Manure and Commercial Fertilizer Nutrients Relative to Cropland and Pasture Requirements: Is the Pollution Risk Growing on Corn/Livestock Farms?

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Abstract

Recent trends in livestock concentration in major corn producing states suggest that increasing risk of water pollution from manure applications may be offsetting declines in risk of water pollution from chemical fertilizer. Analysis of data from ARMS surveys found that potential excess nitrogen and phosphorous per corn acre increases sharply between 1996 and 2001 when manure nutrient credits are included. Cohort analysis of farms found that the level of technical efficiency appears to be positively associated with potential nutrient pollution from both sources. In general, the results suggest that adjusting the performance measures to include excess nutrients as a Abad output@ would tend to narrow the gap between high and low performance compared to measures that ignore pollution.

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Introduction

There have been long-standing concerns in the U.S. about water pollution problems associated with crop and livestock production. These concerns are reflected in national, state and local laws and regulations designed to control pollution from both point and nonpoint sources. Efforts to improve water quality have been guided since the early 1970's by the Federal Water Pollution Control Act, PL 92-500, as amended. This legislation is commonly referred to as the Clean Water Act (CWA). Since the early 1970's, large confined livestock operation point source discharges have been regulated through National Pollutant Discharge Elimination System (NPDES) permits required by the CWA.

Public concerns are translating into proposals for more stringent regulations at the local, state and national levels on all livestock producers, not only the large operations. The most recent rule to control runoff from animal feeding is the concentrated animal feeding operations (CAFO) regulations published on February 12, 2003 (EPA). This rule requires all large CAFOs to develop and follow a plan for handling manure and wastewater. Concerns over the combined effects of pollution from both crop production and livestock production, as well as nonagricultural sources are addressed through the Total Maximum Daily Load program of the CWA. [1 2]

The need for controlling and reducing pollution from both crop and livestock remains. The problem is particularly acute in those areas where livestock production has become more concentrated in large operations and when intense crop production uses large amounts of commercial fertilizer, both of which increase the pollution potential. (Kellogg, et al.; Ribaudo, et al.)

Farmers have been adopting improved and more precise fertilizer management practices, helping to bring fertilizer application rates closer in line with crop requirements, thus improving fertilizer use efficiency

1 A TMDL or Total Maximum Daily Load is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The Clean Water Act, section 303, establishes the water quality standards and TMDL programs.

2 New rules for strengthening the TMDL program were put into a final rule in July 2000, but withdrawn in March 2003 as they were deemed unworkable.

and reducing that available for runoff into streams and lakes (Fixen and West). However possible improvements in water quality from reduced use of chemical fertilizers may be offset by recent trends in livestock concentration. Our estimates of reductions in excess nitrogen applications, based only on chemical fertilizer use relative to agronomic requirements, point to declining pollution risk since the mid 1990's in major corn producing states. Between 1995 and 2000 we estimate that excess nitrogen levels in eleven major corn-producing states dropped almost 50 percent to about 17 pounds per acre. Excess nitrogen levels in Iowa were virtually zero pounds per acre in 2000 compared to 9 pounds per acre in 1995. Similarly, we estimate that in Illinois excess nitrogen per acre was 27 pounds per acre in 2000 compared to 52 pounds in 1995. Only Kansas, Nebraska, and South Dakota showed small increases.

However these estimates of excess nitrogen may increase sharply if nutrient credits from manure are included. According to Kellogg et al., close to 40 percent of total manure production in 1997 occurred in the eleven major corn-producing states. The concentration of hog production on much larger farms in these states accelerated during recent years, suggesting that the potential risk of water pollution from manure nutrients has grown markedly. (McBride and Christensen, McBride and Key) Using contracted production as a proxy for integrated production of hogs in large specialized units, we estimate using USDA survey data that between 1995/96 and 2000/2001 contracted pork production in major corn producing states nearly doubled to about 20 billion dollars of sales. One result is that the supply of manure on farms and/or in a county increasingly exceeds what the crops can use (Ribaudo and others). These changes have created a manure management challenge only beginning to be addressed by water quality regulations.

The purpose of this study is to quantify and assess factors relating to the increasing risks of water pollution from excess nutrient concentrations in many corn/livestock producing states during 1996-2001. We do this by 1) developing farm level estimates of excess nutrients that derive from both commercial fertilizer and manure, and 2) calculate farm-level efficiency scores (performance measures of economic activity) and assess factors influencing efficiency using a stochastic production frontier approach involving estimation of an output distance function over time. We construct a panel data set of farms for

1996 and 2001 data based on pseudo cohorts. The nutrient balance concept used to calculate excess nutrients involves the development of measures of manure output (the actual quantity and value of N, P, and K produced) and manure applied for crop production. The analysis uses 1) six years (1996-2001) of USDA's Agricultural Resource Management Survey (ARMS) data, incorporating both 1)whole farm data, including income and operator characteristics, and 2) corn production practices and cost data at the field level.

