Prevention versus Utilization of Excess Nutrients from Animal Feeding Operations: The Case of Managing Nutrient Uncertainty*

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Abstract

Nutrients are a major source of water quality impairment. This paper compares efficient use of nutrients in a wholly owned animal-crop production system versus an integrator-operator animal-crop production system and highlights the operator's tradeoff between prevention and utilization of excreted nutrients under conditions of uncertainty. Results derived from the comparison of different production systems are used to infer the consequences of implementation of nutrient land application restrictions, a key element in the recently drafted United States Department of Agriculture and United States Environmental Protection Agency Unified Strategy for Animal Feeding Operations.

Key words: Animal agriculture, integrator, manure management, margin of safety, water quality

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Introduction:

Nutrients are a major source of water quality impairment. Recently, political attention has focused on large confined animal feeding operations as a major source of nutrients, primarily the nutrients found in animal waste. To reduce nutrient loading from confined livestock and poultry farms the United States Department of Agriculture and United States Environmental Protection Agency drafted the Unified Strategy for Animal Feeding Operations. Although still in the review process, the "Unified Strategy" could require confined animal feeding operators to account for generated nutrients from their operation and limits the amount of land-applied nutrients to "optimal" agronomic rates. In several livestock regions of the United States, animal nutrients are generated by animal feeding operations in excess of those needed to land apply at optimal agronomic rates. If these excess nutrients are not properly managed, they may enter surface or ground water and degrade water quality.

In this paper, we compare the profit maximizing decisions of a wholly owned animal-crop production system versus an integrator-operator system in which an integrator supplies feed and animals and the operator has sole responsibility for the excreted waste. It is assumed that the contracting arrangement between the integrator and the operator does not incorporate the waste management costs into the contract.[1] The relevance of this analysis stems from the growing concern over the increased concentration of the livestock industry and the hog industry in particular (Martinez 1999). If, for a given operation, total cropland does not change and with increased concentration more animals are raised, then less land will be available for land application thus tipping the nutrient balance toward "excess" nutrient application. The Unified Strategy would limit this excessive application.

[1] Other USDA Economic Research Service (ERS) researchers are also investigating animal waste management issues. Aillery et al. develops a regional model to assess waste management options for the Chesapeake Bay Watershed. Huang, Magleby and Somwaru analyze the impact of the Unified Strategy on hog farmers in the Heartland who maximize net returns from crop production. The analysis in this paper differs from the Huang, Magleby and Somwaru by focusing on the tradeoff between prevention and utilization, as well as highlighting the role of joint production, contracting and nutrient uncertainty in the decision making process. The examination of the integrator-operator (contracting) system in this paper also complements ERS research that focuses on the role contracting plays in hog farm productivity (Key and McBride).

This paper focuses on the tradeoff between preventing nutrients from entering the production stream versus utilizing the nutrients once they have reached the end of the animal production component as a means by which the operator can reduce the waste management cost. The operator's available options are grouped into two categories: prevention and utilization. Reductions of nutrients in animal waste can be prevented by altering feed rations or by instituting a phased feeding routine, which matches the nutrient content of the feed to the nutrient requirement for a given age and weight of the animal. In the analysis that follows, only feed ration alterations are considered. Utilization measures involve relocating excess nutrients off the operator-owned land in such a way that they will not degrade water quality elsewhere.

Once off the feeding operation the animal waste containing the excess nutrients may be applied to cropland, composted, pelletized for use as a fertilizer or converted to bio-fuel. Again, we limit the available options to only land application and assume that the operator leases the land thus avoiding the complications that arise when trading animal waste between operators. These simplifying assumptions do not alter the qualitative result and allow the analysis to clearly focus on the issue of trading off prevention and utilization measures to satisfy the regulator's land application constraint (the regulator's problem will be described below). Past research has examined the economic costs and benefits of altering feed rations (Bosch, Zhu and Kornegay 1996, Bosch, Zhu and Kornegay 1997; Honeyman 1993; Boland, Foster and Preckel 1999; Boland, Preckel and Foster 1998; Parker 2001). As discussed below, we enhance the fed ration allocation problem by incorporating uncertainty about the nutrient content of the feed ration. Chen (1973) first examined the role of nutrient uncertainty in optimal feed rationing.

