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On-farm Manure Storage Adoption Rates: the Roles of Herd Size, Spreading Acreage and Cost-share Programs[1]

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The Issue

At a time when the general trend in concentrated animal feeding operations (CAFOs) is toward larger herds, proposed policy changes in the United States extend regulation downward to smaller operations and to manure-spreading acreage requirements. These are operations that typically have been subject only to state, not national, environmental regulations. How these smaller operations behave – in particular, what influences their manure handling decisions – is an important question given these proposed regulatory changes. This research examines the factors influencing the decision to adopt on-farm manure storage by smaller CAFOs in North Dakota raising a variety of different livestock.

Implications and Conclusions

The decision to adopt on-farm storage is more a function of herd size than of geography. Simply put, operations with larger herds, regardless of available spreading acreage, tend to be more likely to adopt on-farm manure storage. A marked difference in practice also appears between producers who are currently regulated and producers who have been exempt from regulation but would come under inspection as part of the proposed regulatory changes. The research and analysis reported here does reveal one very encouraging piece of information: cost-share programs work. Participation in manure storage cost-share programs, whether funded by state or federal sources, appears to exert a positive and significant effect on manure storage adoption rates.

Introduction

The last decade has seen significant consolidation and expansion within the U.S. livestock sector. These structural changes have led to concentrated animal feeding operations (CAFOs) that are both larger and denser than in the past (Letson and Gollehon, 1996). As a result of this concentration, nutrient surpluses from manure pose a significant threat to water quality across the United States (USEPA, 1994; Gollehon and Caswell, 2000).

Currently, smaller CAFOs are subject primarily to state-level manure regulations rather than federal-level EPA regulations. However, proposed changes in EPA regulation may extend federal oversight downward to include smaller CAFOs (USEPA, 2001). As noted by Metcalfe (2000), most current federal manure management legislation defers regulatory responsibility to individual states when state-level regulations have either lower AU (animal unit) thresholds or are viewed as being more stringent than EPA standards. The EPA currently identifies 43 states as having manure management standards that are at least as stringent as EPA requirements (USEPA, 1999). For these states, the effectiveness of state manure management regulations will determine whether or not animal waste poses a threat to water quality. Given the importance of state-level regulations, research examining the manure management practices of CAFOs should be state-specific. Additionally, since the regulatory changes proposed by the EPA focus on both smaller CAFOs and on-farm spreading acreage, attention should be paid to how smaller CAFOs handle their manure and whether or not on-farm spreading acreage influences their manure storage decisions.

To assess these issues, the present research examines how on-farm acreage influences manure storage decisions (as measured by on-farm manure storage adoption rates) among livestock operations in North Dakota. An on-farm manure storage adoption model conditioned on CAFO size (as measured by herd size and on-farm spreading acreage), knowledge of cost-share programs, and state-level manure management regulatory status is developed and applied to farm-level survey data describing beef cattle CAFOs in North Dakota.

Previous Research

Economic research evaluating manure management generally falls into two categories. The first emphasizes optimal policy design and focuses on how best to reduce the environmental threats from livestock waste, while the second evaluates the on-farm impacts of alternative manure management methods. The first category of research is typified by Moffit, Zilberman, and Just (1978); Matulich, Carman, and Carter (1976); Schnitkey and Miranda (1993); Goetz and Zilberman (2000); and Innes (2000). All of these studies have shown that regulation tends to be less efficient than emission taxes in reducing pollution and that policies should vary spatially to accommodate the differences in pollution potential due to variations in farm attributes.

The second type of research examines the on-farm consequences of adopting alternative manure management methods and recommended best management practices. This category of research tends to emphasize the impacts on farm income of different manure storage methods, and is exemplified by Ashraf and Christenson (1974); Forster (1975); Fleming, Babcock, and Wang, (1998); Van Dyke et al.(1999); and Van Dyke, Bosch, and Pease (1999). While early work in this area found that manure management polices imposed significant costs on producers, more recent work which recognizes the nutrient value in manure has either shown smaller costs or actual benefits to producers who utilize manure as a source of nutrients (see Van Dyke et al., 1999 or Fleming, Babcock, and Wang, 1998). Benefits are primarily due to an increase in recoverable nutrients available for sale off-farm through improvements in manure storage facilities.