Thus, we can readily incorporate a farm's manure output along with corn, soybeans, other crops and livestock, and include nutrient credits from applied manure as an input along with other production inputs. This technique allow us to develop performance measures or efficiency scores. We rank farms' relative performance within states and identify factors influencing performance, including levels of excess nutrients and the ratio of manure applied to manure produced. Finally, we infer the relative risk of water pollution based on these findings, recognizing that pollution risk may vary by climate and soil type.

Nutrient Balance Use

We employ well-known techniques, as described in Kellogg et al., to calculate excess nitrogen and phosphorous at the farm level. Excess nitrogen (phosphorus) is defined as the difference between the amount of nitrogen (phosphorus) available from all sources (chemical fertilizers plus soybean, legume and/or manure credits) and the amount of nitrogen (phosphorus) removed during the crop production process.

We develop farm-level estimates of excess nitrogen (phosphorus) from commercial fertilizer and manure sources for 12 major corn producing states—Colorado, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio, South Dakota, and Wisconsin. Cattle, hogs, dairy, and poultry are major sources of manure in these states. Using hogs as an example we see substantial specialization in 2001 hog production. Of the 18 most specialized hog Agricultural Statistics Districts in the United States, two thirds are located in these states (Figure 1).

Livestock specialization suggests significant shifts in livestock concentrations within the corn-producing states, and hence, significant increases in excess nutrients in selected ASD. For example, hog output per farm, measured as value of production adjusted for inflation, increased sharply in most of the major corn producing states between 1995 and 2000 (USDA Costs and Returns data). In the states intensively surveyed (Illinois, Indiana, Iowa, and Minnesota, each with 50 or more observations in each time period) hog output per farm increased dramatically—276 percent in Illinois, 202 percent in Iowa, and 185 percent in Minnesota. Only Indiana showed no appreciable growth in hog output per farm. In the less intensively surveyed states, (i.e., with fewer observations, Michigan, Nebraska, Ohio, South Dakota, and Wisconsin) the data also suggest large increases in output per farm. In the thinly surveyed states (Kansas and Missouri) there was little increase in output per farm. Changes in concentration in other species were mixed during 1995-2000. USDA data indicate close to a 200 percent increase in cattle output per farm in Kansas and South Dakota but only small increases in dairy output per farm in the key dairy states of Michigan, Minnesota, and Wisconsin. Poultry output per farm increased nearly 200 percent for the major corn producing states, but concentrations by state cannot be identified from the available USDA data.

Model

We use a multi-output distance function and stochastic frontier and inefficiency procedures to estimate efficiency scores and assess factors influencing efficiency. The output distance function permits a multi-input, multi-output technology without requiring observations on output and input prices as described by Coelli and Perelman (1996, 2000). In contrast to a cost or profit function, the output distance function does not require a system of equations in the estimation procedure. The output distance vector considers how much the outputs may be proportionally expanded with inputs held fixed. In this sense, it implies revenue maximization. The appropriate functional form is ideally flexible, easy to calculate, and permits the imposition of homogeneity. Following Coelli and Perelman, and Morrison et. al. a translog stochastic frontier production model is estimated for over time as :

(1) $\ln(Y_{MIt}) = \alpha_0 + \alpha_{t1}\, t + \alpha_{t2}\, t + \Sigma_m \alpha_m \ln Y^*_{mit} + .5\, \Sigma_m \Sigma_n \beta_{mn} \ln Y^*_{mit} \ln Y^*_{nit} + \Sigma_m \gamma_{mt} \ln X^*_{mit}\, t + .5\, \Sigma_k \Sigma_l \beta_{kl} \ln X_{kit} \ln X_{lit} + \Sigma_k \Sigma_m \beta_{km} \ln X_{kit} \ln Y^*_{mit}$, + $V_{it} - U_{it}$, where $Y^*_{mit} = Y_{mit}/ Y_{MI}$.