Figure 1 depicts the animal-crop production stream. The nutrients are introduced into the production stream through the feed rations. If the animals are grown under contract, then it is assumed that the integrator, the supplier of feed and animals to the operator, does not bear the waste management cost, a downstream pecuniary externality, that results from excess nutrients in the animal waste. The operator bears the cost and the only option available in this integrated system is for the operator to apply the nutrients over additional acreage. Under a contracting regime, the downstream recipient of the waste, the operator, may choose to enter an agreement where by the liability of the nutrient in the stream are jointly held by the integrator and the operator thereby internalizing the externality. In actuality, co-permitting has been discussed as a provision of the Unified Strategy. We will see in the theoretical and empirical sections of this paper that the unencumbered integrator mixes feed rations in such a way that fewer nutrients can be found in the generated animal waste.[2]

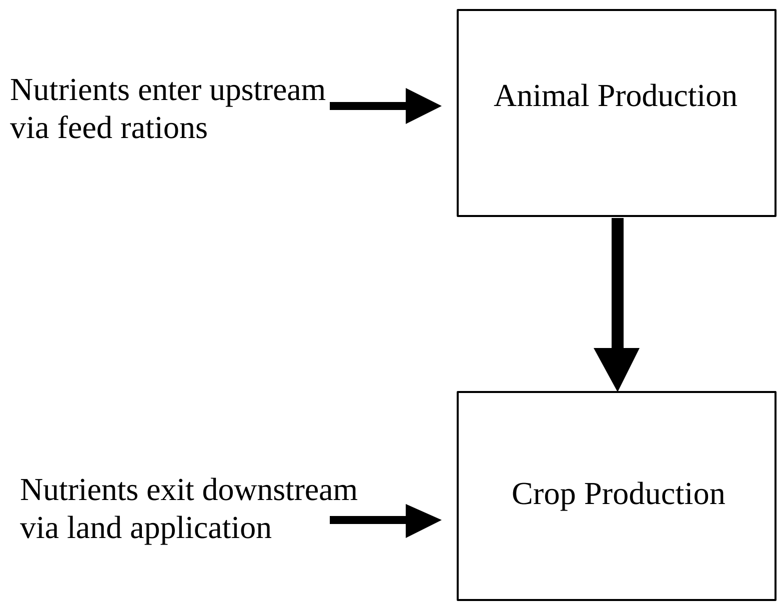

Figure 1. Flow of Nutrients through Integrated Animal-Crop Production System

The operator's problem is complicated by the fact that the nutrients contained in the feed rations or in the animal waste are not known with full certainty. As noted in Chen (1973), relying on the expected quantity of the nutrients in the feed ration will fall short fifty percent of the time. We assume that the integrator or operator in the wholly owned system wishes to meet the nutrient requirements of the animal more often than fifty percent of the time. Chen's analyzes on protein content presents data on different feed ingredients with the standard deviation that vary from 1.28 to 0.20. From the data used in the empirical analysis of this paper we see that the standard deviations for phosphorus and nitrogen

[2] Sunding and Zilberman (1998) conclude that a life-cycle approach to product liability may increase efficiency over single assignment liability. However, their research suggests that no liability may result in a more efficient use of the polluting input. Walls and Palmer (2001) also provide a life-cycle assessment of externalities and waste production. These authors examine social optimal policies primarily taxes, which in a sense is a method for

concentrations in manure vary from 0.868 and 1.755 respectively and correspond to expected values of 2.087 and 3.852 pounds per ton of manure.

Because the operator faces uncertainty associated with the nutrient content of the feed ration and the animal waste, probabilistic constraints on the objective function are imposed such that the operator meets the nutrient requirements of the animal and the crop being planted with a margin of safety. The concept of a margin of safety allows the operator, in principle, to minimize the probability that the realized quantity of nutrients in the feed ration or the animal waste is less than the necessary quantity for optimal animal or plant growth. Van Kooten, Young and Krautkraemer (1997), apply a similar approach to the problem of dynamic cropping decisions. This model allows us to investigate the role of uncertainty associated with the nutrient requirements for "optimal" animal and plant growth when deciding between prevention and utilization options.

