# Substitutability of Livestock Manure for Chemical Fertilizer: A Contingent Valuation Analysis of Crop Producers

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In the last twenty years, new federal regulations have been implemented that control how animal feeding operations must handle their manure. Nearly all livestock manure is applied to crop and pasture land at some point following storage and treatment. Because manure is very costly to transport due to its bulkiness, many livestock operations choose to apply manure at rates greater than what crops can consume during the cropping season. Continuous over-applications of manure eventually lead to nutrient runoff, potentially polluting surface and ground waters. As a result, new regulations have been passed to minimize nutrient runoff by requiring manure applications to be consistent with the nutrient uptake of the specific crop.

Management of manure has become a serious issue. Ribaudo notes that lagoon spills or leaks have recently occurred in a dozen states. In 1995, a lagoon break resulted in 25 million gallons of swine waste entering the New River of North Carolina (Ogishi, Metcalfe, and Zilberman). Bacteria in animal waste have also been blamed for the deaths of numerous people. In 1993, a dairy was considered to have contributed to a bacterial outbreak in Milwaukee's drinking water that caused 104 deaths and sickened more than 400,000 people (Innes).

Recently, new regulations in the Environmental Protection Agency's Clean Water Act are forcing confined animal feeding operations (CAFOs) to increase the land area that they apply manure (Ribaudo). As legislation forces livestock producers to revolutionize manure management practices and seek off-farm acres to apply manure, a better understanding of the market for manure is desired. Numerous studies have noted that compliance costs for livestock operations depend on the distance manure must be transported and the willingness of crop producers to pay for manure. Unfortunately, the willingness-to-pay (WTP) for manure by crop producers has not been estimated. Using data collected from a mail survey, WTP will be estimated using a random utility framework. By determining what specific factors affect the price of manure, better information can be provided to livestock producers about the federal regulation impacts and characteristics of manure preferred by local crop producers.

**Background**

The federal government has regulated waste discharged from CAFOs since 1972, when the Clean Water Act's National Pollution Discharge Elimination System permit program designated farms with 1,000 or more animal units (CAFOs) as "point sources" of pollution (Ogishi, Metcalfe, and Zilberman). Many argue that regulations have been ineffective in preserving water quality. Ogishi, Metcalfe, and Zilberman state that the ineffectiveness apparently stems from the faulty design of regulations and the political motivation to save family farms. Innes argues that in order for the government to prompt producer behavior that accounts for environmental costs, the government must regulate observable producer choices. These include the extent to which producers' waste storage lagoons protect against storm overflows, the number of animals that a production facility is designed to handle, and the distance between livestock facilities.

New rules in the Clean Water Act defined by the EPA in 2003 require concentrated animal feeding operations to meet nutrient application standards as defined in a nutrient management plan (Ribaudo et al.). As a result, larger livestock operations do not have adequate access to land to spread their manure under new regulations. Consequently, Metcalfe et al. note that these larger operations producing excess manure must move the manure further from the production facility and face higher manure distribution costs.

Ribaudo et al. estimated the impacts of new government regulations, shedding light on manure distribution and management costs. However, the consequences are difficult to quantify because the percent of crop producers willing to accept livestock manure and how much they are willing to pay is unknown. Many animal feeding operations already operate under narrow margins, so compliance costs can mean the difference between a profit and loss for the operation. A recent article by Ribaudo in a USDA-ERS publication stated that the compliance cost to a swine operation with more than 2500 animals could range from $1,450 to $32,500 depending on the willingness of local landowners to accept manure. Clearly, better information is needed on willingness to pay for manure.

A manure marketing survey conducted by the University of Nebraska-Lincoln (UNL) indicated that the most common financial arrangement for feedlot operations' manure removal was to give manure away at no charge (54%) (Glewen and Koelsch). Research suggests that livestock producers may underestimate the value of their manure. The UNL study found that over 30% of feedlots exporting manure received a price greater than zero for their manure application.