Choosing corn output, arbitrarily, homogeneity is imposed by dividing the distance function by the value of corn output. In this specification Y_{MIt} represents the value of corn produced at time t and Y^*_{mit} represent the ratios of soybean output to corn output, other crops output to corn output, and livestock (augmented by the difference between manure produced and manure applied) output to corn output, all measured as the value of production, at time t. The X_{it} represent expenditures on six inputs: labor, fuel, fertilizer and other chemicals, miscellaneous operating expenses, capital services, and land cost valued at the quality-adjusted price of land at time t . The error term, V_{it} is assumed to be independently and identically distributed random errors, and U_{it} is a non-negative variable, called technical inefficiency effects , associated with the technical inefficiency of production of the observations involved. It is assumed that the inefficiency effects are independently distributed and U_i arises by truncation (at zero) of the normal distribution with mean μ, and variance s^2 , where μ_I is defined by

$$(2)\quad \mu_i = \delta_0 + \delta_1 \text{acres} + \delta_2 \text{ age} + \delta_3 \text{ education} + \delta_4 \text{ rent} + \delta_5 \text{ debt} + \delta_6 \text{ biocorn}$$
$$+ \delta_7 \text{ biosoybeans} + \delta_8 \text{ off-farm} + \delta_9 \text{ app/manure}$$
$$+ \delta_{10} \text{ cohortsmall} + \delta_{11} \text{ cohortmedium} + \delta_{12} \text{ cohortlarge}$$

where acres is a continuous variable representing acres per farm, age represents the age of the operator, education represents the education score for the operator (where 1=less than high school, 2=high school diploma, 3=some college, 4=BA or BS degree, and 5=graduate school), rent represents the ratio of acres rented to total acres operated, debt represents the debt/asset ratio, biocorn represents the proportion of corn acres in GMO corn, biosoy represents the proportion of soybean acres in GMO soybeans, off-farm represents the ratio of off-farm earnings to farm earnings, app/manure represents the ratio of manure applied to manure produced, cohortmed1 represents the dummy for small commercial farms, cohortmedium represents a dummy for medium and large family farms, and cohortlarge represents a dummy for very large family farms and nonfamily farms. All continuous variables (that is, all of the inefficiency effects except for the cohort dummies) are in logs. The maximum-likelihood estimates for the parameters of the stochastic frontier model defined by equations (1) and (2) were estimated using

FRONTIER Version 4.1 (Coelli). We used classical regression techniques, suitable for ARMS data aggregated by pseudo cohort levels as discussed below.

The expected signs on the coefficients for acres, rent, biocorn, and biosoy, are negative, signifying that these variables are likely to be negatively related to inefficiency and positively related to efficiency. Similarly, the expected signs on the coefficients for age, debt, and off-farm are likely to be negative. The expected coefficients for education, excessn, excessp are ambiguous. The coefficients on excessn and excessp are ambiguous because it is unclear whether larger operations with relatively more livestock, and hence more excessn and excessp are likely to be more technically efficient on average than large grain farms with relatively little excessn and excessp. We expect that the ratio of manure applied to manure produced is positively related to efficiency in that it represents efficient use of the manure resource. The coefficient for off-farm is likely to be positive because we have not included off-farm income as an output. Nor have we included off-farm hours worked as part of the wage bill. Thus, in our model, off-farm is likely to be positively related to inefficiency and hence, negatively related to efficiency, because time spent in off-farm employment negatively influences the quality and availability of on-farm employment.

Data

Our approach uses U.S. farm and field level data from the 1996-2001 Agricultural Resources Management Study (ARMS) surveys. ARMS is an annual survey covering farms in the 48 contiguous states, conducted by the National Agricultural Statistics Service and the Economic Research Service. States in or near the Corn Belt were selected because they represent major soil types, and cropping patterns, and because major shifts in livestock populations occurred in these states during the period analyzed. In order to allow inferences to the state and regional level we use weighted observations. The twelve corn- producing states included in the sample are CO, IL, IN, IA, KS, MI, MN, MO, NE, SD, OH, and WI.

Five outputs are included in the model estimation. The crop outputs are corn, soybeans, and other crops, measured as the total value of production of each. Livestock production is measured as the total value of livestock production. Manure production is measured as the value of nitrogen, phosphorous, and potassium available for crop production (see Kellogg et al.). For the variable inputs, labor costs are the annual per-farm expenditures on labor; energy costs are expenditures on gasoline, diesel fuel and other fuels; fertilizer costs (augmented by the cost of manure applied[3]) are expenditures on fertilizer, lime and other chemicals; and materials costs are expenditures on seed, feed and miscellaneous operating expenses. Capital machinery is measured as the annualized flow of capital services from assets (excluding land). Our land variable is an annualized flow of services from land and is constructed as an annuity based on a 20-year life and 10 percent rate of interest.