The imposition of a land application restriction further complicates the operator's decision making process. The regulator in this analysis seeks to minimize the "over-application" of nutrients so that water quality improvements can be realized. The regulator understands that there is uncertainty in the nutrients that are land applied and so applies a margin of safety approach to restricting land applications. The operator, under this type of regulatory regime, shall not exceed an upper limit on nutrient application within an arbitrary set frequency. In other words, the probability that the nutrient application exceeds the upper limit of the assimilative capacity of the crop and land characteristics shall be arbitrarily small.

The theoretical and empirical work on nutrient use, whether it is nutrient content of feed rations or fertilizer use in crop production, has provided explanations for why observed levels of nutrient use differ from recommended levels. Risk preferences and uncertainty are commonly used as explanations for the observed "over-application." In the analysis that follows it is shown that joint production systems can also result in greater levels of nutrient use in feed rations. The same cannot be said for crop production. For crop production to result in greater nutrient use the producer must face a self-imposed minimum

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spreading liability. This will depend on the market structure since the incidence of the tax will depend on the structure.

nutrient constraint on land application. It is also shown that uncertainty, via a probabilistic constraint on nutrient content, produces the “apparent” excess levels of nutrients. In the analysis the operator is assumed to be risk neutral and thus the findings from this paper avoid explaining away the excessive application of nutrients as a result of risk aversion.

The previous research on livestock feeding operations has been extensive. Unfortunately, few have focused on a systems approach as applied in this analysis (see Roka and Hoag 1996; Hoag and Roka 1995; and Schnitkey and Miranda 1993, for exceptions). We explore a more rigorous treatment, however, incorporating probabilistic constraints where the uncertainty about the nutrient content is applied to both feeding rations and crop production. Also, we incorporate a probabilistic constraint as a regulator choice, which follows from the work of Lichtenberg and Zilberman (1988) on controlling environmental risks.[3]

In the analysis, profit-maximizing operators of animal-crop production systems are evaluated. While exploring the decision making process of these operators certain assumptions are made to simplify the presentation and focus attention on the economic tradeoffs between prevention and utilization. These assumptions include fixing the number of animals and thus the capital expenditures on buildings and waste storage, raised by the operation. This assumption renders this analysis as a short run examination and, although in the long run decisions on the number of animals and capital expenditures are crucial to understanding the evolution of the livestock industry in response to the Strategy, the tradeoff between prevention and utilization is primarily a short run problem. Second, we assume the cultivated crop is fixed. Crop production is not typically limited to a single crop and some crops may be more desirable from the stand point that they uptake a greater quantity of nutrients. Nonetheless, in most instances there are only a few dominant crop options.

In the empirical analysis, we test the implications of the theoretical model, where we examine the role production systems and land holdings play in efficient nutrient use and the imposition of downstream

[3] The theoretical work posited by Lichtenberg and Zilberman originated with the work of Charnes and Cooper who developed chance constraint optimization and Kataoka’s work on stochastic programming. For empirical applications of this margin of safety approach see Lichtenberg, Zilberman and Bogen, and Harper and Zilberman for

externalities. In addition, the cost to hog operators from complying with the Unified Strategy given the inability of the operator to satisfy a desired level of safety in meeting nutrient requirements of the animals and crops grown is evaluated. The data used in the empirical analysis comes from a national survey conducted for the 1998 USDA Hogs Production Practices and Costs and Returns Report under the 1998 USDA Agricultural Resource Management Study Phase III.

In the following section the theoretical model is presented. Three separate scenarios are depicted, highlighting the importance of uncertainty in the operator's decision to adopt prevention measures versus utilization measures for handling nutrients in the production stream. Section 3 details the empirical analysis, including a brief description of the data, the empirical models and results. Section 4 concludes.

