Manure Application Standards and EQIP Payments: The Distribution of Economic and Environmental Costs and Benefits across US Hog Farms

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Abstract

Implementation of new CAFO regulations and EQIP payments could have important implications for the structure of the hog sector. This study uses a farm-level positive mathematical programming model to estimate the distribution of the economic and environmental effects of these new policies across regional and scale typologies.

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1. Introduction

Livestock waste can degrade both air and water quality through volatilization and evaporation to the atmosphere, runoff to surface water, and leaching to ground water. Manure related air quality concerns include odorous gases (ammonia and hydrogen sulfide), particulate material (by-products of ammonia), and greenhouse gases (methane and nitrous oxide). Water pollutants from manure include nitrogen, phosphorus, antibiotics, and pathogens.

The Environmental Protection Agency has recently introduced regulations for concentrated animal feeding operations (CAFOs) under the Clean Water Act. These regulations require, among other things, that CAFOs applying manure to land meet nutrient application standards defined by a Comprehensive Nutrient Management Plan (CNMP) (USEPA, 2003). To help defray the costs of the meeting the new regulations, producers can apply for financial assistance from the USDA's Environmental Quality Incentives Program (EQIP). Producers can receive up to $450,000 during 2002-2007 to help them develop and implement a nutrient management plan, and to transfer and apply manure to land in an approved manner (USDA, NRCS, 1999; USDA, ERS, 2002). In addition, the USDA is encouraging the adoption of CNMPs by all animal-feeding operations not subject to EPA regulations. Funding for EQIP has been authorized to increase from 2002 levels of $200 million to more than $1 billion by 2005 (USDA, NRCS 2002).

The distribution of costs and benefits of the new CAFO regulations and EQIP payments could have important implications for the structure of the hog sector. The distribution of payments to large producers could confer advantages to this group resulting in further concentration in production. On the other hand, the costs of meeting CAFO regulations may not be fully offset by EQIP payments, and the distribution of economic costs could vary widely across farm size categories and regions (Ribaudo, Cattaneo, and Agapoff, 2004). In addition, production choices with environmental implications are likely to differ widely within and across regions. Understanding the distribution of economic and environmental effects of proposed policies is important for regulatory agencies seeking to target a wider group of producers.

A major challenge in modeling the economic and environmental effects of manure-management policy is incorporating the diversity of farming systems in the United States. The severity of air and water quality degradation caused by livestock production depends largely on how manure is stored and disposed of: the rate at which manure is applied to crops, the method of application (incorporation or spreading), and storage facility used (covered or uncovered lagoon or slurry pit). Manure handling techniques vary across and within geographic regions and are often correlated with farm characteristics such as scale, resource endowments, and organizational arrangements. In the Heartland region, for example, the use of pit versus lagoon storage is strongly correlated with the scale of an operation (McBride and Key, 2003). In the Southern Seaboard region, the availability of farmland on which to apply manure decreases with size of an operation more sharply than in the Heartland region.

Recent examinations of manure management policy in the context of water quality (e.g. Johansson and Kaplan, 2003) have used a regional approach that captures spatial variation in policy and impacts, but does not allow for differentiated policy responses within regions, nor an analysis of the distributional effects environmental and economic effects environmental policies below the regional level. Other research has focussed only on the costs of meeting environmental regulations, and has not analyzed the environmental consequences of these policies (e.g. Ribaudo, Cattaneo, and Agapoff, 2004).

This study uses a farm-level mathematical programming model to estimate the distribution of economic costs and environmental benefits of manure management regulations across farm size and geographic regions. In the model farms maximize profits by choosing livestock and crop output levels, the quantity of manure transported applied on and off farm, and the quantity of manure spread versus incorporated into the soil. The model is calibrated with data from the 1998 USDA-ARMS survey of hog operations using positive mathematical programming (Howitt, 1995). The calibrated model measures changes in profits and environmental performance after imposition of the manure application regulations and EQIP payments.

To evaluate the imposition of manure application constraints, the model accounts for the flow of nitrogen through the production process. Nitrogen enters through feed rations (corn and soybean) and is retained by the animals or excreted in manure. Once excreted, nitrogen may be released into the atmosphere through air emissions or contained in the manure storage facility until it is applied to cropland. Nitrogen also enters cropland through commercial fertilizer applications. The crop retains some of the applied nitrogen, and some is released into the atmosphere through air emissions, leached into the groundwater, or lost to surface water through runoff. From the scientific literature, we estimate relationships for air ammonia and excess soil nitrogen levels as functions of animal production, crop mix, and manure storage and handling technologies.

Results indicate that the consequences of the recent manure application standards and EQIP payments vary according to the scale and location of the farm - characteristics correlated with the availability of cropland and manure storage and handling technologies. We find that current CAFO regulations, because they impose greater costs on land-scarce farms in land-scarce regions, lower profits disproportionately for larger operations located in the Mid-Atlantic and "South and West" regions. The regulatory costs for large farms are not fully offset by EQIP subsidies, implying recent policy changes have not favored large farms. Model simulations also a reveal that significant environmental benefits could be achieved by extending nutrient application regulations to medium-scale hog operations (300-1000 Animal Units). Among medium-scale farms, the greatest benefits per dollar of EQIP payments could be achieved in the Corn Belt, where cropland for applying manure is a relatively abundant.

2. Analytic Model

Innes (2000) developed a spatial model of regional livestock production and three associated externalities: spills from animal waste stores, nutrient runoff from excess application of manure to croplands, and ambient pollution. An important premise of Innes' analysis is that regulators are unable to monitor environmental outcomes, including manure application rates. In fact, recently implemented EPA CAFO regulations are predicated on verifiable nutrient application plans. Feinerman, Bosch, and Pease (2003) extend Innes' analysis by evaluating state regulatory standards for manure spreading in Maryland and Virginia. Their approach uses a derived manure demand function to simulate the effects of manure spreading regulations on welfare and excess nutrient loading in soil. In this study, we extend the scope of past analyses to consider current Federal manure spreading regulations across both regions and farm scale categories.

We construct a hog farm model that captures the essential decisions associated with hog production and manure disposal. The severity of water quality degradation from livestock production depends primarily on how manure is stored and disposed of. The application of manure to fields when nutrients in the manure exceed what crops can absorb has been associated with increased algae production, reduced fish populations and diminished recreational opportunities (USEPA, 1998). Because of the high cost of transporting manure relative to the value of the nutrients contained in the manure, farmers have an incentive to over-apply manure to land located near their livestock facilities. A nutrient application standard can force farms to transport manure a significant distance from the hog facility. Farmers incurring manure transportation costs have an incentive to reduce the nutrient content of manure – either by storing manure in lagoons before applying it, or by surface applying manure rather than injecting it.

Positive mathematical programming (PMP) is used to calibrate the model to base year data without having to add constraints that cannot be justified by economic theory. PMP takes advantage of the fact that it is easier to collect information about output and input levels at the farm level than information about costs. The observed outputs and inputs levels result from a complicated decision process based in part on a cost function that is known to the farmer but difficult or impossible to observe directly. Some costs – perhaps associated with the environment, risk, or technology – may be hidden to the researcher even when a detailed survey instrument is available. PMP incorporates information about unobservable costs by using a quadratic cost function that approximates the true underlying cost function.