To support empirical production studies using panel data, the temporal pattern of a given farm's production behavior must be established. In the absence of genuine panel data, repeated cross-sections of data across farm typologies may be used to construct a pseudo panel data (see Deaton, Heshmati and Kumbhakar, Verbeek and Nijman). The pseudo panels are created by grouping the individual observations into a number of homogeneous cohorts, demarcated on the basis of their common observable time-invariant characteristics, such as quality of land as determined by geographic location and size of farm as determined by the gross value of sales. The subsequent economic analysis then uses the cohort means rather than the individual farm-level observations.

Farm-level data were assigned to cohorts by typology, (and sub typology), by gross value of sales, by state, and by year for the corn-producing states using ERS farm typology groups described in Table 1. The data in typologies 1 through 3 (limited resource, retirement, and residential) is relatively limited compared to the traditional farm data in typologies 4 through 7 – particularly cohorts 1 and 2. Hence, typologies 1 through 3 were grouped into three cohorts by level of agricultural sales in both

regions. Similarly, the data in typologies 4 and 6 were used to form three cohorts, while data in typologies 5 and 7 were grouped into two cohorts each. These categories are summarized in Table 2. The resulting panel data set consists of 13 cohorts by state, for 1996-2001, measured as the weighted mean

3 The ratio of manure applied to manure produced is calculated as the ratio of manure costs of application to the value of manure produced, derived from survey information in the 2001 ARMS corn survey. Information on manure applications in the 2001 corn survey are based on one surveyed field per farm. We assumed that manure application estimates derived from phase II information in 2001 were applicable to 30 percent of all corn acres on the farm surveyed (see McBride and Key).

values of the variables to be analyzed. In total we have 780 annual (cohort) observations (130 per year, a balanced panel), summarizing the activities of 2283 farms in 1996, 2690 farms in 1997, 1602 in 1998, 1866 in 1999, 1567 in 2000 and 1254 in 2001. To translate these nominal values into real terms for the panel data, all variables are deflated by the estimated increase or decrease in cost of production in 1997-2001 compared to 1996 (in terms of agricultural prices by output and input as reported by USDA in Agricultural Prices). We augmented phase III data to impute information on manure costs of production and application rates by using data from 2001, assuming that the same relationship of manure production and application rates to livestock output held in 1996 through 2000. We also imputed state level nitrogen and phosphorous application rates from NASS sources into phase III surveys for 1997 through 2000 in order to calculate excess nitrogen and excess phosphorous levels per farm.

An example of the summary sample data used in the output distance function estimations for 2001 is presented in Table 3. The average farm size varies from 273 acres in the limited resource typology to 2,222 acres on the very large family farm typology. Manure production per farm is highest on the very large family farms followed by industrial farms, but excess nitrogen (at close to 130 pounds per corn acre) and excess phosphorous (at close to 50 pounds per corn acre) are highest on smaller commercial farms, which tend to represent the majority of dairy operations in the corn states analyzed. The average age of farmers is highest in retirement and low sales typologies, and lower in the residential and higher sales farm typologies. The farmer education average of 2.5 is between a high school diploma (2) and some college (3), and tends to be slightly greater in the high sales typologies.

Output distance function results

The maximum-likelihood (ML) estimates of the parameters of the output distance stochastic production frontier are presented in Table 4. Given the pseudo-cohort nature of the data, cohort dummies are added to take account of cohort-specific effects (Heshmati and Kumbhakar). About half of the coefficients of the model are significant at the 10 percent level or better. The estimate of the variance parameter, ?, is also significantly different from zero, which implies that the inefficiency effects are significant in determining the level and variability of output of farmers in the corn states analyzed.

Turning to the factors influencing efficiency, we find that the coefficient on *acres operated* is negative and significant, indicating that the size effect is negatively associated with technical inefficiency and, therefore, positively associated with technical efficiency, confirming our hypothesis. Among the other factors influencing efficiency we find that the coefficients on acres rented, acres in GMO corn, acres in GMO soybeans, and the ratio of manure applied to manure produced are all significant and positively influence the efficiency frontier. In contrast, we find that the coefficient on age is significant and negatively influences the efficiency frontier. We do not find that the ratio of off-farm earnings to farm earnings to be highly significantly related to technical inefficiency. This is not surprising given the focus on farms producing corn.

Using the coefficients found in Table 4, an increase in farm size of 10 percent would increase the efficiency of production on the corn farms analyzed by 8.4 percent. Similarly, an increase of biocorn and biosoy acres of 10 percent would increase efficiency by 3.1 and 3.5 percent, respectively. But the coefficient of particular interest to our analysis is the ratio of manure applied to manure produced. We find that an increase of 10 percent in the ratio of manure applied to manure produced appears to be consistent with a 1.6 percent increase in efficiency.