Both the earlier and more recent work related to on-farm manure management suggests that cost represents a major barrier to adoption of manure best management practices. To cope with this perceived obstacle, various types of cost-share programs have been implemented to reduce the cost to farms of improving their manure handling procedures. These cost-share programs may be federal (such as the well-known EQIP) or state-level (such as the North Dakota Department of Health's Section 319 cost-share program). Regardless of source, the goal of these cost-share programs is to reduce the cost of improved manure storage to a point where animal feeding operations adopt facilities that meet the desired manure handling standards. While these programs were adopted in response to perceived cost barriers, their effectiveness at promoting adoption has not been evaluated.

Consequently, two primary issues should be addressed when examining on-farm manure storage adoption decisions by CAFOs. The first is the issue raised by proposed EPA regulations, specifically, whether or not on-farm spreading acreage influences manure storage decisions. The second relates to the degree to which cost is a barrier to improved manure storage and if cost-share programs promote adoption of improved manure storage. The first issue addresses the impacts of regulation; the second examines whether or not CAFOs actually respond to existing programs in the intended manner.

While previous research has been useful in demonstrating the potential for improved profits through adoption of alternative manure handling methods, these studies are all normative rather than positive in nature. The distinction is important. Normative studies indicate possible outcomes, while positive studies analyze observed results. If CAFOs view their on-farm spreading acreage as part of their whole-farm manure storage decision, then on-farm manure adoption decisions should respond to changes in this acreage. Additionally, if CAFOs actually view cost-share programs (like EQIP) as cost-reducing, then adoption rates for manure storage should respond positively to knowledge of or participation in cost-share programs. The present research examines whether or not on-farm manure handling decisions account for both on-farm spreading acreage and cost-share programs. As such, this research moves beyond previous normative research for a positive evaluation of CAFO decision-making.

Changes in manure management, such as adoption of on-farm storage, represent a fundamental change in production technology by the CAFO. There are two potential forces that motivate CAFOs to adopt on-farm manure storage. The first is the coercive force of government through regulation; the second is the implied potential for higher profits through reduced operational costs. The question is which force exerts a greater influence in the adoption process. The answer is by no means clear. The ability of a CAFO to adopt alternative manure management practices will be limited by the unique attributes of the CAFO. Simply put, not all CAFOs can adopt on-farm manure storage. The physical characteristics of an enterprise can limit the ability of a CAFO to adopt manure storage (Safley, 1994).

For adoption to occur, manure management techniques must either be the most profitable or the least-cost method of dealing with animal waste for a particular CAFO (Fleming, Babcock, and Wang, 1998; Carreira and Stoecker, 2000). Both profitability and cost will in turn depend on the heterogeneous attributes of the animal feed operation adopting the manure management practices. Since not all CAFOs will be equally able to adopt manure storage, the effectiveness of environmental policies promoting adoption will be limited by farm attributes. Establishing how environmental regulations interact with the heterogeneous attributes of CAFOs when choices are made with regard to manure management techniques is critically important for all regions faced with surpluses of manure.

As mentioned above, one limiting aspect of existing manure storage studies is that they are generally normative rather than positive in nature: they assume that all CAFOs will adjust their manure handling in response to regulation. Although Just and Antle (1990) observed that agricultural producers will often modify their production practices in response to environmental policy changes, they noted that full evaluation of a policy's effectiveness also requires analyzing the behavior of producers who opt not to comply with a policy change. Consequently, studying the impact of manure management policies should also examine why some enterprises comply with policy requirements while others do not.

Empirical Model

The methods a CAFO uses to handle manure are a reflection of the livestock production technology used by the CAFO. Therefore, the choice across alternative levels of storage adoption is a choice across alternative production methods. An individual CAFO will choose among alternative sets of manure management practices and opt for the most profitable set.

