of unobserved differences compared with those who do not test. In other words, the test could be endogenous to the amount applied. Based on ARMS data, a minority of farmers employ an N-soil test. In fact, about a quarter of the farmers in the ARMS survey conducted a soil test. When the sample is limited to farmers who use manure and commercial fertilizers in combination, only 13 percent conduct an N-soil test. A set of instruments--National Commodity Crop Productivity Index measures, soil percolation, and average precipitation--are correlated with soil testing, but uncorrelated with the disturbance process in the demand equation.

Nitrogen Prices Several sources of plausibly exogenous variation can be used to argue for meaningful price variation: distance to the nearest ammonia plant, capacity of the plant, and distance to New Orleans (the central terminal for imported ammonia). One of the greatest sources of variation comes from differences in the distance to an N fertilizer producing plant. Most of the U.S. nitrogen fertilizer supply is produced near the source of the primary input (natural gas), away from the Corn Belt, and in the South and Southwest (Huang 2007). To move N fertilizer around the country, the industry uses rail, river, and truck freight, as well as pipelines. Because of rising natural gas prices, ammonia is increasingly being imported into the United States, where a majority of the ammonia enters from the Gulf of Mexico, mostly New Orleans. Differential transportation costs and capacity lead to differences in prices throughout the country. Tests of each instrumented variable are reported in table 2.

Estimation

A reduced-form equation was used to estimate a partial-equilibrium static demand model derived from profit maximization theory. The derived estimates represent the application rate for N fertilizer. The data are cross-sectional and include observed per-acre N use on the field as reported by the farmer. Nitrogen costs are estimated by computing the reported total cost of fertilizer, minus the cost of custom application. Because the reported cost includes the cost of N, phosphorus (P), and potassium (K), a share variable represents the component's relative size, per pound, in the total amount of fertilizer applied.

The two-stage least squares model was estimated with two endogenous variables. Equation 1 is the outcome equation where *Y* represents per-acre rate of N applied on the field for farm *i* in region *r*, using

$$(1)\quad Y_{irt} = \alpha_1 + \hat{P}_{irt}\beta_1 + \hat{T}_{irt}\lambda_1 + \mathrm{X}_{irt}\delta_1 + \phi_{1r} + \upsilon_{1t} + \varepsilon_{irt} \ ,$$

$$(2)\quad P_{irt} = \alpha_2 + X_{irt}\beta_2 + Z^{P}{}_{rt}\delta_2 + \phi_{2r} + \upsilon_{2t} + \kappa_{irt} \ ,$$

$$(3)\quad T_{irt} = \alpha_3 + X_{irt}\beta_3 + Z^{T}{}_{rt}\delta_3 + \phi_{3r} + \upsilon_{3t} + u_{irt} \ .$$

Endogenous variables, $\hat{P}$ and $\hat{T}$, are instrumented N price and N-soil testing probability from equations 2 and 3. The excluded instruments for N price are represented by $Z^{P}{}_{rt}$, and the excluded instruments for N-soil test are represented by $Z^{T}{}_{rt.}$ The matrix ***X*** is a set of independent variables that includes characteristics of the operator, such as the age, the length of time the operator has been farming, and whether the operator works off the farm. Also included as explanatory variables are characteristics of the farm operation, including the per-acre annual value of production, the per-acre value of the land, how many acres of the land were owned by the operator, and the price received for the crop. Time and USDA production region dummy variables are also included, represented by and . The disturbance terms are , , and *u*.

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Who Do Farmers Trust for Their Information?

Table 1
Influences on farmers' nitrogen fertilizer application decision[1]

	Year	
	2001	2005
N-Soil or tissue test	18.8%	27.0%**
	(1.80)	(2.20)
Crop consultant recommendation	13.0%	17.6%**
	(0.90)	(1.80)
Fertilizer dealer recommendation	28.7%	40.8%**
	(1.97)	(2.70)
Extension service recommendation	3.20%	4.40%**
	(0.06)	(0.80)
Cost of nitrogen and/or expected commodity price	11.4%	17.2%**
	(0.76)	(2.40)
Routine practice (including yield goal)	11.4%	71.5%**
	(0.76)	(2.30)
Observations	1646	1377

[1]Percentage who reported affirmatively. Sources are not mutually exclusive. ** Statistically different from 2001 at 1 percent.
Note: Data are weighted and the standard errors are calculated using the jackknife delete-a-group method.
Source: 2001 and 2005 ARMS, Phase II, Cost of Production Practices and Costs Report.

