The Cost of Increasing Adoption of Beneficial Nutrient-Management Practices

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Background

Entities producing greenhouse gas emissions subject to a cap under the proposed American Clean Energy and Security Act would be required to hold allowances for those emissions by, for example, purchasing offsets from crop producers who reduce their use of nitrogen. Almost 242 million acres were planted to barley, corn, cotton, oats, peanuts, sorghum, soybeans, and wheat in the United States in 2006 (USDA 2008), and roughly 167 million of those acres received 8.7 million tons of chemical and/or manure nitrogen (USDA ARMS). Forty-five percent of those treated acres were planted to corn, which received 65 percent of the total amount of nitrogen applied (figure 1).

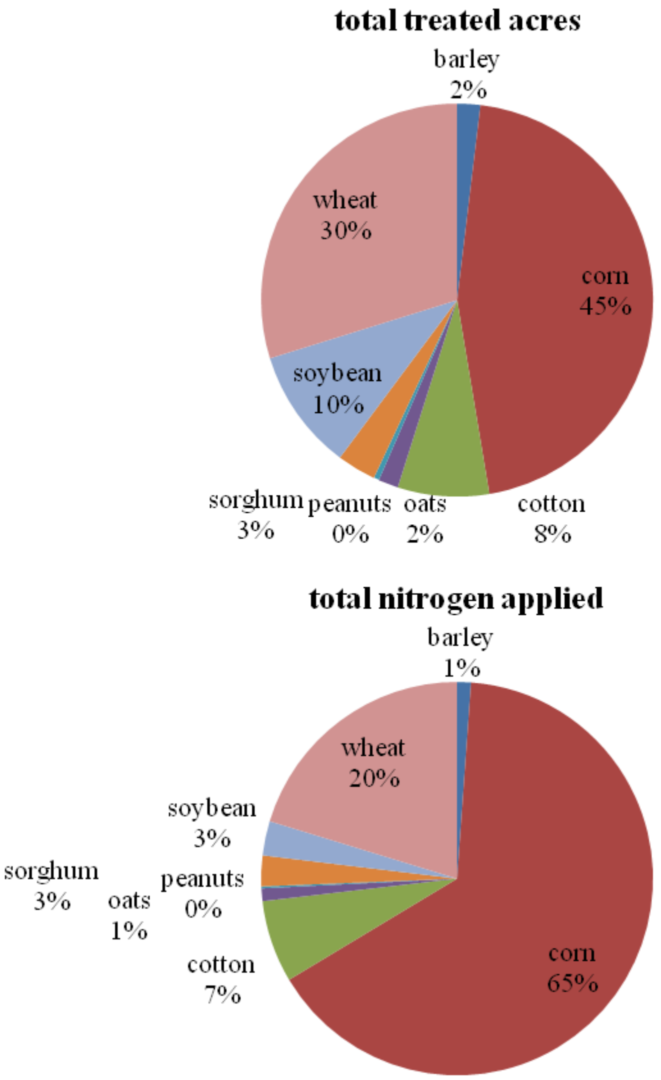

Figure 1. Percentages of total acres treated with chemical and/or manure nitrogen and percentages of the total amount of nitrogen applied to these eight crops in 2006

Objectives

We examined the cost of offsets tied to reductions in the nitrogen application rate on U.S. cornfields. We had three specific objectives, which were to estimate:

- the impact on production costs of reducing the application rate holding output fixed;
- the per-acre cost of offsets associated with application-rate reductions; and
- the aggregate cost of offsets that might be sold by U.S. corn producers.

Data and Methods

We used field-level ARMS data collected from 2,185 corn producers in 2001 to estimate the levels of four inputs, including chemical nitrogen fertilizer (lbs of nitrogen applied to the field), pesticides (acres treated in the field), fuel and lubricants (machine hours devoted to the field), and seeds (tons applied). Fertilizer, pesticide, and seed expenditures were used to estimate average prices. Missing values were imputed using a combination of state-level averages, estimated from the survey data, and state-level price data from other sources. Fuel and lubricant consumption was estimated using data on reported trips to the field, hours spent, machine and engine types, and engineering routines. State-level prices for gasoline, diesel, liquid petroleum, and natural gas were used to estimate expenditures. Each price was given by the ratio of total expenditure to total quantity. We used the reported yield goal and planted acres to estimate expected output.

We used these data to estimate a translog cost function and three share equations simultaneously using Iterated Seemingly Unrelated Regression to obtain maximum likelihood estimates (e.g. Christensen and Greene). We deflated cost and the fertilizer, pesticide, and fuel prices using the seed price to impose linear homogeneity. We imposed the cross-equation restrictions but not concavity.

We estimated costs associated with reducing the application rate by finding the nitrogen prices needed to induce percentage reductions. We used the estimated minimum costs of production after the artificial increases in the prices of nitrogen minus minimum costs before the increases to estimate the costs associated with the percentage reductions.

Results

The only coefficient estimates that were not statistically different from zero at the one-percent level were the estimates on $\ln(y)^2/2$, which was significant at the 10-percent level, and $\ln(p)\ln(y)$, where p and y denote the pesticide price and expected output, respectively.

All of the estimated cost shares were positive and all of the own-price elasticities of input demand were negative for 680 of the 2,185 respondents. This occurred because concavity of the cost function was not imposed. For the 680 respondents, mean own- and cross-price elasticities are reported in table 1. The own-price elasticity of demand for chemical nitrogen, at -0.29, agrees well with previous estimates. Nitrogen and pesticides were substitutes for each of the other inputs, and fuel and seeds were very minor complements.