Profitability under a given set of manure management practices will depend upon a variety of factors. The first, and simplest, is herd size. Herd size is denoted *l*. The physical attributes of a CAFO (such as acres available for spreading, production facilities, and the regulatory status of the CAFO) will also determine adoption. Physical traits of the CAFO are contained in the vector θ.[2]

Profits when the CAFO adopts on-farm manure storage are denoted $\pi^S(l,\theta)$, while profits under non-adoption are $\pi^{NS}(l,\theta)$. For CAFOs to adopt on-farm storage, the difference between profits with and without storage must be positive, or

(1) $$\pi^S(l,\theta) > \pi^{NS}(l,\theta)\ .$$

Equation (1) reduces the on-farm manure storage adoption decision to a comparison of profits between adopting and not adopting. The difference in profits will depend upon herd size and the physical traits of the CAFO. Since the adoption decision hinges on the relative profits of storage and non-storage, a common policy tool to promote adoption is cost sharing. The point behind cost sharing is to ensure that the positive difference between storage and non-storage required by equation (1) is met.

Given differences in CAFO attributes such as herd size and on-farm acreage available for manure spreading, it is impossible to identify *a priori* which CAFOs will adopt on-farm manure storage. For example, CAFOs with larger on-farm acreage available for spreading may be more able to spread manure, but may also be less likely to feel a need to do so. Similarly, CAFOs of similar physical size but raising different types of livestock may face different adoption decisions as well. Finally, awareness of or participation in cost-share programs may increase or decrease the perceived profitability difference between adoption and non-adoption. Consequently, adoption of on-farm storage must be addressed empirically to examine how on-farm acreage and cost-share programs affect adoption of on-farm manure storage.

There are two different routes for empirically estimating whether or not a particular CAFO will or will not adopt on-farm manure storage. The first is to directly estimate profit functions for each CAFO with and without adoption. While potentially precise, this approach is highly data intensive and not easily accomplished. A second, and more feasible, approach is to utilize a discrete-choice model. Assuming that CAFOs maximize profits within a random utility framework, the adoption decision suggested in equation (1) can be modeled as a discrete-choice regression (Ben-Akiva and Lerman, 1985). In particular, if equation (1) is re-expressed as the difference between expected profits, such that

(2) $$E[\pi^S(l,\theta,a)] > E[\pi^{NS}(l,\theta,a)]\ ,$$

and it is further assumed that expected profits under adoption and non-adoption follow a Weibull distribution, then the difference between profits under adoption and non-adoption follows a logistic distribution and the adoption decision reduces to a simple logit regression (Domencich and McFadden, 1975). In that instance, direct estimation of profits is unnecessary and the decision to adopt on-farm manure storage can be expressed as a binomial logit where the explanatory variables are on-farm acreage available for manure storage, herd size, knowledge of or participation in cost-share programs, and other relevant CAFO characteristics.

Data, Estimation and Results

North Dakota livestock operations serve as ideal candidates for analyzing manure storage decisions made by CAFOs that would be affected by the proposed regulation. The economy of North Dakota is heavily dependent on agriculture, and relative to its population the state is a significant producer of agricultural products. For example, in 2000 North Dakota ranked 12th nationally in beef cattle production and accounted for approximately 3 percent of all U.S. beef cattle production (North Dakota Agricultural Statistics, 2000). More importantly, North Dakota CAFOs are relatively small and typically fall into size ranges currently exempt from EPA regulations.[3] North Dakota CAFOs are, therefore, relatively typical of smaller CAFO operations that will be affected by proposed changes in current EPA regulations. This research examines the decision to adopt on-farm manure storage and the impacts of on-farm and regional acreage on this decision using data on CAFOs raising beef cattle, dairy cattle, and hogs in North Dakota.

Data for the analysis come from a telephone survey of 354 North Dakota livestock producers conducted in February 1999. This phone survey randomly targeted beef, dairy and pork producers. Telephone numbers for the producers were obtained from the North Dakota Brand Registry for beef producers, from the North Dakota Department of Agriculture Dairy Registry for dairy producers, and from the North Dakota Pork Producers Council for hog producers. Of the 354 producers surveyed, 108 were beef producers, 145 were dairy producers, and 101 were hog producers. More importantly, 81 of the producers surveyed were listed as having "approval to operate from the North Dakota Department of Health". This represents nearly one-fifth of the producers in the state with "approval to operate" at the time of the survey. For a more detailed discussion of the survey procedures, please see Klenow and Birchall (2000).