There are three steps to the PMP calibration (Howitt, 1995). In the first step, a constrained linear programming model is used to derive dual values associated with the "calibration constraints". In the second step, the dual values are used to parameterize a calibrated quadratic objective function. In the third step, the calibrated model is used for economic analysis, by imposing environmental policy constraints.

2.1 Linear program to calculate dual values.

In the first step, the linear objective is to maximize total net revenues:

$$(1) \qquad \max_{X1_{ir}} \sum_{r} \sum_{i} X1_{ir} \left(P_{ir} - C_{ir} \right) ,$$

where $X1_{ir}$ is the level of each output *i* in region *r*. The cost of producing each output is $C_{ir} = \sum_{j} A_{ijr} W_{jr}$, where A_{ijr} is the amount of input *j* required to produce a unit of output and W_{jr} is the input price. The optimization is subject to $j \times r$ resource constraints:

(2) $$\sum_{i} A_{ijr} X1_{ir} \leq \sum_{i} A_{ijr} X0_{ir}\ ,\ \forall\ j, r$$

where $X0_{ir}$ is the initial observed activity level, so that $\sum_{i} A_{ijr} X0_{ir}$ is the initial level of input *j*.

Inputs include land, capital, feeder pigs, feed corn, feed soy, and chemical fertilizer nitrogen. Outputs include hogs, corn, soybeans, and "other crops" (defined as the value of all other crops produced). All three crops can be produced under three fertilization regimes: 1) chemical fertilizer, 2) manure fertilizer surface applied, or 3) manure fertilizer injected into the soil. We use the extension of PMP developed by Röhm and Dabbert (2003) to allow for a greater policy response between crop fertilization regimes than between crops. To do so we define three "variant activities" (chemical fertilizer, manure-spread, and manure-injected) for each crop and impose calibration constraints that distinguish between variant activities and the total activity for each crop. In practice, this approach results in greater substitution between, for example, corn fertilized by spreading manure and corn fertilized by injecting manure, than between corn and "other crop" production.

The calibration constraints for each activity are:

(3) $$X1_{ir} \leq X0_{ir}(1 + \varepsilon_1),\ \forall\ i,r \qquad \text{dual: } \hat{\lambda}_{i,r}$$

where ε_1 is a small perturbation (see Howitt, 1995). Following Röhm and Dabbert, we include three additional calibration constraints corresponding to each set of variant activities. For corn activities, the additional calibration constraint is:

(4) $$\sum_{i \in cv} X1_{ir} \leq \sum_{i \in cv} X0_{ir}(1+\varepsilon_2), \ \forall \ i,r \qquad \text{dual: } \hat{\lambda}_{corn,r}$$

where *cv* is the set of corn variant activities: *cv* = {corn – chemical fertilizer, corn – spread manure, corn – injected manure}. There are two additional constraints analogous to (4) corresponding to soybean variant activities *sv* and other crops variant activities *ov*.

From the 1998 ARMS survey and other sources, we observe prices P_{ir}, W_{ir}, the output levels $X0_{ir}$, and most of the input-output coefficients A_{ijr} (see appendix for details). It would be desirable to include manure nitrogen as an input. However, we do not observe manure application rates, only the amount of land on which manure is applied.

2.2 Estimate calibrated quadratic cost function

In step 2 we define quadratic total variable costs as $\frac{1}{2}\hat{Q}_{ir}X2_{ir}^2$, where $\hat{Q}_{ir} = \left(\hat{\lambda}_{ir} + \hat{\lambda}_{crop,r} + C_{ir}\right) / X0_{ir}$, $\hat{\lambda}_{ir}$ are the estimated dual values associated with (3) the calibration constraints, and $\hat{\lambda}_{crop,r}$ are the estimated dual values associated with (4) the calibration constraints for each crop activity: *crop* $\in$ {*corn, soybean, other*}. Since (4) applies only to crops, $\hat{Q}_{ir} = \left(\hat{\lambda}_{ir} + C_{ir}\right) / X0_{ir}$ for *i=hogs*. The objective in step 2 is to maximize total net revenues:

(5) $$\max_{X2_{ir}} \sum_r \sum_i P_{ir}X2_{ir} - \frac{1}{2}\hat{Q}_{ir}X2_{ir}^2$$

subject to the resource constraints:

(6) $$\sum_i A_{ijr}X2_{ir} \leq \sum_i A_{ijr}X0_{ir}, \ \forall \ j, r$$

Solution of the non-linear optimization problem defined by (5) and (6) results in the initial output levels $X0_{ir}$.

2.3 Estimate activity levels for policy scenarios using calibrated cost function

Having characterized the farmer's non-linear optimization problem that results in the observed initial values, the final step is to impose policy constraints and compare solutions to the initial values. In this paper we consider imposition of the CAFO nitrogen application constraint and accompanying EQIP payments that reduce costs of abiding by the CAFO rules.[1]

First we incorporate into the optimization a manure transportation cost that depends on the how the manure is stored and handled. Prior to implementation of the CAFO manure application rules, farmers had little incentive to transport manure off-farm, and few did. According to the 1998 survey, fewer than 2% of farms transported manure off farm. The CAFO manure application rules require farmers to apply manure at a rate that plants can absorb. In response to the CAFO rules, farmers without adequate cropland will need to transport some manure off-farm (Ribaudo et al, 2003).

For the policy analysis, the farmer's objective is:

$$(7) \qquad \max_{X3_{ir}, COV_r} \sum_r \sum_i P3_{ir} X3_{ir} - \frac{1}{2} \hat{Q}_{ir} X3_{ir}^2 - (1 - EQIP) MTC_r - CC_r$$

where MTC_r is the cost of transporting manure off-farm, which is a function of technology choices that affect that nutrient availability to the crop – and consequently the amount of land on which the manure must be spread. Farms eligible for EQIP payments receive a share of the manure transportation costs and receive a subsidy for applying manure at the agronomic rate to their own cropland. *EQIP* is defined as the share of manure transportation costs financed by EQIP. The EQIP subsidy for applying manure at the agronomic rate is expressed as a per-crop unit subsidy and appears in the optimization as a higher price *P3*.

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[1] We assume for this analysis that all CAFOs are eligible for and receive EQIP payments. In fact, farmers must apply for EQIP payments and be accepted into the program. In addition, EQIP may face financing constraints that would limit payment availability. This possibility is not considered in this analysis.

The decision by lagoon farms to cover their lagoon is reflected in the binary choice variable COV_r (1 if covered, 0 otherwise). The cost of covering a lagoon is simply a cost κ per unit of hog output: $CC_r = COV_r \cdot \kappa \cdot X3_{hogs,r}$. We do not expect farmers to cover their lagoons in response to a nutrient application constraint. Farmers would have an incentive to cover their lagoons if they face an ammonia nitrogen emission constraint. We include the option to cover the lagoon in the model to allow for future analyses of ammonia emission policies.