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Farmers increasingly rely on N-soil testing when making their application decision.

Fertilizer dealers have significant influence on the application decision.

Extension and crop consultant services play a lesser role in the decision making process.

The Behavioral Response to N Prices is Higher Than Previously Thought

Historically, estimated demand elasticities suggest N demand is relatively insensitive to prices. While no true consensus exits, estimates generally hover in the range of -.20 to -.50. (See, for example, Griliches (1958); Heady and Yeh (1959); Carman (1979); Ray (1982); Denbaly and Vroomen (1993); and Hansen (2004)). Evidence now shows that rising fertilizer prices encourage farmers to manage N more carefully. The price elasticity of demand is estimated between -0.6 and -1.29 (see table 2).

Table 2 also reports the impact of soil tests on N applied to the field. The coefficients show that N-soil testing can be an effective management practice for reducing excess N applications. Results show that farmers who use an N-soil test reduce their use of commercial N at the mean by up to 0.9 percent per acre, or about 14 lbs/acre, relative to nontesters. IV estimates show that OLS underestimates the impact of soil testing.

Table 2
Estimated impact of price and N-soil testing on applied nitrogen

	Soil test		Nitrogen price	
Dependent variable	OLS[1]	IV[2]	OLS[1,3]	IV[1,3]
Chemical nitrogen	0.048	-.790**	-.253**	-1.29*
	(0.041)	(.266)	(0.042)	(.616)
Model R^2	.15	--	.15	--
Model F	--	9.10 [<0.000]	--	4.99 [<0.000]
Partial R^2		0.019		0.0056
Instrument F		8.73 [<0.000]		10.19 [<0.000]
Hansen J Statistic		3.53 [0.473]		
Durbin-Wu-Hausman		25.13 [<0.000]		
N=2176				
Chemical nitrogen in the presence of manure	0.09	.313	-.351	.413
	(.169)	(.730)	(.236)	(1.087)
Model R^2	.22	--	.22	--
Model F	--	6.66 [<0.000]	--	6.66 [<0.000]
Partial R^2		0.0142		0.0071
Instrument F		2.76 [0.012]		0.93 [0.476]
Hansen J Statistic		13.29 [0.01]		
Durbin-Wu-Hausman				0.316 [0.854]
N=604				
Total chemical nitrogen	0.04	-.913**	-.201**	-0.60
	(0.041)	(.288)	(.056)	(.583)
Model R^2	.11	--	.11	--
Model F	--	7.47 [<0.000]	--	7.47 [<0.000]
Partial R^2		.0132		0.0074
Instrument F		5.49 [<0.000]		5.08 [<0.000]
Hansen J Statistic		3.39 [0.495]		
Durbin-Wu-Hausman		14.62 [0.001]		
N=2780				

[1] Jackknife standard errors.
[2] Robust standard errors.
[3] Values can be interpreted as elasticities.
* Statically significant at the 5 percent level. ** Statically significant at the 1 percent level.
Notes: Standard errors in parentheses. P-values in brackets.
Source: ARMS 2001 and 2005.