Similarly, a study by Metcalfe et al. during the late 90's evaluated the production practices of Oklahoma swine producers and how federal regulation affected them. The survey revealed seven respondents had either acquired permanent manure application easements on others' land or had developed long-term contracts with other landowners for manure application. Five of the seven contractual arrangements had a price of zero. Because of the small sample size, the strength of any statistical conclusions about WTP was severely limited.

Following a study by Kuriyama evaluating environmental resources, the WTP for manure will be estimated using a contingent valuation survey with a dichotomous choice question.

Although contingent valuation has been used for several years in valuing decision factors, it often falls under criticism due to the procedure's tendency to overstate WTP (Lusk). As a result, the survey and statistical analysis includes tools and procedures to decrease this hypothetical bias and ensure the strength and validity of the results. With exception to the Metcalfe et al. study and the University of Nebraska survey, little research has been dedicated to determining crop producers' WTP for manure. Thus, to provide the missing information for estimating compliance costs, crop producers' WTP must be determined to prevent additional policy failures as literature and agriculturalists cite.

**Survey Data and Methods**

The data used in this study were collected from a mail survey sent to Oklahoma crop producers in August of 2003. The producer list was obtained from an Oklahoma State University database where the recipients had previously identified a willingness to participate in surveys. As a result, the response rate was nearly sixty percent. Of the 513 surveys sent out, 292 were returned and completed.

The goal of the research is to determine the WTP of Oklahoma crop producers for livestock manure using a contingent valuation survey. The survey employed numerous factors potentially affecting the WTP for livestock manure. Producer demographics measured in the survey were crop systems managed, number of acres, types of livestock managed, past livestock manure application, annual income, and preferred time of manure application.

Most importantly, a contingent valuation question was posed. Each crop producer was given a hypothetical situation where they would save either $10 or $20 in chemical fertilizer costs. The crop producer was then provided with a specific price for the manure and asked if they would be willing to accept the manure at that given price. For producers observing a savings of $10, the price could assume a price between $-10 to $15. Surveys with savings of $20 have a potential price range of $-10 to $25, where a negative price refers to a scenario in which the producer is paid to accept manure. Only one contingent valuation question was posed in each survey.

Besides price, other attributes were randomly varied in the contingent valuation question. The manure was described as liquid swine manure, solid swine manure, or solid chicken manure. Another variant was whether the manure would be incorporated into the soil. Following the scenario, the producer could answer with “yes” indicating she would accept manure at the given price, “no” meaning she would not accept, or “no answer.” Later, the “no answer” was coded as a “no” response to help reduce the hypothetical bias as previous studies suggest (Haab and McConnell). To view a sample of the contingent valuation question and a table further defining the variables measured, please refer to Figure 1 and Table 1.

Immediately following the dichotomous choice question was a follow up question measuring an individual’s certainty of accepting the offer on a scale of 1 to 10; 10 being very certain. This was used to further discriminate against “yes” responses and reduce hypothetical bias as suggested by Champ and Bishop. It should be noted that in previous studies, such as Kuriyama, contingent valuation modeling using dichotomous choice variables tend to overstate WTP in comparison to open-ended valuation formats. Lusk notes that careful analysis must be considered in estimating and interpreting the parameter values to reduce the effects of hypothetical bias and WTP overstatement.

Preliminary research about willingness-to-pay suggests that livestock producers may underestimate the value of manure. If this is true, more crop producers would be willing to accept manure than livestock producers perceive. This would suggest greater land availability to livestock producers for manure removal relative to the location of their operation, and as Ribaudo et al. indicate, when more land is available transportation, application, and distribution (compliance) costs decline.