Manure transportation costs depend on the nutrient content of the manure (how it was stored), how it is applied (injected or spread), on the availability of land on which to apply the manure, and on what crops it is applied. Estimates for the transportation costs per hundredweight of hog are based on a transportation cost model proposed by Fleming et al (1998) (see appendix for details). Manure transportation costs equal the quantity of hogs used to produce manure transported off-farm $hogs\_off_r$ multiplied by the manure transportation costs per hundredweight of hog. Manure transportation costs are distinguished for lagoon operations, which may or may not cover their lagoons:

(8) $$MTC_r = hogs\_off_r\left(COV_r * T_{\mathrm{cov}er,r} + (1 - COV_r) * T_{un\mathrm{cov},r}\right),$$

and for pit storage operations which may inject (versus surface apply) manure into some portion of the land on which manure is applied:

(9) $$MTC_r = hogs\_off_r\left(INJ_r * T_{inject,r} + (1 - INJ_r) * T_{surf,r}\right),$$

where transportation costs per hundredweight of hog produced $T_{e,r}$ depend on the manure storage and handling technology $e \in$ {covered, uncovered, surface-applied, injected}.

For lagoon operations, COV_r is a binary choice variable. For pit storage operations, INJ_r is the share of manure-applied cropland on which manure is injected:

(10) $$INJ_r = \sum_{i \in mi} A3_{i,land,r} X3_{i,r} \Big/ \sum_{i \in m} A3_{i,land,r} X3_{ir} \text{ ,}$$

where *m* is the set of manure crop activities (corn, soybean and other crops, either spread or injected) and *mi* is the set of all cropping activities on which manure is injected.

The quantity of hogs that produce manure applied off-farm equals the total manure nitrogen produced times divided by the manure nitrogen available to crops per hundredweight of hogs NH_e (which depends on the cover technology):

$$\text{(11)} \qquad hogs\_off_r = manN\_off_r \left(\frac{COV_r}{NH_{\text{cov}}} + \frac{1 - COV_r}{NH_{un\,\text{cov}}} \right)$$

Manure transported off-farm equals total manure produced (hogs produced times manure per hog) minus the manure that is applied on-farm:

$$\text{(12)} \quad manN\_off_r = X3_{hogs,r}\left(COV_r \cdot NH_{\text{cov}} + (1 - COV_r)NH_{un\,\text{cov}}\right) - manrate_r \sum_{i \in m} X3_{ir}\, A_{i,\,fertN,r}$$

The manure used on farm equals the pounds of manure nitrogen applied on farm if it were applied at an agronomic rate (the rate at which chemical fertilizers are applied) multiplied the factor, $manrate_r$. From the survey we know the average rate at which manure is applied to receiving land, but we do not know the rate applied to individual crops. Consequently, we assume that farmers apply manure at the same factor above the agronomic rate for all crops. There are equations analogous to (11) and (12) for pit storage operations.

We consider the effect of two policies: a nitrogen application standard and EQIP payments. CAFO rules require a nutrient management plan that requires growers to apply manure nitrogen at or below the rate at which plants can absorb (the agronomic rate). This policy is imposed by constraining $manrate_r$ to be less than or equal to 1. The effect of EQIP payments can be modeled by adjusting the share of off-farm manure transportation costs borne by EQIP and by adjusting the per-unit subsidy for crops produced in accordance with CAFO application guidelines.

3. Results

3.1 Initial production and manure use

Tables 1 - 3 present the initial levels of production, inputs, nitrogen to soil and air, and emission technologies for three farm-size categories: Concentrated Animal Feeding Operations (CAFOs) defined as having at least 1000 animal units, "medium-scale" operations with between 300-1000 AU, and "small-scale" operations with fewer than 300 AU.[2] Model outcomes are shown for four multi-state production regions: the Eastern Corn Belt (IL, IN, MI, OH, WI); Western Corn Belt (IA, KS, MN, MO, NE, SD); Mid-Atlantic (NC, SC, VA); and South and West (AL, AR, GA, KY, N, CO, OK, UT). The values in the tables are calibrated to the 1998 ARMS survey. Before implementation of the nutrient application standards, all hog manure is applied on-farm to corn, soybean, and other crops, so there are no manure transportation costs and no manure is used off-farm.

CAFOs (table 1) produce about 54% of the nation's hogs, with production concentrated in the Western Corn Belt and Mid-Atlantic regions. Crop production by CAFOs occurs mainly in the Corn Belt regions, with most land under production located in the Western Corn Belt. CAFOs are predominantly livestock operations, and even farms in the Western Corn Belt region - the largest corn producing region, only grow about half the corn they use for feed.

Nationally, CAFOs apply manure nitrogen at 7.4 times the agronomic rate, on average. This very high rate reflects the quantity of manure produced by farms relative to the amount of land on which operators spread manure in 1998. The rate at which manure nitrogen was applied to crops in excess of what they can absorb varied widely across the regions. In the Mid-Atlantic and the South and West regions, hog farmers applied manure at over 16 times the agronomic rate, while farmers in the Corn Belt regions applied manure at 3-4 times the agronomic rate. The more extreme over-application of manure in the Mid-Atlantic, South and West reflects the relative scarcity of available cropland for spreading manure in those regions (Ribaudo, et al, 2003).

Medium-scale hog operations (table 2) produce about 33% of the nation's hogs. Medium-scale producers are more heavily invested in crop production than are CAFOs –

farming in total about 2-3 times as much land. Because of their involvement in crop production, medium-scale hog operations have relatively more land at their disposal and apply manure at an average of only 2.2 times the agronomic rate, significantly lower than the average rate for CAFOs.

Small-scale operations (table 3) produce about 13% of the nations hogs, and consist of a sizeable, but rapidly shrinking, number of farms (McBride and Key, 2002). Small-scale hog farms are heavily invested in crop production, cultivating a total of 20.8 million acres, compared to 7.9 million for medium-scale operations and 3.6 million for CAFOs. On average, small-scale hog farms do not apply manure nitrogen at a rate exceeding what crops can absorb. Only farms in the relatively land-scarce Mid-Atlantic region exceed the agronomic application rate.

Injecting manure into the soil makes more nitrogen available to crops but reduces ammonia nitrogen volatilization and associated odor nuisances. Manure injection is strongly correlated with the scale of the operation - with small-scale operations injecting at an average rate of only 9.6% compared to 25.6% and 19.2% for CAFOs and medium-scale operations, respectively. This pattern may be explained by the high fixed costs associated with manure injection equipment, which may make manure injection uneconomical for small-scale operations. The pattern may also be explained by the fact that larger operations apply manure at higher rates to their fields and would consequently have more severe odor problems than smaller operations if they did not inject their manure.

3.2 Nutrient application standards and EQIP payments

Tables 4 - 6 present the outcomes of the model after nutrient application standards are imposed and EQIP payments are distributed. The EPA application regulations that currently only apply to CAFOs require that farmers adhere to a nutrient balance plan specifying that nutrients are applied to crops at an agronomic rate. Adherence to a nutrient balance plan effectively eliminates excess nitrogen applied to the soil. Here we assume all farms, regardless of scale, must abide by a nutrient balance plan and are eligible to receive EQIP payments.