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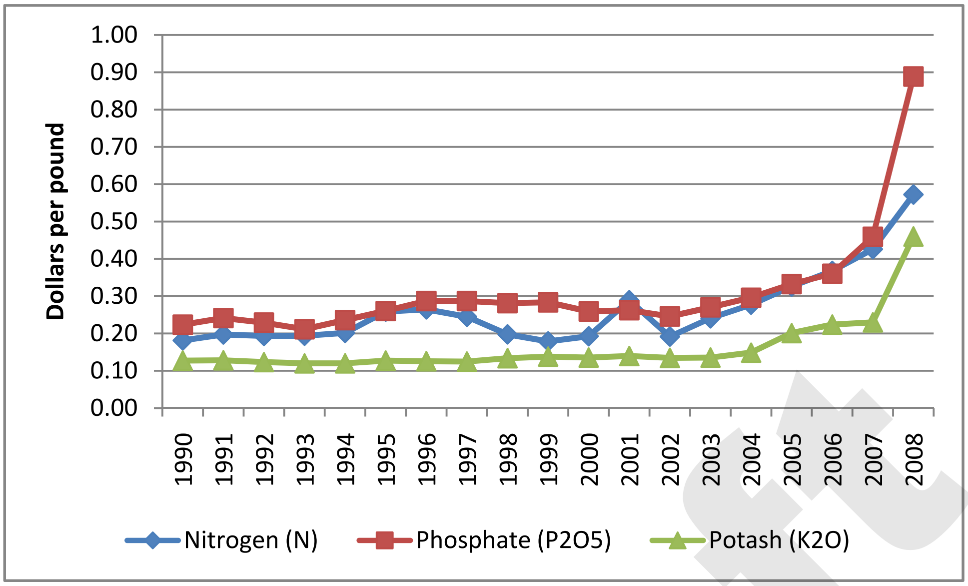
Figure 1
Nominal prices (April) of U.S. fertilizer nutrients, 1990-2008



Source: Economic Research Service calculations based on data from USDA, National Agricultural Statistics Service.

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Recent High N Prices May Effect N Management Behavior Beyond Demand

In 2001, the ARMS incorporated a unique set of questions designed to solicit farmers' attitudes toward a recent increase in the price of commercial N (see fig. 1, year 2001-2002). The ARMS question asked whether farmers reduced their application rates of commercial N due to higher prices and, if so, by what amount and by how much. The survey also asked about other behavioral changes: whether they increased the use of manure or other organic N; whether they switched to a different type of commercial N; and whether they more carefully managed the N on the field. Table 3 presents a summary of the self-reported effects of higher N fertilizer prices on the application of N.

Table 3
Reported changes in commercial N fertilizer management

	year	
	2001	2005
Reduced N	10.7%	24.1%**
	(1.01)	(1.80)
Reduced by how much[1]	21.2%	17.0%**
	(1.50)	(8.30)
Increased manure	1.90%	3.10%**
	(0.40)	(6.00)
Changed the type of N	2.20%	5.20%**
	(0.40)	(0.80)
Managed N more carefully	7.70%	20.7%**
	(0.70)	(1.50)
Observations	1646	1377

[1] Only reported if reduced N.
** Statistically different from 2001 at the 1%.
Notes: Data are weighted. Jackknife standard errors in parentheses.
Source: ARMS 2001 and 2005, Phase II, Cost of Production Practices and Costs Report.

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Clearly, prices matter for applied amounts (quantity demanded), but prices also influence management behavior on the farm, and farmers' answers to questions about high prices have policy implications.

Overall, reported management changes were more prevalent in 2005 than 2001.

In 2005, more farmers reported that they managed their N more carefully.

Substitution of manure fertilizer for chemical N in response to higher prices was also more pronounced in 2005 than 2001, though the use of manure was still small in either year.

Model results for price impact in table 2 are corroborated by the changes observed between 2001 and 2003 in table 3.

Expectations About Price Shape Behavior

Policymakers and program managers considering options for reducing N fertilizer applications must take into account the behavior of the farmer—the input response to prices and information. Despite decades of relatively price-insensitive N demand, these are the first results to show that farmers are becoming more sensitive to increasing N prices. The differences in farmers' self-reported price effects between 2001 and 2005 provide more evidence of this behavior (see table 2); the number of farmers who reported that the price of N caused them to reduce the amount applied was more than double that of 2001. If policy makers are interested in reducing the “overuse” of N or more closely aligning N rates with test recommendations, policy options, such as changing input costs, can influence the amount of N applied and its management.

Survey evidence demonstrates that expectations are formed over several production seasons, and the response of farmers to the ARMS questions about high N prices suggests that implementing management changes may not be immediate. Farmers experiencing year-over-year growth in the cost of fertilizer may take incremental steps to change their management behavior. Changing management practices could require farmers to make capital investments in new equipment, for example, purchasing new tillage equipment or waiting for contracts to expire. For these reasons, policymakers may want to consider that it takes time to adjust nutrient management practices or they should institute policies that encourage farmers to do so.

Finally, while prices are important for N demand, the sources of information are important as well. The most common source of information, such as advice from a fertilizer dealer, plays a large role in influencing fertilizer applications decisions.

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