North Dakota identified manure as a potential threat to water quality in 1972 and set standards for on-farm manure storage at that time. Under regulations administered by the North Dakota State Health Department, North Dakota defines appropriate manure storage as being capable of handling a minimum of six months of manure production and/or a 3.5 – 4.2 inch rainfall in a 24-hour period (North Dakota Livestock Regulations, 1989). In the present analysis, meeting these standards (the state-defined manure Best Management Practices) is defined as having on-farm storage, while not meeting these standards is defined as not having storage. Adoption of on-farm manure storage by North Dakota beef producers was modeled as a binomial logit using the LIMDEP econometric package.[4]

Table 1 Summary of Survey Results

	Animal	Average	Minimum	Maximum	Units
Spreading acres	*swine*	1199.08	10	12160	acres
	dairy	662.659	20	4000	
	beef	1119.95	10	5000	
Herd size	*swine*	309.277	7	3500	AU
	dairy	80.1201	0.5	757.167	
	beef	382.49	25	8000	
BMP adoption	*swine*	0.309278			% of respondents
	dairy	0.303704			
	beef	0.301887			
NDDH approval	*swine*	0.164948			% of respondents
	dairy	0.155556			
	beef	0.40566			

The explanatory variables consist of three continuous variables and four discrete variables. The continuous variables are the number of cattle on the CAFO (in AU), the acres available for manure spreading on the CAFO, and an interaction term between acreage and herd size.[5] Discrete variables are *swine* and *dairy*, both binary variables indicating if the CAFO raises one of these two types of animals; *EQIP*, a binary variable indicating if the producer was familiar with either the Natural Resource Conservation Service's EQIP cost-share program or the North Dakota Department of Health's Section 319 cost-share program; and *approval*, a binary variable indicating if the CAFO had an "approval to operate" from the North Dakota Health Department. Additionally, interaction terms between the two livestock binary variables (*swine* and *dairy*) and the continuous variables were also included. The data are summarized in table 1.

The logit results from LIMDEP are shown in table 2. On balance, the logit model performs very well in describing the manure storage adoption decision by North Dakota beef CAFOs and successfully predicts 80.3 percent of all storage decisions. Additionally, the model performs well according to statistical measures such as the log-likelihood test ($\chi^2 = 96.51$ with 13 degrees of freedom) while the McFadden's R^2 is 0.24. It is necessary to report a battery of goodness-of-fit measures because limited dependent-variable models, like a logit, lack a single goodness-of-fit measure (Maddala, 1987).

Given proposed policy changes by the EPA and recent research suggesting profit potentials exist in improved on-farm manure storage, the parameter estimates related to acreage are of the most interest in this analysis, and the discussion addresses these variables first. Acreage available for manure spreading is significant, but not relative to herd size. By itself, on-farm spreading acreage is marginally significant and negative,

Table 2 Logit Coefficients for Manure Storage Adoption by Beef CAFOs in North Dakota

Parameter	**(units)**	***Coefficient***	***(t-value)***
Constant		-3.05939	-4.97894****
Animal units	(AU)	0.0033961	2.81512****
Spreading acreage	(acres)	-0.000378673	-1.34868*
AU x acres	(AU x acres)	-5.92671E-08	-0.379862
Approval	(1/0)	2.2274	6.02445****
EQIP	(1/0)	0.95652	1.61779**
Swine	(1/0)	1.24382	1.65792**
Dairy	(1/0)	1.0545	1.39701*
Swine x acres	(acres)	0.000829101	2.17573***
Swine x AU	(AU)	-0.00339079	-2.25803***
Swine x EQIP	(1/0)	-0.361902	-0.451381
Dairy x acres	(acres)	0.000801439	1.95512***
Dairy x AU	(AU)	0.00349007	0.776423
Dairy x EQIP	(1/0)	-1.17758	-1.55198*
Log likelihood chi-squared test	96.51		
Degrees of freedom	13		
McFadden's R^2	0.24		
Percentage correct	80.37		