We find the mean technical efficiency score for all farmers is 0.757 implying that farms could reduce their inputs by about 26 percent without compromising output if they could achieve best management practices by producing on the frontier.

To illuminate the performance results of the output distance function, we divided the farms into two equal groups based on their efficiency scores--a high group with technical efficiency scores averaging .882 and a low performance group with technical efficiency scores averaging 0.633—and compared the mean levels of the characteristics for each group. Results reveal that high performance farms are on average close to twice as large as low performance farms, (1098 acres compared to 660), are operated by farmers that about four years younger, rent 37 percent more land, plant substantially more of their corn and soybean acres to GMOs, exhibit higher ratios of manure applied to manure produced, exhibit larger levels of excess phosphorous per corn acre, but also appear to exhibit comparable levels of excess nitrogen per corn acre.

Given the livestock concentration trends we have observed in recent years, it is just as important to examine economic performance and factors influencing performance by state as it is to examine factors influencing high and low performance in aggregate. We find that the relatively large beef operations in Nebraska are the most technically efficient, on average, with a score of 0.800 as shown in Table 5. They are followed closely by medium beef and hog operations in Missouri, with a score of 0.784. Interestingly, Nebraska operations exhibit about average excess nitrogen and excess phosphorous while excess nitrogen and phosphorous levels are both well above average in Missouri. In contrast, small dairy operations in Michigan are the least technically efficient with a score of 0.698 and they exhibit among the highest levels of excess nitrogen and phosphorous. The performance comparisons in Table 6 also indicate that high performance appears to be associated with significantly higher excess nutrients in Illinois and Indiana, whereas in Iowa the reverse is true. In general, differences in mean levels of excess nutrients[4] are not highly significant in other states. However, the cohort evidence strongly suggests that the cross section data with substantially more observations by state would likely yield evidence that the level of excess nutrients is significantly different by performance group in most states. The implication is that--assuming that storage, processing and sales of nutrients are minor---adjusting the performance measures for pollution related to agricultural production (i.e. incorporating an output representing pollution) would generally tend to narrow the gap between high and low performance measures compared to performance measures that ignore pollution.

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4 Excess nitrogen per farm is calculated as the difference between (commercial nitrogen + manure nitrogen available for crop production after accounting for losses due to volatilization, collection, storage, treatment, transfer, spillage, and runoff losses + soybean acres times 35, assuming a yield of 35 bushels per acre and a credit of 1 pound of nitrogen per bushel of soybeans + hay acres times 135, assuming a credit of 1 pound of nitrogen per acre of hay) and (corn bushels times 0.9 + sorghum bushels times 0.9, assuming that a bushel of production of corn and of sorghum requires .9 pounds of nitrogen). Similarly, excess phosphorous per farm is calculated as the difference between (commercial phosphorous + manure phosphorous available for crop production after accounting for losses due to collection, storage, treatment, transfer, spillage, and runoff losses) and (corn bushels times 0.15 + sorghum bushels times 0.18, assuming that a bushel of production of corn and of sorghum requires 0.15 and 0.18 pounds of phosphorous, respectively).

Nutrient Balance Results

Analysis of data from ARMS surveys found that potential excess nitrogen and phosphorous per corn acre increased sharply between 1996 and 2001 when manure nutrient credits are included. For example, if we ignore manure credits, we estimate that Illinois farms in 2001 averaged 18 pounds of excess nitrogen per corn acre and 46 pounds of excess phosphorous. But if we include manure and other credits we estimate that the average excess nitrogen per acre of corn on Illinois farms increases three-fold to 54 pounds and excess phosphorous rises 3 pounds. In general, adding manure credits raises estimated excess nitrogen estimates dramatically in all corn-producing states, but excess phosphorous per corn acre increases most sharply in states with growing beef numbers as beef manure is characterized by relatively large amounts of phosphorous available for crop production (Kellogg et al.).

We find that, given manure credits, region-level estimates of excess nitrogen and phosphorous per acre of corn during the period of analysis held roughly steady. Based on the USDA survey data analyzed, average excess nitrogen per acre of corn for the aggregate 12 corn-producing states hovered in the range of 75 to 90 pounds per acre of corn in 1997- 2001. Average excess phosphorous per acre of corn held steady at about 40 pounds. As shown in table 5, excess nitrogen measured per acre of corn declined in three states, (Illinois, Indiana, and Missouri) but increased significantly in most of the remaining states. The largest absolute increases excess nitrogen occurred in Iowa, Michigan, Minnesota, and Wisconsin. Excess phosphorous increased modestly overall, with sharp increases in Michigan and Wisconsin offsetting modest declines or little change in other states.