Theoretical Model:

Three models are presented that highlight the efficient use of nutrients in an animal-crop production system. In these models it is assumed that the operator considers the nutrients contained in the manure as a viable alternative to chemical fertilizers. First, the case of nutrient certainty is presented. It can be shown from this first model that an operator who simply raises hogs will use fewer nutrients in the feed ration than an operation with joint animal and crop production. This hog-only operation serves as a proxy for the integrator-operator system, where it is assumed that the integrator hires the operator to feed and house the hogs and all animal waste decisions are the sole responsibility of the operator. In other words, this integrator-operator system does not internalize the costs or benefits from the nutrients introduced into the production stream via the feeding rations. In the second model uncertainty is introduced by imposing two probabilistic constraints on the profit maximizing objective function. Here we see how the uncertainty associated with feed rations and manure nutrient content affect the manager's allocation decisions. With this second model we can infer that uncertainty about the nutrient content will result in greater nutrient use in the feeding ration and greater overall levels of fertilizer use to supplement

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environmental risk to farm labor and Litchtenberg and Penn as it relates to water quality impairment from poultry operations.

the available manure. Finally, in the third model we introduce the land application constraint. This constraint also embodies uncertainty by imposing a probabilistic limit on nutrient application. Although, the hog operations are used to describe the animal production component in these models and the only nutrient considered is phosphorus, the model can easily be adapted to other animal species and nutrients.

In all the models a risk neutral agent maximizes profits from both animal production and crop production by selecting phytase (r) and rock phosphorus (r) to supplement the hog feed ration at the animal production operation, and fertilizer application (f) and leasing land (L) as part of the crop production operation. There are other variables that the operator could select including the number of animals, the manure storage technology, the crop to cultivate and many others. However, ignoring these latter choices will not alter the qualitative result we wish to highlight, namely the difference between a wholly owned system and an integrator-operator system, and the tradeoff between preventative measures to reduce nutrients in the production stream versus utilizing the nutrients once they have entered the stream.

Even with this simplified model there are still many components that must be made explicit. First, the feed ration consists of a fixed quantity of ingredients that comprise the basic nutrient needs of the animal. However, not all the phosphorus in this ration is available when consumed by the swine. Let us denote the phosphorus in the ration as $\bar{r}$. If phytase is added the swine can absorb a greater portion of this phosphorus. Alternatively, rock phosphorus can be added which is more readily available for the swine than $\bar{r}$. Note, if rock phosphorus is used as a supplement, then each animal will excrete a greater quantity of the phosphorus because not all the rock phosphorus is utilized either. Let the total quantity of phosphorus consumed be denoted as $\bar{r} + r$. Mathematically, we represent the retained phosphorus per animal with the following expression

$$y = f(r)[\bar{r} + r], f(0) \neq 0, f_r > 0, f_{rr} < 0 \qquad (1)$$

where f, is a concave function that determines the portion of phosphorus that the animal retains after consuming the supplemented feed ration. It follows then that the excreted phosphorus is

$$[1 - f(r)][\bar{r} + r] \tag{2}$$

The final specification for the animal production component is the swine growth function

$$h(y), h_y > 0, h_{yy} < 0. \tag{3}$$

Now, without elaborating on the storage system we will assume a fixed proportion of the excreted phosphorus is lost through spillage or runoff due to rainfall events, which will be denoted as $m^h \in (0,1)$. The phosphorus that remains we will define as available phosphorus from manure (*m*), which on a per acre basis is

$$m = m^h x[1 - f(r)][\bar{r} + r]/[L + L^o] \tag{4}$$

where *x* is the herd size, and L^o is the operator's acreage holding. The crop production decision also includes a choice of applying phosphorus fertilizer in addition to manure such that the per acre applied phosphorus is $ap = m + f$. The final specification is the crop growth function,

$$Y(ap), Y_{ap} > 0, Y_{apap} < 0. \tag{5}$$

The objective function for the unconstrained certainty scenario is

$$\underset{r,r,f,L}{Max}\ [p^h h(y) - c^r r - c^r\ r]x + [p^y Y(ap) - c^f\ f - c^a][L + L^o] - c^L L \qquad (6)$$

where p^h and p^y are the net prices for hogs and the cultivated crop, respectively, c^r and c^r are the per pound cost of rock phosphorus and phytase, respectively, c^f is the per ton cost of phosphorus fertilizer, c^a is the per acre application cost, which is assumed to be identical for applying manure and fertilizer, and c^L is the cost to lease an acre of land.[4]

The first order conditions are

$$[p^h h_y y_r - c^r]x + [p^y Y_{ap} ap_r][L + L^o] \leq 0 \qquad (7)$$

$$[p^h h_y y_r - c^r]x + [p^y Y_{ap} ap_r][L + L^o] \leq 0 \qquad (8)$$

$$[p^y Y_{ap} ap_f - c^f][L + L^o] \leq 0 \qquad (9)$$

$$[p^y Y_{ap} ap_L][L + L^o] + [p^y Y(ap) - c^f\ f - c^a] - c^L \leq 0 \qquad (10)$$