To conform with nutrient management plans, farms increase the share of their own land on which they apply manure, decrease the share of the land cultivated using chemical fertilizer,

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[2] To classify operations we use the EPA definition, where one animal unit equals 2.5 hogs weighing more than 55 pounds. For calculations requiring conversion to weight gain per year, 1 AU is defined as 5 cwt.

increase exports of manure off-farm, and reduce slightly their output of hogs. Comparing farms of different scales, we find that CAFOs averaged a 1.45% decline in total profits as a result of the nutrient application standards, compared to only a 0.08% decline for medium operations. Because of EQIP payments, small operations actually increased profits by 0.74%. The relatively small declines in total operation profits that result from the policies can be attributed to EQIP payments and to the fact that profits are defined as returns to labor. If profits included labor costs then the cost of a policy, as a share of profits, would be larger.

Because farms have less land available for spreading manure in the Mid-Atlantic and West and South regions, farms in these regions incur a larger increase in manure transportation costs, and consequently a larger decline in profits. Profits for CAFO operations in the Mid-Atlantic and “South and West” regions fall 3.25-3.5% while profits in the Corn Belt regions fall 1.3-1.7%. Profit declines for medium-scale operations are smaller than for CAFOs but follow a similar geographic pattern. Medium-scale farms in the Western Corn belt region actually had a slight increase in profits. Small-scale operations in every region gain from the application standards and payments. Of the small-scale farms, only those in the Mid-Atlantic region apply manure in excess of agronomic rates and therefore face costs from the regulations.

Farmers complying with the application standards receive EQIP payments for land on which they spread manure and for manure transportation costs. EQIP is assumed to pay 50% of the costs of transporting manure off-farm. Farmers respond to the lower effective manure transportation cost by transporting more manure off-farm, and by reducing the substitution between cropland under chemical and manure fertilization regimes. As shown in tables 4-6, the importance of manure transportation subsidies relative to payments for environmental practices depends on region and size. For relatively land-scarce CAFOs, EQIP manure transportation cost payments represent 82% of all EQIP payments, while for medium-scale operations transportation subsidies account for only 52% of payments, and for small operations less than 1% of payments. Relatively land-scarce farms in the Mid-Atlantic and “South and West” regions receive proportionately more EQIP payments for manure transportation compared to for crop production.

Table 7 illustrates how EQIP payments as a share of profits vary according to farm scale and geographic location. Payments as a share of profits are positively correlated with the scale of the operation: EQIP payments equal 2.1%, 1.1% and 0.8% of profits for large, medium, and small operations, respectively. Farmers in the Mid-Atlantic and “South and West” receive disproportionately more EQIP payments than do farmers in the Corn belt regions for all size categories. From the discussion in the previous paragraph, it follows that the distribution of payments across farm-size categories and regions would be more equal if EQIP paid a smaller share of manure transportation costs.

Table 8 shows the reduction in excess soil nitrogen per dollar of EQIP payments. The simulation shows that, on average, there is a greater reduction in excess nitrogen per dollar for medium-scale operations compared to large-scale operations. This is an important finding considering that currently only large operations are subject to EPA soil application standards. Table 8 illustrates that regulating most small-scale operations would not be cost-effective: except for in the Mid-Atlantic region, there would be no environmental benefits from applying the nutrient application standards to small operations.

The methodology used by this study differs substantially from that used in the earlier study by Ribaudo et al (2003). At the farm level, Ribaudo et al estimate the net costs of following a nutrient standard by region and farm size using a modified Fleming model (Fleming et al, 1998). Their approach does not account for EQIP payments nor does it allow for optimal farm-level response in terms of crop allocation, input levels, output levels, or production choices such as injection versus spreading of manure. Nonetheless, the variation across regions in the costs of following nutrient standards presented in Ribaudo et al is similar to the results of this paper: operations in the Mid-Atlantic and South and West regions incur larger cost increases (hog operation profit declines) than do operations in the Corn Belt regions. For the Corn Belt regions Ribaudo et al estimate small declines in net costs associated with imposition of the nutrient standards, while we find small increases in the net costs. This difference can be attributed mainly to different assumptions about parameters in the Fleming model used to compute costs of hauling and applying manure and in computing the benefits from replacing commercial fertilizer with manure nutrients.

4. Conclusions

In 2003 the US Environmental Protection Agency began enforcing nutrient standards for concentrated animal feeding operations. These standards require nutrients from livestock manure to be spread on cropland at a rate not exceeding the agronomic nutrient demand of the crops grown on that land. To help defray compliance costs associated with the EPA regulations, Congress increased funding for the Environmental Quality Incentives Program, made large operations eligible for EQIP payments, and earmarked 60 percent of program funding for practices related to livestock production. EQIP provides technical assistance, cost-share, and incentive payments to defray the costs of implementing conservation practices.

In this study we considered how the costs of complying with nutrient application standards and the associated EQIP payments for conveying manure to agricultural land and applying waste according to a nutrient management plan varied across farm-scale categories and regions. Simulations using a Positive Mathematical Programming model indicated that applying manure standards to farms in all size categories results in a distribution of costs and benefits that favors smaller farmers located in the Corn Belt. Large operations (CAFOs) faced the greatest profit declines as a result of the nutrient application standards. Profit declines for medium-scale operations were about half the relative size experienced by large operations. Small-scale operations actually gained from the regulations, as they were able to collect payments from EQIP for conservation practices they were already employing. Among large and medium operations, those located in the relatively cropland-scarce Mid-Atlantic and South and West regions incurred the greatest cost from the regulations.

Our findings indicate that the recently expanded EQIP payments will not favor large farms at the expense of smaller operations. For CAFOs, compliance costs outweighed benefits from EQIP payments in all regions. Expanding the CAFO nutrient standards to include medium-scale operations (300-1000 AU) would impose additional costs on these farms. However, compared to the pre-policy scenario, medium-scale operations suffer smaller relative losses than do CAFOs. In terms of the distribution of growers' welfare losses from the policies, we find that both scale and regional equity could be improved by shifting subsidy payments towards manure transportation subsidies and away from subsidies for cropping practices.

We also find that expanding CAFO nutrient application standards to operations with 300-1000 AU could achieve cost-effective environmental benefits. We estimate that, on average, there was a greater reduction in excess nitrogen per EQIP dollar for medium-scale operations compared to large-scale operations. This is important considering that currently only CAFOs are subject to EPA soil application standards although, in some states farms with less than 1000 AU are subject to nutrient application standards (Metcalfe, 2000). Medium-scale operations produce about 72,000 tons of excess soil nitrogen – about half of the estimated 138,000 tons produced by CAFOs – implying substantial environmental benefits could be achieved by regulating this sector. Results also indicate that regulating small-scale operations (less than 300 AU) would not be cost-effective as most small-scale operations are currently abiding by nutrient application standards.