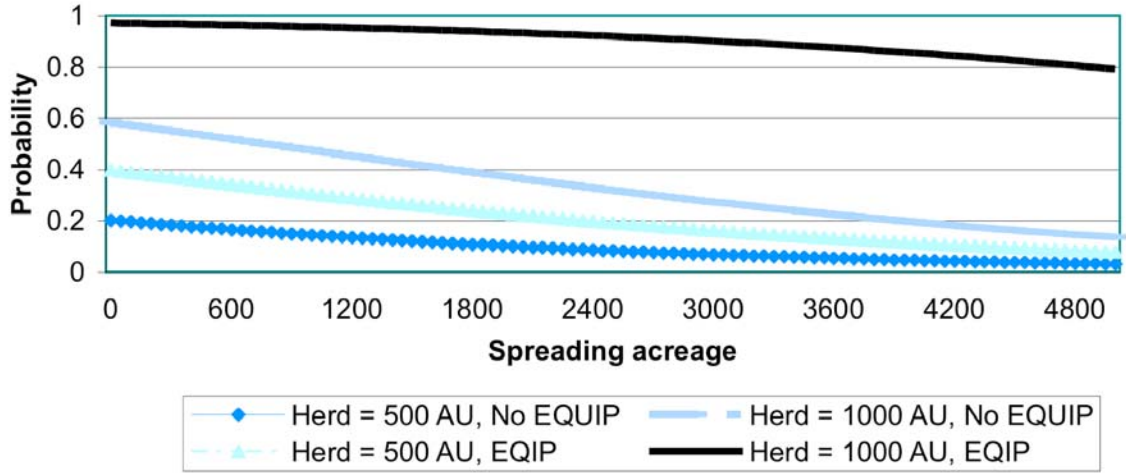
Significance α = 0.2*
0.1**
0.05***
0.01****

Note: Missing responses to some questions reduced the sample for the logit model to 321.

which suggests that CAFOs with larger geographic footprints are less concerned with manure storage issues. The other on-farm spreading acreage term – the acreage/herd size interaction term – is negative and insignificant. Overall, on-farm acreage available for manure spreading is important to manure storage decisions, but does not appear to matter relative to herd size.

However, when the manure spreading acreage is evaluated specifically for swine and dairy, the effects of acreage are both positive and strongly significant. This is in sharp contrast to the basic (beef) results. It appears that the role of on-farm spreading acreage in manure storage adoption decisions varies by the type of livestock a CAFO produces. Given that current North Dakota regulations focus on herd size and do not differentiate across livestock types, this result raises serious questions about how current CAFO policies are targeted. Specifically, it suggests that spreading acreage influences storage decisions – but only for specific types of livestock.

The other variable of policy interest relates to the two cost-share programs, EQIP and the North Dakota Department of Health Section 319 program. The dummy variable for

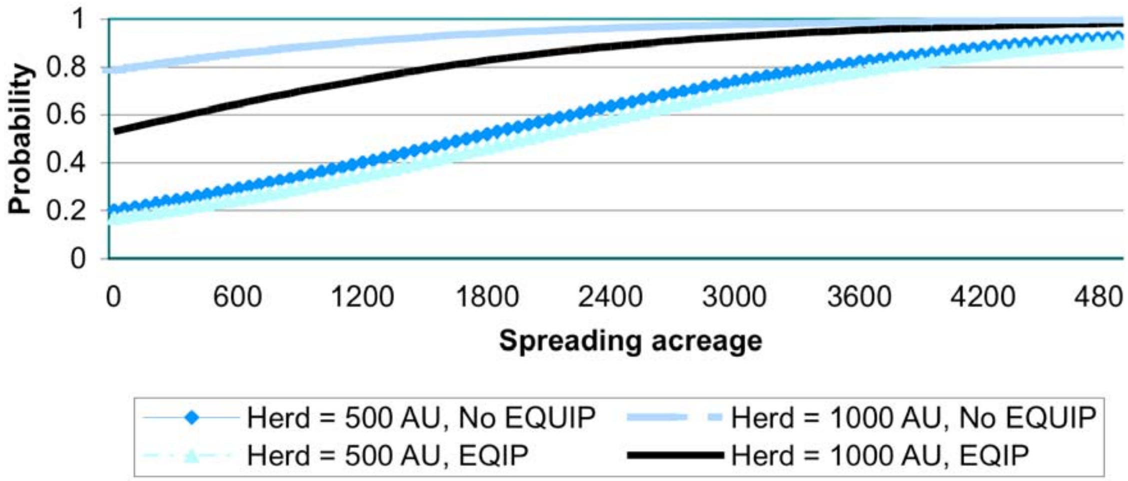


Note: Evaluated at means of continuous variables, and at mode of categorical variables.