Equations (7) through (10) define the optimal levels of phytase, rock phosphorus, fertilizer and land under conditions of full certainty about nutrient contents of the feed ration and the manure. As usual, the levels are chosen so that the marginal cost and marginal benefit for each decision variable are equivalent. From equation (7) we see that phytase use may be higher when production is decoupled given that the marginal cost of phytase use in crop production $[p^y Y_{ap} ap_r][L + L^o] < 0$ is not realized in the decoupled production scenario. This implies that phytase use may be lower in a wholly owned joint production system. Another interpretation is that the value of manure generated via a phytase feed is lower than when rock phosphorus is used. From equation (8) we see that rock phosphorus use will be greater in a wholly owned animal-crop production system given the crop production benefits attributed to additional phosphorus in the manure, $[p^y Y_{ap} ap_r][L + L^o] > 0$. This result can explain why some analysts have inferred that operators use "excess quantities of nutrients." Finally, the expansion of this farm beyond the initial land holding (L^o) is discouraged by the loss of nutrient value when the manure is spread over a greater quantity of land, $[p^y Y_{ap} ap_L][L + L^o] < 0$.

The above derivation provides a benchmark for which the model now departs to incorporate producer uncertainty. First, the available phosphorus in the feed ration is uncertain. The producer will supplement the feed rations with nutrients such that the probability that the available nutrients are less than the nutrient requirement is less than a specified safety margin (a). If the phosphorus requirement of the animal is r^* then we can construct the following probability constraint

$$P[y \le r^*] \le 1 - a \tag{11}$$

If we assume the available phosphorus in the feed (y) is normally distributed then we can rewrite this constraint as

$$m(y) - F(1-a)s(y) \ge r^* \tag{12}$$

where $F(\cdot)$ represents the cumulative normal distribution, $m(y)$ is the expected value and $s(y)$ is the standard deviation. In addition the operator does not want the cultivated crops to receive nutrients below some threshold level (r^L). This second margin of safety constraint is written as

$$P[ap \le r^L] \le 1 - b \tag{13}$$

[4] The cost of leased land could be made to be an increasing function of the quantity of land to reflect the increased cost of finding additional acreage and transporting the manure to this land but the qualitative results do not change

where b is the margin of safety. Again, if we assume the applied phosphorus (*ap*) is normally distributed then we can rewrite this constraint as

$$m(ap) - F(1-b)s(ap) \geq r^L \qquad (14)$$

The first order conditions for the producer-imposed margin of safety model are (12),(13) and

$$\begin{aligned}&[p^h h_y y_r - c^r]x + [p^y Y_{ap} ap_r][L + L^o] \\ &+ l^1[m_y - F(a)s_y]y_r + l^2[m_{ap} - F(b)s_{ap}]ap_r \leq 0\end{aligned} \qquad (15)$$

$$\begin{aligned}&[p^h h_y y_r - c^r]x + [p^y Y_{ap} ap_r][L + L^o] \\ &+ l^1[m_y - F(a)s_y]y_r + l^2[m_{ap} - F(b)s_{ap}]ap_r \leq 0\end{aligned} \qquad (16)$$

$$[p^y Y_{ap} ap_f - c^f][L + L^o] + l^2[m_{ap} - F(b)s_{ap}]ap_f \leq 0 \qquad (17)$$

$$[p^y Y_{ap} ap_L][L + L^o] + [p^y Y(ap) - c^f f - c^a] - c^L + l^2[m_{ap} - F(b)s_{ap}]ap_L \leq 0 \qquad (18)$$

From equation (15) we see that the imposition of safety margins further reduces the incentive to use phytase and increases the incentives to use rock phosphorus. The fertilizer use is now greater than in the unconstrained model and again we can see why hog operators and crop producers have an incentive to use greater quantities of phosphorus. This result confers with the theoretical findings in Babcock (1992), where uncertainty is used to explain why farmers may use "excessive" or "inefficient" quantities of fertilizer. The imposition of safety margins also reduces the incentive for leasing land.