Summary and Conclusions

The agricultural production environment in the major corn-producing states changed dramatically between 1996 and 2001, due to increased efficiency in commercial fertilizer use and large increases in livestock populations per farm. Average manure production per farm increased from about 4 tons per acre of corn in 1997 to close to 6 tons in 2001. One result is that the supply of manure on farms or in a county increasingly exceeded what the crops used. These changes have created a manure management challenge only beginning to be addressed by water quality regulations.

The relative technical efficiency of corn enterprises in major corn producing states was analyzed using a multi-output parametric approach. In order to provide a realistic representation of the production process on corn/livestock farms we augment the livestock output with the difference between manure production and manure credits and we incorporate manure/livestock as an output along with corn, soybeans, other crops. We also summarize nutrient balance trends in the corn states analyzed.

The farm survey data indicate that potential excess nitrogen and phosphorous per corn acre increased somewhat between 1996 and 2001 for the states analyzed. Increases in manure production off-set progress in balancing commercial fertilizer with crop requirements in most states. Regarding technical efficiency, we find that operations with high levels of manure applied to manure produced tend to be more technically efficient than operations with low levels of manure applied to manure produced. Factors influencing or associated with performance differ by states. We find that the relatively large corn/beef operations in Nebraska are the most technically efficient, followed closely by medium corn/beef and corn/hog operations in Missouri. Interestingly, Nebraska operations exhibit about average excess nitrogen and excess phosphorous while excess nitrogen levels are well above average in Missouri. Both states exhibit low ratios of manure applied to manure produced. In contrast, small corn/dairy operations in Michigan, are the least technically efficient and exhibit among the highest levels of excess nitrogen and phosphorous. In general, the results suggest that adjusting the performance measures to include excess nutrients as a "bad output" would tend to narrow the gap between high and low performance compared to measures that ignore pollution.

In future research it would be desirable to assess the degree of substitutability of manure with other outputs. This may be accomplished by estimating the marginal rate of transformation of one output for another, i. e. the ratio of output shadow prices, which reflect the slope of the production possibilities frontier at the observed output mix. We hypothesize that because farmers likely would have difficulty valuing the manure output, that the marginal rate of transformation of manure relative to other outputs is likely to be quite high, reflecting difficulty in substitution.

Also, given the regional complexity of the production and use of manure it would be desirable to extend the analysis of manure production and use. The ARMs surveys for 1996-2001 provide a rich source of cross-section information with which to more precisely identify the significance of factors influencing the level of performance in the corn-producing states analyzed above. Also, this would provide information to elaborate on differences in efficiency and manure management by type of livestock operation. Finally, GIS techniques may be used to map nutrient and excess nutrient loadings by state and ASD.

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Table 1. The Farm Typology Groups

Small Family Farms (sales less than $250,000)

1. Limited-resource. Any small farm with: gross sales less than $100,000, total farm assets less $150,000, and total operator household income less than $20,000. Limited-resource farmers may report farming, a nonfarm occupation, or retirement as their major occupation

2. Retirement. Small farms whose operators report they are retired (excludes limited-resource farms operated by retired farmers).

3. Residential/lifestyle. Small farms whose operators report a major occupation other than farming (excludes limited-resource farms with operators reporting a nonfarm major occupation).

4. Farming occupation/lower-sales. Small farms with sales less than $100,000 whose operators report farming as their major occupation (excludes limited-resource farms whose operators report farming as their major occupation).

5. Farming occupation/higher-sales. Small farms with sales between $100,000 and $249,999 whose operators report farming as their major occupation.

Other Farms

6. Large family farms. Sales between $250,000 and $499,999.

7. Very large family farms. Sales of $500,000 or more

8. Nonfamily farms. Farms organized as nonfamily corporations or cooperatives, as well as farms operated by hired managers

Source: U.S. Department of Agriculture, Economic Research Service

Table 2. Group Definitions by Agricultural Statistics Districts Groupings

Cohort	***Typology***	***GV Sales***	***Cohort***	***Typology***	***GV Sales***
COH1	1-3	<2,499	COH9	6	250,000-330,000
COH2	1-3	2,500-29,999	COH10	6	330,000-410,000
COH3	1-3	>30,000	COH11	6	>410,000
COH4	4	<10,000	COH12	7	<1,000,000
COH5	4	10,000-29,999	COH13	7	>1,000,000
COH6	4	30,000-99,999			
COH7	5	100,000-174,999			
COH8	5	175,000-249,999			