This study examined the distributional consequences of manure application standards and EQIP payments across hog farms of different sizes and geographical regions. Future work could extend this analysis to examine how benefits and costs are distributed across farm organizational strategies (contracting versus independent production) and across manure storage and handling technologies (lagoon versus pit storage). Future work might also examine the consequences of hypothetical air ammonia regulations. The effects of these regulations would likely vary substantially across farm sizes and regions as ammonia emissions are correlated with manure storage and handling technologies. Finally, this study analyzed the effect of nutrient application standards assuming full EQIP payments would be available to all farms. It is possible that EQIP might face a decline in federal funding that would restrict payments to farmers, or that farmer enrollment in the program would be less than 100 percent. Future work could examine the distributional consequences of application standards under reduced EQIP payments or reduced enrollment.

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Appendix: Variable Definitions and Sources of Data

Table A1. Initial production, $X0_{ir}$

Outputs	Units	Value	Source
Corn fertilizer	100 bushels	*	USDA ARMS Survey 1998
Corn manure surface	100 bushels	*	USDA ARMS Survey 1998
Corn manure inject	100 bushels	*	USDA ARMS Survey 1998
Soy fertilizer	100 bushels	*	USDA ARMS Survey 1998
Soy manure surface	100 bushels	*	USDA ARMS Survey 1998
Soy manure inject	100 bushels	*	USDA ARMS Survey 1998
Other fertilizer	$ (VOP)	*	USDA ARMS Survey 1998
Other manure surface	$ (VOP)	*	USDA ARMS Survey 1998
Other manure inject	$ (VOP)	*	USDA ARMS Survey 1998
Hogs	CWT.	*	USDA ARMS Survey 1998

* Estimated mean value varies by region and size of operation

Table A2. Output price, P_{ir}

Outputs	Units	Value	Source
Corn (all)	$/100 bushels	284	NASS – (average price 1997-99)
Soy (all)	$/100 bushels	700	NASS – (average price 1997-99)
Other (all)	-	1	-
Hogs	$/cwt.	46.92	NASS –(average price 1997-99)

Table A3. Input price, W_{jr}

Inputs	Units	Value	Source
Land	$/acre	68.2	NASS Agricultural Land Values Final Estimates 1998, Statistical Bulletin Number 957 (national average) (use 7% of land value as rental rate)
Capital	$	1	(by definition)
Feeder Pigs	$/cwt	80.25	NASS – (average price 1997-99)
Feed Corn	$/100 bushels	284	same as corn
Feed Soy	$/100 bushels	700	same as soy
Fertilizer - N	$/lb.	0.185	NRCS (and ERS, AER 824, p.35)

Table A4. Resource Use, A_{ijr}

Input-output	Units	Value	Source
Land-corn	acres/100 bushels	*	USDA ARMS Survey 1998
Land-soy	acres/100 bushels	*	USDA ARMS Survey 1998
Land-other	acres/$	*	USDA ARMS Survey 1998
Capital-corn	$/100 bushels	49.3	ERS Statistical Bulletin 974
Capital-soy	$/100 bushels	127	ERS Statistical Bulletin 974-4
Capital-other	Share of value	0.17	Same rate as corn
Capital-hogs	$/CWT.	*	USDA ARMS Survey 1998
Feed corn-hogs	100 bushels /CWT.	*	USDA ARMS Survey 1998
Feed soy-hogs	100 bushels /CWT.	*	USDA ARMS Survey 1998
Feeder pigs-hogs	CWT/CWT	*	USDA ARMS Survey 1998
Fertilizer-N-corn	lbs./ 100 bushels	80.0	Manure application standard, Kellogg, R.L., C.H. Lander, D. Moffitt, and N. Gollehon. 2000.
Fertilizer-N-soy	lbs./ 100 bushels	236.7	“”
Fertilizer-N-other	lbs./ $	0.282	Same rate as corn

* Estimated mean value varies by region and size of operation

Table A5. Manure off-farm transportation net costs ($/CWT hog) by region and manure storage and handling technology, T_{re}

Manure Storage	Storage or Handling Technology	Eastern Cornbelt	Western Cornbelt	Mid-Atlantic	South and West
Lagoon	Uncover	1.33	1.36	2.01	2.15
	Cover	5.32	5.38	6.57	6.83
Pit	Surface	1.20	1.25	2.29	2.53
	Inject	1.61	1.66	2.82	3.08

Source: Estimated. Base manure handling costs from Fleming et al. 1998. Unit mile cost from USDA, NRCS, 2003 *Costs Associated with Development and Implementation of Comprehensive Nutrient management Plans*. Lagoon cover costs from Massey, et al. *Agronomic and economic impacts of lagoon based swine operations complying with the proposed EPA zero discharge rule*.

Table A6. Nitrogen available to crops and nitrogen ammonia emissions by manure storage and handling technology

Manure Storage	Storage or Handling Technology	Soil Nitrogen available to plants, $Npercwt_e$ (lbs/CWT)	Air ammonia emissions from house and storage (lbs/CWT)	Air ammonia emissions from land application (lbs/CWT)	Total air ammonia emissions, AmN_e (lbs/CWT)
Lagoon	Uncover	1.53	7.21	0.42	7.62
	Cover	5.07	2.69	1.39	4.08
Pit	Surface	4.83	3.00	1.32	4.32
	Inject	5.95	3.00	0.20	3.20

Source: US EPA *National Emission Inventory-Ammonia Emission from Animal Husbandry Operations*, 2004.

Table A7. EQIP payments per unit of output by crop and region

Crop	Unit	Eastern Cornbelt	Western Cornbelt	Mid-Atlantic	South and West
Corn	$/100 bu	8.87	8.28	53.00	49.70
Soybean	$/100 bu	27.44	24.44	85.62	86.92
Other	Share of value	0.05	0.11	0.13	0.17

Source: Estimated using EQIP program data, Farm Service Agency, USDA

Table 1. Production, Inputs, Nitrogen to Soil and Air, and Emission Technology – Concentrated Animal Feeding Operations (1000+ AU)