Now the regulator steps in and imposes a regulatory constraint. The regulator sets an upper limit (r^H) on phosphorus application per acre based on the nutrient uptake of the cultivated crop. The crop

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and thus we maintain the linear specification.

producer cannot exceed this upper limit except under "special" circumstances. To account for all possibilities the regulator requires that the probability that the applied phosphorus exceeds the upper limit is less than a predetermined safety margin. We write this constraint as

$$P[ap \geq r^H] \leq g \tag{19}$$

where g is the safety margin. Again, assuming that ap is distributed normally we can rewrite this constraint as

$$m(ap) + F(g)s(ap) \leq r^H \tag{20}$$

Finally, in this last model we see the tradeoff between the Unified Strategy requirement limiting land application of phosphorus and the producer's margins of safety to insure the animals and cultivated crops receive phosphorus at levels to insure proper economic and physical growth.

The first order conditions are now (12),(13), (20) and

$$\begin{aligned}&[p^h h_y y_r - c^r]x + [p^y Y_{ap} ap_r][L + L^o] + l^1[m_y - F(a)s_y]y_r \\ &\quad + l^2[m_{ap} - F(b)s_{ap}]ap_y - l^3[m_{ap} + F(b)s_{ap}]ap_y \geq 0\end{aligned} \tag{21}$$

$$\begin{aligned}&[p^h h_y y_r - c^r]x + [p^y Y_{ap} ap_r][L + L^o] + l^1[m_y - F(a)s_y]y_r \\ &\quad + l^2[m_{ap} - F(b)s_{ap}]ap_r - l^3[m_{ap} + F(b)s_{ap}]ap_r \geq 0\end{aligned} \tag{22}$$

$$\begin{aligned}&[p^y Y_{ap} ap_f - c^f][L + L^o] \\ &+ l^2[m_{ap} - F(b)s_{ap}]ap_f - l^3[m_{ap} + F(b)s_{ap}]ap_f \geq 0\end{aligned} \tag{23}$$

$$\begin{aligned}&[p^y Y_{ap} ap_L][L + L^o] + [p^y Y(ap) - c^f f - c^a] - c^L \\ &\quad + l^2[m_{ap} - F(b)s_{ap}]ap_L - l^3[m_{ap} + F(b)s_{ap}]ap_L \geq 0\end{aligned} \tag{24}$$

From equation (21) the operator's incentive to use phytase is increased due to the reduced cost of satisfying the regulator's constraint $-l^3[m_{ap} + F(b)s_{ap}]ap_y > 0$. From equation (22) the opposite can be said for rock phosphorus where the regulator's constraint imposes a higher marginal cost from using rock phosphorus, $-l^3[m_{ap} + F(b)s_{ap}]ap_r < 0$. Equation (23) and (24) show similar incentives for reducing fertilizer use and increasing cultivated acreage. The imposition of the regulator's constraint on land application therefore has wide reaching implications for trading off prevention measures, increasing the use of phytase, and utilization measures, increasing cultivated acreage. In the next section, an empirical analysis provides statistical evidence to support the hypotheses implicit in the first model. These results are then used to infer the implications for animal-crop production system as it pertains to prevention and utilization solutions to satisfying the regulator's constraint.

Empirical Analysis:

Data from the 1998 Agricultural Resource Management Study Phase III are used in the empirical analysis. The data set consists of 1633 observations spanning 22 hog producing states. Table 1 provides definitions for the variable names. Table 2 lists the observations by state, the average inventory of animal units and the percentage of the systems in each state that operate under an integrator-operator arrangement. The number of animal units (AUs) raised on an average system varies considerably from 4,788.4 AUs in Utah to 81.2 AUs in Wisconsin. The average acreage per AU also varies across states with 42.19 acres per AU in South Dakota to 1.48 acres per AU in North Carolina. The variation in the percentage of the systems that are integrator-operator is perhaps the most striking with Arkansas and North Carolina having 85 percent of the systems as integrator-operator systems and Tennessee having only one percent of the surveyed systems as integrator-operator systems. Table 3 contains additional summary statistics for several key parameters for both the wholly owned production systems and the integrator-operator systems. The integrator-operator systems have lower average values for all the parameters of interest. These means are statistically different at the 0.001 significance level.