Figure 1 Manure storage adoption by North Dakota beef CAFOs by herd size across spreading acreage.

these two programs, EQIP, indicates if the respondent was familiar with either of these two cost-share programs. The coefficient for this parameter is both positive and significant. Additionally, while the EQIP/livestock-type interaction variable is negative for both swine and dairy, it is either insignificant or only marginally significant. These results suggest awareness of cost-share programs exerts a uniformly positive influence on the adoption of on-farm manure storage.

Unlike a conventional least-squares model, the parameter estimates do not directly measure the marginal effects of each parameter on the probability of adopting on-farm storage. This is especially true relative to herd sizes and spreading acreage, since the various parameters have different signs for different types of livestock. Consequently, while the estimated parameter values suggest beef CAFOs with larger areas are less likely to adopt storage, and while swine and dairy CAFOs are more likely to adopt, the net effects of competing forces on adoption of storage are not immediately clear. To show these impacts, figure 1 shows the probability of adopting on-farm storage as a function of on-farm spreading acreage for beef cattle producers. Adoption curves are shown for both the current EPA regulatory threshold of 1000 AU and the proposed EPA threshold of 500 AU. Additionally, adoption curves are shown for those CAFOs that are familiar with either the EQIP or NDDOH Section 319 manure storage cost-share programs. This allows comparison both across the two different size categories of CAFOs and between CAFOs that are more or less familiar with available cost-share programs.



Note: Evaluated at means of continuous variables, and at mode of categorical variables.

Figure 2 Manure storage adoption by North Dakota dairy CAFOs by herd size across spreading acreage.

For beef cattle, all adoption curves decline in spreading acreage, and the likelihood of adoption is uniformly lower for the smaller herd size. Simply put, small herd size CAFOs with large areas for manure spreading are less likely to adopt on-farm manure storage, and the acreage effects dominate herd density effects. However, CAFOs that are familiar with the two cost-share programs are more likely to have on-farm manure storage that meets state standards. This suggests that both the federal and state cost-share programs are having the desired result. Figure 2 shows similar adoption curves for dairy producers.[6] Unlike beef CAFOs, these producers show an increase in the likelihood of adopting adequate on-farm manure storage as a function of spreading acreage. For dairy producers, EQIP leads to higher adoption rates but this is less noticeable for producers with larger herds.

Across all livestock types, it appears knowledge of cost-sharing programs like EQIP at least correlates with adoption of improved on-farm manure storage, even though the basic adoption rates vary across livestock types. It is important to note that these effects display the marginal contribution of cost-share programs to the manure storage decision, since the EQIP parameter reflects the difference in adoption rates for CAFOs with and without knowledge of EQIP. At the margin, the effects of EQIP appear to be strong, uniform and positive – making it a robust policy instrument that at the least correlates with the goal of improved manure storage.

As noted previously, the primary focus of this research is to address how on-farm manure spreading acreage and cost-share programs influence manure storage adoption decisions. On-farm spreading acreage generally reduces the likelihood of adopting on-farm manure storage for beef cattle and increases the likelihood for swine and dairy. This effect varies across both herd size and knowledge of cost-share programs. The policy implications of these results, particularly relative to proposed regulatory changes by the EPA, are significant. To start, the fact that acreage influences manure storage decisions differently across herd sizes and livestock-types suggests storage decisions are not the same for all enterprises. Indeed, it appears that dairy and swine operations with larger geographic footprints are less likely to have inadequate storage and to pose a threat to water quality than are beef operations of similar geographic size. As such, the EPA may want to focus on different types of livestock operations rather than their overall geographic footprints. Additionally, it appears that awareness of cost-share programs corresponds to higher levels of manure storage adoption. The degree to which this is a cause of adequate storage or simply a correlation is not clear from these data. Either way, it suggests that cost-share programs are achieving the desired policy goal: adoption of adequate on-farm manure storage. Between the two policies, it appears that on-farm spreading acreage should be evaluated differently across livestock types, while EQIP should not.