Table 3: Summary Statistics for Selected Variables in Corn States, 2001

Type	Farms (%)	Area (%)	Corn	Soybeans	Excess Nitrogen	Excess Phos	Manure Output	Manure Applied	Livestock	labor	Manure Produced	Acres	Age	Educ.
			--- dollars -------		---# per acre------		----Dollars per farm-------------------				tons			
Limited Resource	4.4	1.4	13,043	2,574	67.50	46.08	378	94	3,382	20,057	38	273	50.17	2.28
Retirement	11.4	4.0	6,947	2.124	100.93	27.01	508	166	13,226	10,932	87	217	68.86	2.03
Residental/ lifestyle	38.35	14.8	9,433	2,988	82.26	38.77	584	65	8,647	14,232	28	285	48.80	2.55
Farming/ lower sales	23.5	21.3	8,105	2,355	127.19	50.90	1,263	314	19,091	25,649	140	326	56.85	2.22
Farming/ higher sales	12.5	25.1	24,795	7,254	84.01	34.02	2,059	668	53,763	34,780	668	759	51.42	2.49
Large family farms	5.0	15.2	48,775	12,515	91.77	43.77	4,191	1,156	137,570	45,914	1,156	1,206	49.17	2.64
Very Large Family Farms	2.8	15.6	100,726	24,490	93.52	41.83	10,559	3,701	565,507	79,293	3,701	2,222	49.08	2.85
Nonfamily Farms	2.0	2.7	99,278	23,713	91.33	44.48	10,192	3,449	547,269	81,097	1,600	2,162	48.25	2.79
All Farms	100.0	100.0	26,772	7,170	93.09	41.10	2,513	746	88,486	33,171	358	718	52.05	2.47

Table 4. Output Distance function Results

Variable	Parameter	t-test
Constant	-0.041	(0.02)
Labor	0.153	(0.36)
Fuel	0.697	(1.64)
Fertilizer	0.345	(0.80)
Miscellaneous	0.423	(0.96)
Capital	-0.476	(1.62)
Land	-0.115	(0.20)
Soybeans/Corn (Soy)	-0.422	(12.22)
OthCrops/Crop (oth)	-0.095	(7.58)
Livestock/Corn (Liv)	-0.264	(19.44)
Soy*Soy	-0.049	(7.69)
Oth*oth	-0.011	(5.07)
Liv*Live	-0.030	(14.08)
Soy*Oth	0.001	(1.29)
Soy*Liv	0.039	(5.26)
Oth*Liv	-0.001	(0.20)
Labor*labor	-0.080	(2.43)
Labor*Fuel	0.123	(3.16)
Labor*Fertilizer	0.003	(0.05)
Labor*Miscellaneous	-0.097	(1.87)
Labor*Capital	0.007	(0.21)
Labor*Land	0.126	(1.70)
Fuel*Fuel	-0.001	(0.04)
Fuel*Fertilizer	0.001	(0.01)
Fuel*Miscellaneous	-0.065	(1.05)
Fuel*Capital	0.022	(0.94)
Fuel*Land	-0.127	(1.89)
Fert*Fert	0.026	(1.64)
Fertilizer*Capital	0.049	(1.26)
Fertilizer*Land	-0.076	(1.31)
Fert*Miscellaneous	-0.023	(0.47)
Misc*Misc	0.051	(1.58)
Misc*Capital	-0.064	(1.26)
Misc*Land	0.118	(1.90)

Table 4. Output Distance function Results (continued)

Capital*Capital	-0.006	(0.34)
Capital*Land	0.060	(1.40)
Land*Land	-0.048	(1.10)
Time dummy two	0.303	(5.07)
Time dummy three	0.040	(0.68)
Time dummy four	0.196	(3.52)
Time dummy five	0.033	(0.54)
Time dummy six	0.139	(2.22)
Inefficiency const	-1.478	(1.48)
Acres	-0.836	(10.30)
Age	0.309	(1.53)
Education	0.404	(2.38)
Rent	-0.488	(8.40)
Debt	0.113	(2.86)
Biocorn	-0.315	(5.71)
Biosoy	-0.346	(8.51)
Off-farm	-0.042	(1.36)
App/manure	-0.160	(11.71)
Cohortsmall	-1.103	(6.33)
Cohortmedium	-2.968	(15.36)
Cohortlarge	-1.485	(5.96)
F^2	1.422	(13.30)
(	0.956	(161.90)
Log-liklihood	-32.53	
Technical efficiency	0.757	

Table 5. Output Distance Function Technical Efficiency Results and Characteristics by state (2001 data)