Table 1. Variable Definitions

Variable Name	Definition
AU	Animal Unit=1,000 lbs. of liveweight
IO	=1, if integrator-operator system =0, if wholly owned system
Ac/AU	Acres per animal unit
P/ton	Pounds of phosphorus per ton of manure
N/ton	Pounds of nitrogen per ton of manure
Ac/Pton	Total operation acres per pounds of phosphorus per ton
Ac/Nton	Total operation acres per pounds of nitrogen per ton

Table 2. Observations, Average AUs, Average Acres/AU, and Percent IO, by State

State	Observations	AUs	Acres/AU	%IO
Alabama	65	157.1	6.86	15
Arkansas	61	436.5	1.94	85
Colorado	29	123.0	34.93	7
Georgia	71	162.7	8.38	4
Illinois	136	329.0	9.92	9
Indiana	83	357.0	5.54	10
Iowa	88	286.5	6.28	23
Kansas	54	253.1	20.97	6
Kentucky	42	200.6	9.60	5
Michigan	59	420.8	11.82	17
Minnesota	97	292.3	8.94	27
Missouri	82	302.6	8.38	5
Nebraska	64	304.4	13.31	6
North Carolina	206	1000.1	1.48	85
Ohio	116	204.1	8.06	19
Oklahoma	63	646.8	18.87	57
South Carolina	59	329.6	16.73	39
South Dakota	65	219.5	42.19	6
Tennessee	75	123.5	11.13	1
Utah	13	4788.4	8.67	39
Virginia	49	966.2	10.53	22
Wisconsin	56	81.2	16.54	4
Total	1633	44.8	12.78	27

Table 3. Expected Value for Key Parameters

System	Observations	Variable	Mean	Median
Wholly Owned	1197	P/ton	2.21	2.21
		N/ton	4.14	4.13
		Ac/AU	14.25	4.99
		Ac/Pton	341.45	185.41
Integrator-Operator	436	P/ton	1.74	1.52
		N/ton	3.07	2.40
		Ac/AU	1.51	0.14
		Ac/Pton	169.78	61.88

The analysis that follows examines the differences between wholly owned animal-crop production systems and integrator-operator systems and compares the nutrient concentrations in the generated manure, the animal units raised, and the acreage used in the production system. Inferences drawn from these comparisons are used to examine how the Unified Strategy will affect the different systems as well as the tradeoff between prevention and utilization. In the near future, a simulation model will be calibrated using this data to evaluate the cost of complying with the Unified Strategy for varying scenarios based on producer and regulator margins of safety. This latter exercise will provide a range of outcomes that allows us to better understand the impact that the Unified Strategy may have on livestock operations and ultimately on water quality conditions.

First, the theoretical result that an integrator-operator production system uses a lower quantity of rock phosphorus in the feed ration and thus generates lower phosphorus concentration in the manure is examined. The negative correlation between P/ton and IO and the difference of means test, which showed that P/ton for the integrator-operator systems was statistically lower at the 0.001 significance level, support the theoretical finding that integrator-operator systems will have less nutrient concentrations in the generated manure. Table 4 presents the correlation coefficients derived in the empirical analysis (all of the correlation coefficients are statistically significant at the 0.001 significance level). The same relationship exists between the nitrogen concentration and the IO variable. However, this difference in nutrient concentration may be attributable to the manure handling system employed in the waste management component (not specified in the theoretical model). Lagoon handling systems reduce the total phosphorus content by nearly 60 percent whereas a pit system retains approximately 95 percent of the total phosphorus (Moore). Furthermore, a review of the relationship between production system, and between lagoon versus pit systems shows that 80 percent of IO systems operate lagoon systems while only 46 percent of wholly owned operations operate lagoon systems. The correlation between contracting and lagoon systems is 0.43 and is statistically significant at the 0.001 level of significance.

The second test involves drawing a relationship between the acreage per animal by production system. The correlation and difference of means tests between acreage per animal and IO, which are both statistically significant at the 0.001 level, shows that the integrator-operator systems have significantly less land per animal unit. This suggests that the integrator-operator systems may not have sufficient land holding to spread the lower nutrient concentrated manure. Given lower nutrient concentrations in the generated manure, a nutrient restriction per acre may have a greater impact on the integrator-operator systems if the integrator-operator system has less land per animal unit and the lower acreage dominates the lower nutrient concentrated manure.