Table 1. Mean elasticities of demand for fertilizer, pesticides, fuel and seeds, ε_{ij}

		i			
		nitrogen	pesticides	fuel	seeds
nitrogen	*j*	-0.29	0.26	0.18	0.04
pesticides		0.16	-0.30	0.02	0.02
fuel		0.10	0.02	-0.19	0.00
seeds		0.04	0.02	-0.01	-0.06

Notes: Means are for the 680 corn producers whose estimated cost shares and own-price elasticities of demand were positive and negative, respectively.

Holding output fixed and increasing the price of nitrogen to induce reductions in application rates, the mean costs of reducing the application rate by one and two percent is $1.88 and $3.75 , respectively (figure 1). The cost of reducing the application rate increases at a decreasing rate with the percentage reduction; however, the relationship is essentially linear from a practical standpoint. Five- and 10-percent reductions in the application rate would cost $9.31 and $18.37 per treated acre, respectively.

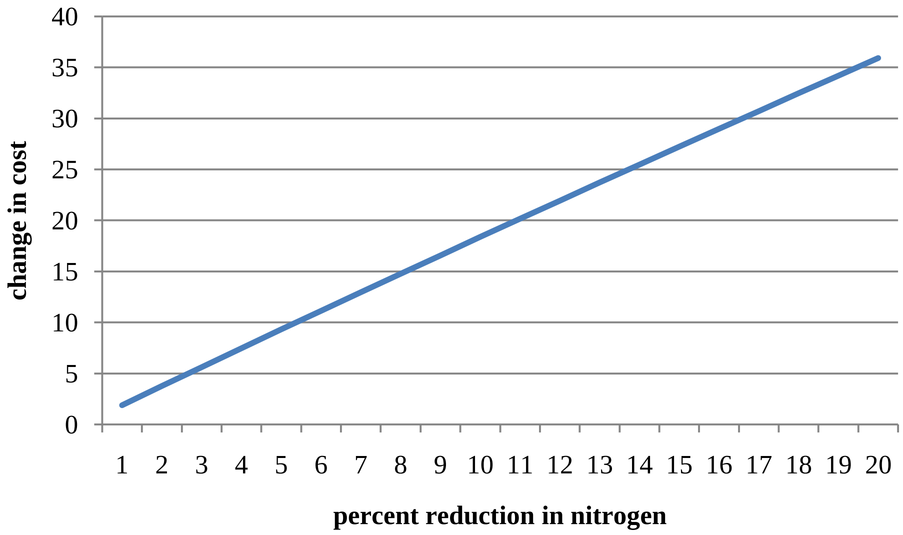

Figure 3. Mean changes in minimum production costs per acre by percentage reductions in the nitrogen application rate

Aggregate costs of offsets potentially sold by U.S. corn producers will depend on how the program is designed. If any U.S. corn producer can participate, the aggregate cost would depend on the number of acres receiving nitrogen and the desired percentage reduction in nitrogen. ARMS data suggest that 72.9 and 79.4 million corn acres were treated with nitrogen in 2001 and 2005, respectively. According to the estimates reported in figure 3, the cost of offsets sold by U.S. corn producers to reduce their chemical nitrogen application rates by 10 percent would have been $1.3 and $1.5 billion in 2001 and 2005, respectively, reducing the total amount of nitrogen applied in those years by 547 and 569 thousand tons. These estimates might be viewed as upper bounds on the cost of reducing nitrogen use on U.S. corn farms by 10 percent.

Lower-bound estimates can be obtained assuming a corn producer can participate in the offset program only if they typically apply more nitrogen than required to satisfy their yield goal. Using 2001 and 2005 ARMS data, we estimated a maximum nitrogen application rate equal to the product of corn's assimilative capacity per yield-unit (0.8 and 7.09 lbs N per bushel and ton of grain and silage, respectively) (Lander et al.), the grower's yield goal, and 1.5. We allowed for a 50-percent over-application to account for unavoidable environmental losses that farmers might consider when deciding how much nitrogen to apply.

Our estimates suggest that the nitrogen application rate exceeded the maximum application rate on 20 and 14 percent of acres treated with chemical and/or manure nitrogen in 2001 and 2005, respectively, which amounted to 14.3 and 11.5 million treated acres. The cost of offsets for U.S. corn producers to reduce their chemical nitrogen application rates by 10 percent under this restricted program would have been roughly $263 and $211 million in 2001 and 2005, respectively, reducing the total amount of nitrogen applied in those years by 166 and 138 thousand tons. These costs might further be moderated if information about corn producers who apply more than the maximum amount of nitrogen and/or adopt conservation tillage practices is included in the econometric model.

Future Extensions

These costs might further be moderated if information about corn producers who apply more than the maximum amount of nitrogen and/or adopt conservation tillage practices is included in the econometric model. The next step in our research is to determine whether production costs and cost-minimizing input demands differ for corn producers who apply more than the maximum amount of nitrogen and/or adopt conservation tillage practices, which sequester carbon and reduce greenhouse gas emissions. Related goals are to examine the costs of offsets involving reductions in nitrogen and the adoption of conservation tillage systems. Estimation challenges include:

- The choice of functional form: We are using Diewart and Wales' (1987) Symmetric Generalized McFadden flexible functional form to impose concavity.

- Attending to sample-selection bias in the input demands: Lee and Trost's (1978) two-step endogenous switching model provides a means to simultaneously test the influence input price and technology adoption have on the input-use decisions of conservation-tillage users and nonusers.

- Producing consistent estimates of the adoption and input-demand equations: Symmetry and adding-up restrictions are imposed using a Classical Minimum Distance estimator suggested by Perali and Chavas (2000).

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