State	Technical Effciency	Acres	Age	Ed	Rent	Debt/ Asset	Beef Num	Dairy Num	Hog Num	Poultry Num	Manure Prod	Manure App	Ex N ----2001-----	Ex P	Ex N ---1997-----	Ex P
					%	%	--------per farm---------------				-------------per corn acre-------------------------					
Il	0.769	639	52.76	2.66	72	12.8	19	17	81	1	2.1	0.7	56.30	50.47	78.30	53.87
IN	0.737	505	52.96	2.19	63	12.7	18	10	84	1237	2.7	0.9	70.53	40.98	90.50	43.62
IA	0.744	487	52.33	2.46	53	15.8	41	14	146	623	3.7	0.6	67.72	59.25	54.68	53.62
MI	0.698	514	53.42	2.27	54	12.7	31	35	2	0	6.5	3.9	117.59	42.93	89.11	36.11
KS	0.706	1880	52.47	2.84	58	14.4	125	9	1	0	4.7	0.0	67.87	33.24	64.17	25.17
MN	0.771	567	49.27	2.73	61	19.5	18	39	170	0	5.5	4.0	63.98	39.88	86.38	35.71
MO	0.784	704	53.70	2.32	48	10.7	74	12	26	0	4.9	0.3	110.27	52.34	132.69	52.07
NE	0.803	1150	52.81	2.46	52	14.2	131	1	40	0	4.1	0.4	78.32	30.80	73.69	25.16
OH	0.760	624	52.69	2.30	62	10.2	22	27	42	1466	5.8	1.4	113.46	65.00	101.78	58.47
WI	0.742	384	48.06	2.43	50	17.0	23	72	10	268	14.0	11.3	185.49	48.43	136.02	31.76

Table 6. High versus low performing farms by state and corresponding mean level of characteristics*

State		Technical Effciency	Acres	Age	Ed	Rent	Debt/ Asset	bio corn	bio soy	off-farm	Ex N	t-test	Ex P	t-test	App/ Manure	Livestock/ Output
						----------percent-----------				ratio	--per corn acre-----------------				---------%---------	
IL	High	0.880	1207	54.21	2.93	69	14.6	16	35	0.24	181.80	1.46	127.50	2.21	16	17
IL	Low	0.639	384	58.42	2.66	41	10.8	10	27	1.68	104.26		53.35		5	13
IN	High	0.877	866	52.12	2.68	60	15.1	6	53	0.40	88.11	2.25	43.29	0.49	11	28
IN	Low	0.634	653	53.75	2.48	39	13.0	1	19	1.66	54.05		39.01		6	18
IA	High	0.893	802	51.85	2.79	62	19.9	23	44	0.19	78.22	-1.83	32.10	1.68	5	45
IA	Low	0.646	379	56.09	2.52	38	14.1	14	33	2.22	146.37		57.78		3	31
KS	High	0.850	2156	65.89	3.74	61	18.1	19	62	0.23	120.57	-0.31	57.45	-0.84	1	31
KS	Low	0.573	1243	62.59	3.23	57	18.8	2	26	1.06	134.29		41.97		1	21
MI	High	0.855	896	51.68	2.50	53	14.3	14	35	0.18	282.41	0.08	93.64	-0.23	15	41
MI	Low	0.607	698	54.20	2.46	49	12.8	5	28	1.09	266.19		111.80		11	23
MN	High	0.896	908	49.51	2.86	63	23.5	29	40	0.14	128.76	-0.87	92.56	-1.00	23	42
MN	Low	0.650	412	54.10	2.43	36	12.8	10	21	5.66	237.10		224.52		9	32
MO	High	0.897	1349	54.98	2.84	56	13.2	17	37	0.21	187.90	0.68	57.70	-0.27	3	33
MO	Low	0.666	879	62.41	2.71	43	13.7	18	39	1.37	148.64		63.42		3	22
NE	High	0.891	1474	52.33	2.89	59	17.3	36	59	0.49	95.33	-1.15	30.19	-0.19	1	33
NE	Low	0.708	771	55.44	2.55	42	13.6	15	31	1.44	142.96		31.98		2	23
OH	High	0.878	851	53.57	2.63	65	14.5	12	49	0.21	235.51	-0.67	72.47	-1.53	7	46
OH	Low	0.630	530	69.61	3.19	44	12.2	3	29	2.48	161.49		311.89		5	22
WI	High	0.876	723	50.13	2.62	53	19.9	21	41	0.31	151.19	-1.09	46.76	-1.05	27	62
WI	Low	0.600	411	49.57	2.46	49	15.0	7	22	3.22	187.39		59.41		17	50

*The characteristics data are mean levels of the cohorts for 1996-2001

Figure 1. Manure Use in States Analyzed