The final test compares the acreage per pound of phosphorus per ton of manure. This test allows us to see if the integrator-operator systems face a greater burden associated with managing "excess" manure nutrients. The correlation coefficient between acreage per pound of phosphorus per ton of manure and IO was negative and statistically significant at the 0.001 level. The difference of means test was also statistically significant at the 0.001 level and showed that the acreage per pound of phosphorus per ton of manure was lower for integrator-operator systems than for the wholly owned systems.

Table 4. Correlation Coefficients for Key Parameters

	Ac/AU	P/ton	N/ton	IO
Ac/AU	1	0.10465	0.10628	-0.18816
P/ton	0.10465	1	0.9808	-0.23865
N/ton	0.10628	0.9808	1	-0.26807
IO	-0.18816	-0.23865	-0.26807	1

The following inferences are drawn from the above results and pertain to the potential implementation of the Unified Strategy and the implications for the different systems and the tradeoff between prevention and utilization of nutrients in the production stream. First, the integrator-operator systems are likely to face greater costs associated with complying with the Unified Strategy because they must locate greater additional acres of land to spread manure than the wholly owned systems. Second, the distribution of integrator-operator systems across the states listed in Table 2 suggests hog production will be more adversely effected is some states than in others. In particular, Arkansas and North Carolina far exceed all other states in the share of integrator-operator systems and thus could face greater costs associated with the proper management of manure.

Now turning to the impact of the Unified Strategy on the prevention versus utilization tradeoff. First, it is expected that the relative cost between prevention and utilization will influence the optimal mix. If the Strategy increases the land acreage needed to spread the “excess” manure then the cost of acquiring addition land will most likely increase. This increase in land costs may encourage an increase in the use of feed supplements that increase the retention of nutrients by the animals and thus a lower concentration of manure nutrients. Also, given that it appears that the Unified Strategy would adversely effect the integrator-operator systems more than the wholly owned systems, the operators may place a greater emphasis on prevention measures in the contractual arrangements between integrators and operators. Of course, if co-permitting or joint liability is incorporated into the Unified Strategy, then we may see a concerted effort on both the integrator and the operator to arrange for adopting preventive measures over land application.

Concluding Remarks:

This paper examines the tradeoff between prevention and utilization of nutrients in the animal-crop production stream and the differences in the decision making process between wholly owned production systems and integrator-operator systems. The analysis shows that under wholly owned production conditions some of the apparent excess nutrients in the manure is the result of an optimal decision. Some excess application of nutrients during the crop production component can be explained by the margin of safety used by the operator to insure that the cultivated crop receives a minimum quantity of nutrients. Also, the economic value of nutrients is illustrated when a joint production system is explicitly modeled. In addition, in the empirical analysis it is shown that the operator in an integrator-operator system faces greater challenges under the recently proposed Unified Strategy for Animal Feeding Operations

Several issues were raised above that were conveniently assumed away. In particular, the issues of co-permitting and contracting were not fully explored. In the future, these issues will provide greater insight into designing regulatory schemes to control excess application of nutrients and thus improve water quality. It may also be the case that requiring co-permitting or joint liability may result in decreasing the percentage of operations that contract with integrators. We may see in the future a movement toward further consolidation and less contracting given the costs involved in developing "fair" contracts that allow the downstream externality recipient to share the cost of the externality with the upstream producer (the integrator and its nutrient rich feed).

Overall, this analysis allows us to see that the problem of controlling nutrient runoff from confined animal feeding operations requires a systems approach. Further, it is possible that the regulator can better serve environmental concerns by providing information that reduces the uncertainty about nutrient content thus reducing the "excess" use of nutrients. Also, efforts could focus on reducing the cost of utilizing the nutrients once they have entered the production stream. Reducing the cost of utilization may take the shape of increasing the economic value of the nutrients by supporting value-added technologies such as composting, bio fuel generation, or conversion of manure to pelletized fertilizer. Absent a regulatory requirement, incentives may be needed to encourage farmers to voluntarily reduce the nutrients entering or exiting the production stream. This may require time, as farmers learn about alternative technologies or crops to cultivate that serve to decrease the cost of meeting water quality goals.

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