	Eastern Corn Belt	Western Corn Belt	Mid-Atlantic	South and West	U.S.
Hogs (mil. cwt.)	20.17	48.72	36.41	13.86	119.16
Corn – chem. fertilizer (mil. bu.)	42.19	61.09	2.06	0.80	106.14
Corn – manure spread (mil. bu.)	9.30	48.05	1.28	0.35	58.97
Corn – manure inject (mil. bu.)	16.39	15.85	0.00	0.01	32.26
Soybean – chem. fertilizer (mil. bu.)	14.01	31.25	2.29	0.35	47.91
Soybean – manure spread (mil. bu.)	0.29	4.57	0.26	0.07	5.19
Soybean – manure inject (mil. bu.)	0.50	0.02	0.00	0.01	0.54
Other – chem. fertilizer (mil. $.)	22.53	39.91	23.63	11.96	98.02
Other – manure spread (mil. $.)	0.23	0.46	7.90	2.81	11.39
Other – manure inject (mil. $.)	0.20	4.13	0.00	2.93	7.25
Land (mil. acres)	0.93	2.01	0.39	0.25	3.58
Capital (mil. $)	236	454	289	137	1116
Feeder pigs (million cwt.)	0.89	7.63	6.28	1.79	16.60
Feed corn (mil. bu.)	124.66	258.91	212.81	75.17	671.55
Feed soybean (mil. bu.)	16.53	34.33	28.22	9.97	89.05
Chemical nitrogen (1000 tons)	37	67	7	2	113
Revenue (mil. $)	1266	2937	1767	674	6645
Input costs (mil. $)	452	1225	819	292	2788
Total profits (mil. $)	814	1712	948	383	3857
Hog operation profits (mil. $)	585	1321	915	370	3191
EQIP payments - crops (mil. $)	0.0	0.0	0.0	0.0	0.0
EQIP payments – trans. (mil. $)	0.0	0.0	0.0	0.0	0.0
EQIP payments – total (mil. $)	0.0	0.0	0.0	0.0	0.0
Ammonia N – total (1000 tons)	46.3	132.6	136.4	46.1	361.4
Excess N - soil (1000 tons)	34.7	58.6	28.2	16.3	137.9
Rate (factor of agronomic rate)	4.11	2.75	16.32	16.16	7.37
Manure transport. costs (mil. $)	0.0	0.0	0.0	0.0	0.0
Manure N on-farm (1000 tons)	46.0	90.3	30.2	17.3	183.8
Manure N off-farm (1000 tons)	0.0	0.0	0.0	0.0	0.0
Cover (%)	0.00	0.00	0.00	0.00	0.00
Inject (%)	56.70	22.29	0.45	34.82	25.56

Table 2. Production, Inputs, Nitrogen to Soil and Air, and Emission Technology – Medium-Scale Operations (300-1000 AU)

	Eastern Corn Belt	Western Corn Belt	Mid-Atlantic	South and West	U.S.
Hogs (mil. cwt.)	15.59	48.55	4.40	3.69	72.23
Corn – chem. fertilizer (mil. bu.)	98.20	183.49	0.53	15.80	298.01
Corn – manure spread (mil. bu.)	23.26	96.50	0.55	3.94	124.24
Corn – manure inject (mil. bu.)	15.12	19.28	0.00	0.41	34.81
Soybean – chem. fertilizer (mil. bu.)	37.64	78.82	0.90	4.00	121.36
Soybean – manure spread (mil. bu.)	0.62	3.27	0.06	0.01	3.95
Soybean – manure inject (mil. bu.)	0.51	1.40	0.00	0.00	1.92
Other – chem. fertilizer (mil. $.)	83.03	216.46	8.22	31.52	339.23
Other – manure spread (mil. $.)	1.94	19.58	1.30	0.80	23.61
Other – manure inject (mil. $.)	0.11	1.48	0.00	0.06	1.65
Land (mil. acres)	2.13	5.08	0.12	0.59	7.92
Capital (mil. $)	312	810	64	81	1266
Feeder pigs (million cwt.)	1.05	5.25	0.46	0.13	6.90
Feed corn (mil. bu.)	98.05	315.31	29.36	23.10	465.83
Feed soybean (mil. bu.)	13.00	41.81	3.89	3.06	61.77
Chemical nitrogen (1000 tons)	96	197	2	16	311
Revenue (mil. $)	1477	3953	226	291	5947
Input costs (mil. $)	515	1567	111	118	2311
Total profits (mil. $)	962	2386	115	173	3636
Hog operation profits (mil. $)	414	1214	103	94	1825
EQIP payments - crops (mil. $)	0.0	0.0	0.0	0.0	0.0
EQIP payments – trans. (mil. $)	0.0	0.0	0.0	0.0	0.0
EQIP payments – total (mil. $)	0.0	0.0	0.0	0.0	0.0
Ammonia N – total (1000 tons)	33.2	122.5	16.6	11.6	184.0
Excess N - soil (1000 tons)	21.1	44.8	3.1	3.4	72.3
Rate (factor of agronomic rate)	2.21	1.79	7.49	3.16	2.20
Manure transport. costs (mil. $)	0.0	0.0	0.0	0.0	0.0
Manure N on-farm (1000 tons)	38.1	99.6	3.5	5.2	146.4
Manure N off-farm (1000 tons)	0.0	0.0	0.0	0.0	0.0
Cover (%)	0.00	0.00	0.00	0.00	0.00
Inject (%)	38.11	15.86	0.04	4.76	19.21

Table 3. Production, Inputs, Nitrogen to Soil and Air, and Emission Technology – Small-Scale Operations (<300 AU)

	Eastern Corn Belt	Western Corn Belt	Mid-Atlantic	South and West	U.S.
Hogs (mil. cwt.)	8.42	17.84	0.45	1.84	28.54
Corn – chem. fertilizer (mil. bu.)	193.60	426.58	0.81	18.17	639.16
Corn – manure spread (mil. bu.)	44.73	137.68	0.10	3.18	185.68
Corn – manure inject (mil. bu.)	10.86	15.25	0.01	0.03	26.14
Soybean – chem. fertilizer (mil. bu.)	59.95	142.05	0.77	5.51	208.28
Soybean – manure spread (mil. bu.)	2.43	8.30	0.02	0.19	10.94
Soybean – manure inject (mil. bu.)	0.02	0.49	0.01	0.03	0.55
Other – chem. fertilizer (mil. $.)	291.63	935.35	13.26	191.75	1432.00
Other – manure spread (mil. $.)	8.79	75.92	0.85	10.57	96.13
Other – manure inject (mil. $.)	0.00	0.00	0.00	0.00	0.00
Land (mil. acres)	5.20	13.27	0.19	2.14	20.81
Capital (mil. $)	495	1182	25	125	1827
Feeder pigs (million cwt.)	0.52	0.88	0.02	0.04	1.46
Feed corn (mil. bu.)	70.46	143.90	3.65	15.84	233.86
Feed soybean (mil. bu.)	9.34	19.08	0.48	2.10	31.01
Chemical nitrogen (1000 tons)	190	471	3	41	704
Revenue (mil. $)	1843	4556	43	390	6831
Input costs (mil. $)	611	1526	22	173	2331
Total profits (mil. $)	1231	3030	22	217	4500
Hog operation profits (mil. $)	198	419	10	43	670
EQIP payments - crops (mil. $)	0.0	0.0	0.0	0.0	0.0
EQIP payments – trans. (mil. $)	0.0	0.0	0.0	0.0	0.0
EQIP payments – total (mil. $)	0.0	0.0	0.0	0.0	0.0
Ammonia N – total (1000 tons)	19.5	40.7	1.6	5.7	67.5
Excess N - soil (1000 tons)	0.0	0.0	0.3	0.0	0.3
Rate (factor of agronomic rate)	0.76	0.50	2.41	0.90	0.66
Manure transport. costs (mil. $)	0.0	0.0	0.0	0.0	0.0
Manure N on-farm (1000 tons)	19.1	40.9	0.5	2.7	63.1
Manure N off-farm (1000 tons)	0.0	0.0	0.0	0.0	0.0
Cover (%)	0.00	0.00	0.00	0.00	0.00
Inject (%)	17.77	7.17	7.06	1.88	9.58