Conclusions

Current EPA regulations require permitting of CAFOs of 1000 AU or more, either by the state in which the CAFO resides or under the National Point Discharge Elimination System. Proposed regulatory changes would reduce this threshold to 500 AU and extend EPA rules to on-farm manure spreading acreage. The data describing on-farm manure storage decisions by CAFOs in North Dakota suggest that the proposed expansion of EPA regulatory authority to include on-farm spreading acreage may be misplaced. While beef CAFOs are less likely to adopt adequate on-farm storage as spreading acreage rises, swine and dairy CAFOs show the opposite trend. These results suggest that different types of CAFOs face different manure storage adoption decisions and as a result pose different levels of risk to water quality.

Additionally, the empirical manure storage adoption model developed here suggests that cost-share programs achieve their desired policy end. The point of cost-share programs is to reduce (or even reverse) the difference in profits between adoption and non-adoption of adequate manure storage. As the results here indicate, knowledge of these cost-share programs does correspond to higher probability of adopting adequate on-farm manure storage. Whether this correlation translates to causation is unclear, but the end result is the same. Cost-share programs appear to contribute a positive marginal effect to adoption of on-farm manure storage.

On balance, this research suggests that the physical factors affecting adoption of adequate on-farm manure storage, such as on-farm storage or herd size, vary by livestock type. The factor currently being targeted by the EPA – spreading acreage – varies more across livestock types than generally within a given type of livestock. If the proposed EPA policy is intended to reduce water quality problems created by CAFOs, it would seem that these policies should either be targeted toward dairy and swine operations with smaller geographic footprints or toward beef operations with larger physical footprints. These are the types of operations with the lowest probabilities of adopting adequate on-farm manure storage.

With respect to promoting adoption of on-farm manure storage that meets mandated standards, it does appear that cost-share measures exert a significant and positive influence on adoption rates. Future manure management programs should recognize that these programs are at least strongly correlated with higher adoption rates, even if they are not necessarily their cause. The final conclusion of this research is that both spreading acreage and cost-share programs matter in the manure storage adoption decision, but their effects are anything but uniform across livestock types, herd size, or physical size of operation. Manure management policies should vary in concert with these differing attributes if they are to promote adoption of adequate on-farm storage.

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Endnotes

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[2] Profits normally would be expressed as a function of relevant input and output prices; however, in the present case the data used are for a single state in a single time period. There is inadequate spatial variation in prices to evaluate storage adoption decisions using prices. Instead, primal inputs – in this case land and herd size – are substituted for prices.

[3] In 2000, 95 percent of all North Dakota Beef CAFOs fell below the EPA threshold of 1000 AU (ND Agricultural Statistics); Texas, the number one–ranked beef cattle producer in 2000, had 36 percent of its beef CAFOs above the 1000 AU threshold (Texas Agricultural Statistics, 2000).

[4] Dana Hoag observed to the author that modeling the storage decision as a two-step process, where CAFOs first decide if they will have storage and then those who opt for storage make a second decision to determine if they will meet the state standards, might be better. In that case, a nested logit would be a more appropriate model. However, of 108 beef CAFOs surveyed, only 1 with on-farm storage had on-farm storage that failed to meet the Health Department standards; for the 145 dairy operations, 2 out of 46 permitted operations failed to meet the standard; for 101 hog operations the number was 18 out of 48. Given the correlation between having storage and meeting state standards, a binomial logit with meeting state standards as the dependent variable is appropriate.

[5] As mentioned previously, prices are excluded from the data set. Since the data set is cross-sectional and covers only North Dakota, there is inadequate spatial variation in prices, and including prices makes the data set collinear.

[6] For swine producers, EQIP leads to higher adoption rates, but the effects do not appear to vary across herd sizes.