Table 4. Nutrient Application Standards and EQIP Payments – Concentrated Animal Feeding Operations (1000+ AU)

	Eastern Corn Belt		Western Corn Belt		Mid-Atlantic		South and West		U.S.	
		% chg.		% chg.		% chg.		% chg.		% chg.
Hogs (mil. cwt.)	20.14	-0.12	48.47	-0.52	36.41	0.00	13.86	0.00	118.88	-0.23
Corn – chem. fertilizer (mil. bu.)	42.64	1.07	60.93	-0.25	1.73	-15.86	0.74	-7.80	106.04	-0.09
Corn – manure spread (mil. bu.)	9.73	4.72	52.16	8.56	1.59	24.09	0.45	28.02	63.93	8.40
Corn – manure inject (mil. bu.)	16.38	-0.06	16.20	2.24	0.00	-86.40	0.02	11.30	32.60	1.07
Soybean – chem. fertilizer (mil. bu.)	14.09	0.55	31.10	-0.49	2.17	-4.98	0.33	-5.97	47.69	-0.44
Soybean – manure spread (mil. bu.)	0.31	5.48	5.01	9.61	0.33	27.97	0.09	27.04	5.73	10.52
Soybean – manure inject (mil. bu.)	0.50	-0.41	0.02	3.00	0.00	-53.90	0.02	8.80	0.53	-0.56
Other – chem. fertilizer (mil. $.)	20.60	-8.55	35.70	-10.56	22.11	-6.42	10.82	-9.49	89.23	-8.97
Other – manure spread (mil. $.)	0.23	1.31	0.52	12.87	9.81	24.19	3.56	26.90	14.12	23.94
Other – manure inject (mil. $.)	0.19	-3.85	3.96	-3.93	0.00	-56.70	3.22	10.12	7.38	1.74
Land (mil. acres)	0.93	0.00	2.01	0.00	0.39	0.00	0.25	0.00	3.58	0.00
Capital (mil. $)	235.80	0.00	454.33	0.00	289.23	0.00	136.56	0.00	1115.93	0.00
Feeder pigs (million cwt.)	0.89	-0.12	7.59	-0.52	6.28	0.00	1.79	0.00	16.56	-0.24
Feed corn (mil. bu.)	124.51	-0.12	257.57	-0.52	212.81	0.00	75.17	0.00	670.05	-0.22
Feed soybean (mil. bu.)	16.51	-0.12	34.16	-0.52	28.22	0.00	9.97	0.00	88.85	-0.22
Chemical nitrogen (1000 tons)	37	0.00	66	-1.25	6	-6.98	2	-8.66	111	-1.35
Revenue (mil. $)	1269	0.21	2943	0.19	1770	0.14	676	0.22	6657	0.18
Input costs (mil. $)	452	0.03	1225	-0.07	819	0.07	292	0.08	2788	0.00
Total profits (mil. $)	807	-0.85	1703	-0.55	921	-2.93	371	-3.10	3801	-1.45
Hog operation profits (mil. $)	575	-1.66	1303	-1.34	885	-3.24	357	-3.53	3121	-2.20
EQIP payments - crops (mil. $)	2.6	-	7.4	-	2.4	-	1.5	-	13.8	-
EQIP payments – trans. (mil. $)	9.44	-	15.81	-	29.66	-	13.08	-	67.98	-
EQIP payments – total (mil. $)	12.00	-	23.17	-	32.03	-	14.55	-	81.74	-
Ammonia N – total (1000 tons)	46.3	0.05	132.1	-0.43	136.5	0.04	46.1	0.06	360.9	-0.13
Excess N - soil (1000 tons)	0.0	-100.00	0.0	-100.00	0.0	-100.00	0.0	-100.00	0.0	-100.00
Rate (factor of agronomic rate)	1.00	-75.68	1.00	-63.63	1.00	-93.87	1.00	-93.81	1.00	-86.42
Manure transport. costs (mil. $)	18.9	-	31.6	-	59.3	-	26.2	-	136.0	-
Manure N on-farm (1000 tons)	11.5	-75.08	33.9	-62.42	2.4	-92.00	1.3	-92.72	49.1	-73.30
Manure N off-farm (1000 tons)	34.4	-	55.8	-	27.7	-	16.0	-	133.9	-
Cover (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inject (%)	55.88	-1.45	21.56	-3.27	0.15	-67.86	34.24	-1.65	24.92	-2.48

Table 5. Nutrient Application Standards and EQIP Payments – Medium-Scale Operations (300-1000 AU)

	Eastern Corn Belt		Western Corn Belt		Mid-Atlantic		South and West		U.S.	
		% chg.		% chg.		% chg.		% chg.		% chg.
Hogs (mil. cwt.)	15.57	-0.12	48.39	-0.33	4.32	-1.90	3.68	-0.17	71.97	-0.37
Corn – chem. fertilizer (mil. bu.)	98.93	0.75	185.24	0.96	0.47	-10.75	15.61	-1.19	300.25	0.75
Corn – manure spread (mil. bu.)	23.76	2.16	99.62	3.23	0.56	2.72	4.63	17.53	128.57	3.49
Corn – manure inject (mil. bu.)	15.05	-0.45	19.43	0.79	0.00	5.07	0.47	14.08	34.95	0.41
Soybean – chem. fertilizer (mil. bu.)	37.82	0.48	80.01	1.51	0.95	5.57	4.09	2.19	122.87	1.25
Soybean – manure spread (mil. bu.)	0.64	2.81	3.41	4.43	0.06	9.87	0.01	19.76	4.12	4.30
Soybean – manure inject (mil. bu.)	0.51	-0.90	1.42	0.93	0.00	6.35	0.00	17.00	1.93	0.47
Other – chem. fertilizer (mil. $.)	79.43	-4.33	201.47	-6.92	7.96	-3.16	29.70	-5.79	318.56	-6.09
Other – manure spread (mil. $.)	1.95	0.97	19.93	1.79	1.37	5.33	0.92	15.48	24.17	2.38
Other – manure inject (mil. $.)	0.11	-3.11	1.46	-1.57	0.00	5.38	0.07	15.93	1.64	-1.02
Land (mil. acres)	2.13	0.00	5.08	0.00	0.12	0.00	0.59	0.00	7.92	0.00
Capital (mil. $)	311.54	0.00	809.59	0.00	63.20	-1.77	80.70	0.00	1265.03	-0.09
Feeder pigs (million cwt.)	1.05	-0.12	5.23	-0.33	0.46	-1.90	0.13	-0.17	6.87	-0.40
Feed corn (mil. bu.)	97.94	-0.12	314.27	-0.33	28.80	-1.90	23.06	-0.17	464.07	-0.38
Feed soybean (mil. bu.)	12.99	-0.12	41.68	-0.33	3.82	-1.90	3.06	-0.17	61.54	-0.38
Chemical nitrogen (1000 tons)	96	0.00	197	0.00	2	0.00	15	-1.47	310	-0.07
Revenue (mil. $)	1481	0.28	3968	0.37	223	-1.48	293	0.57	5964	0.29
Input costs (mil. $)	515	0.06	1569	0.14	107	-3.40	118	0.38	2310	-0.04
Total profits (mil. $)	962	-0.07	2388	0.08	112	-2.49	172	-0.62	3634	-0.08
Hog operation profits (mil. $)	409	-1.13	1202	-0.93	100	-3.22	92	-2.44	1803	-1.18
EQIP payments - crops (mil. $)	3.9	-	13.2	-	0.5	-	1.4	-	19.0	-
EQIP payments – trans. (mil. $)	4.57	-	10.80	-	3.29	-	2.27	-	20.94	-
EQIP payments – total (mil. $)	8.47	-	23.99	-	3.79	-	3.68	-	39.93	-
Ammonia N – total (1000 tons)	33.2	0.05	122.2	-0.31	16.3	-1.89	11.6	-0.15	183.3	-0.38
Excess N - soil (1000 tons)	0.0	-100.00	0.0	-100.00	0.0	-100.00	0.0	-100.00	0.0	-100.00
Rate (factor of agronomic rate)	1.00	-54.83	1.00	-44.06	1.00	-86.65	1.00	-68.33	1.00	-54.50
Manure transport. costs (mil. $)	9.1	-	21.6	-	6.6	-	4.5	-	41.9	-
Manure N on-farm (1000 tons)	17.2	-54.95	56.4	-43.40	0.5	-86.06	2.2	-58.06	76.2	-47.96
Manure N off-farm (1000 tons)	20.8	-	42.9	-	3.0	-	3.0	-	69.7	-
Cover (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inject (%)	37.48	-1.65	15.70	-1.02	0.04	0.00	4.65	-2.36	18.96	-1.30

Table 6. Nutrient Application Standards and EQIP Payments – Small-Scale Operations (<300 AU)

	Eastern Corn Belt		Western Corn Belt		Mid-Atlantic		South and West		U.S.	
		% chg.		% chg.		% chg.		% chg.		% chg.
Hogs (mil. cwt.)	8.42	0.00	17.84	0.00	0.44	-1.93	1.84	0.00	28.54	-0.03
Corn – chem. fertilizer (mil. bu.)	193.68	0.04	429.00	0.57	0.81	0.00	17.93	-1.32	641.42	0.35
Corn – manure spread (mil. bu.)	45.47	1.67	139.45	1.29	0.14	40.37	3.70	16.24	188.75	1.65
Corn – manure inject (mil. bu.)	11.00	1.32	15.43	1.23	0.01	32.61	0.04	16.00	26.48	1.29
Soybean – chem. fertilizer (mil. bu.)	60.42	0.79	143.19	0.81	0.77	0.00	5.44	-1.43	209.82	0.74
Soybean – manure spread (mil. bu.)	2.51	3.09	8.43	1.55	0.03	38.60	0.23	17.70	11.19	2.25
Soybean – manure inject (mil. bu.)	0.02	0.00	0.49	1.41	0.01	27.00	0.04	18.00	0.56	2.63
Other – chem. fertilizer (mil. $.)	286.37	-1.80	918.86	-1.76	13.26	0.00	189.77	-1.03	1408.27	-1.66
Other – manure spread (mil. $.)	8.98	2.14	77.50	2.08	1.03	20.13	11.92	12.80	99.42	3.42
Other – manure inject (mil. $.)	0.00	2.00	0.00	2.00	0.00	16.00	0.00	13.00	0.00	3.18
Land (mil. acres)	5.20	0.00	13.27	0.00	0.19	1.92	2.14	0.00	20.81	0.02
Capital (mil. $)	495.26	0.06	1182.91	0.11	24.91	-1.38	125.19	-0.01	1828.27	0.07
Feeder pigs (million cwt.)	0.52	0.00	0.88	0.00	0.02	-1.93	0.04	0.00	1.46	-0.03
Feed corn (mil. bu.)	70.46	0.00	143.90	0.00	3.58	-1.92	15.84	0.00	233.79	-0.03
Feed soybean (mil. bu.)	9.34	0.00	19.08	0.00	0.47	-1.92	2.10	0.00	31.00	-0.03
Chemical nitrogen (1000 tons)	189	-0.08	471	0.00	3	0.00	40	-1.15	703	-0.09
Revenue (mil. $)	1852	0.49	4585	0.65	44	0.59	393	0.82	6873	0.62
Input costs (mil. $)	613	0.26	1533	0.44	22	0.07	173	0.06	2340	0.36
Total profits (mil. $)	1239	0.61	3052	0.75	22	0.07	220	1.41	4533	0.74
Hog operation profits (mil. $)	198	0.00	419	0.00	10	-2.19	43	0.00	669	-0.03
EQIP payments - crops (mil. $)	7.6	-	23.0	-	0.3	-	3.3	-	34.1	-
EQIP payments – trans. (mil. $)	0.00	-	0.00	-	0.23	-	0.00	-	0.23	-
EQIP payments – total (mil. $)	7.60	-	22.97	-	0.53	-	3.28	-	34.37	-
Ammonia N – total (1000 tons)	19.5	0.00	40.7	0.00	1.5	-1.92	5.7	0.00	67.4	-0.04
Excess N - soil (1000 tons)	0	0	0	0	0.0	-100.00	0	0	0	-100.00
Rate (factor of agronomic rate)	0.75	-1.42	0.49	-1.49	1.00	-58.58	0.78	-12.86	0.61	-8.18
Manure transport. costs (mil. $)	0.0	-	0.0	-	0.5	-	0.0	-	0.5	-
Manure N on-farm (1000 tons)	19.1	0.00	40.9	0.00	0.2	-46.57	2.7	0.01	62.9	-0.34
Manure N off-farm (1000 tons)	0.0	-	0.0	-	0.2	-	0.0	-	0.2	-
Cover (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inject (%)	17.77	0.00	7.17	0.00	7.25	2.70	1.88	0.00	9.58	0.05

Table 7. EQIP Payments as a Percent of Profits by Farm Size and Region

	Eastern Corn Belt	Western Corn Belt	Mid-Atlantic	South and West	U.S.
CAFOs (>1000 AU)	1.47	1.35	3.38	3.80	2.12
Medium-Scale (300-1000 AU)	0.88	1.01	3.30	2.12	1.10
Small-Scale (<300 AU)	0.62	0.76	2.43	1.51	0.76

Table 8. Reduction in Pounds of Excess Soil Nitrogen per Dollar of EQIP Payments by Farm Size and Region

	Eastern Corn Belt	Western Corn Belt	Mid-Atlantic	South and West	U.S.
CAFOs (>1000 AU)	2.89	2.53	0.88	1.12	1.69
Medium-Scale (300-1000 AU)	2.50	1.87	0.81	0.91	1.81
Small-Scale (<300 AU)	0	0	0.51	0	0.01