Conversely, crop producers understand the limited market observed by many livestock operations. As Innes suggests, without policies inducing a greater rate of adoption of manure as a fertilizer (such as an ad valorem tax on chemical fertilizer) adverse environmental incidents will continue to grow. Thus, one can infer that crop producers will hold a distinct advantage in negotiating a price for manure application. Additionally, many tangible factors reduce a crop producers' willingness-to-pay. Feinerman, Bosch, and Pease document that several factors reduce a crop producer's utility of manure when considering a fertilization strategy. Some reductions cited are variation in price, increased spreading costs and soil compaction due to the bulkiness of manure, inseparable nitrogen and phosphorus ratio, and incomplete nutrient needs for the crop. Thus, one hypothesis the study plans to test is whether the willingness-to-pay for manure is less than the value of the chemical fertilizer for which it substitutes.

A study by Koundouri, Nauges and Tzouvelekas discussing technology adoption in irrigation state that uncertainty associated with the adoption of any kind of agricultural technology has two features; first, the perceived riskiness of future farm yield after adoption; and second, production or price uncertainty related with the farming itself. Further, they note that farmers adopting new technologies have better access to farming information from various sources (e.g. newspaper television and radio, visits to farm shows, seminar attendance, demonstrations, meetings, etc). Because previous experience is a direct form of information gathering for the producer, it is believed that previous experience will have a significantly positive impact on a producer's decision to adopt new technology. For example, if a producer previously had a positive experience with manure spread on his field or witnessed a successful on-farm demonstration, she will be more likely to pay a price greater than zero.

**Procedures**

To accomplish the objective of this study, WTP will be modeled in a random utility framework. Assuming that willingness-to-pay is linear, the following model represents respondent *i*'s WTP for manure.

(1) $$WTP_i = \beta_1 + \beta_2[dummysav_i] + \beta_3[liqswine_i] + \beta_4[dryswine_i] + \beta_5[incorp_i] + \beta_6[previous_i] + \varepsilon_i = \mathrm{X}_i\beta + \varepsilon_i$$

In (1), *dummysav* represents a dummy variable where the variable takes the value one for $20 in fertilizer savings and zero otherwise. This implies that the intercept will represent the coefficient for $10 in fertilizer savings when all other variables are set to zero. The variables *liqswine* and *dryswine* represent the dummy variables for liquid swine manure and solid swine manure with dry poultry manure serving as the reference group. Dry poultry manure's coefficient would then be observed in the intercept coefficient. The variable *incorp* is a dummy variable representing whether the livestock producer incorporates the manure into the soil and *previous* is a dummy variable assuming the value of one if the crop producer has applied livestock manure to their crop within the last ten years. The term $\varepsilon_i$ is assumed to be distributed $\varepsilon_i \sim \mathrm{N}(0, \sigma^2)$.

Intuitively, a crop producer will accept manure when her WTP is greater than the manure price. Thus, if a survey indicates "yes" the WTP is greater than the price stated in the survey (WTP>P). If the answer is "no," then WTP is less than the stated price (WTP<P). Therefore, a "yes" response will be observed when

(2) $$\varepsilon_i \leq \mathrm{X}_i\beta - P_i$$

where $P_i$ represents price of manure. The equation can then be expressed in probability form representing "yes" and "no" responses as

(3) $$\text{Prob}\quad (WTP \geq P_i) = \Phi\left(\frac{X_i\beta - P_i}{\sigma}\right)$$

(4) $$\text{Prob}\,(WTP \leq P_i) = 1 - \Phi\left(\frac{X_i\beta - P_i}{\sigma}\right)$$

where $\Phi(x)$ is the standard normal cumulative distribution function, i.e. the probability that a unit normal variate is less than or equal to $x$ in this probit model. Equation (3) indicates a "yes" survey response and (4) indicates a "no" response.

The maximum likelihood function for estimating $\beta$ and the variance term is

(5) $$\ln\left(L\left(\beta_k, \sigma \mid X_i, Y_i, P_i\right)\right) = \sum_{i=1}^{N}\left[Y_i \ln\left(\Phi\left(\frac{X_i\beta - P_i}{\sigma}\right)\right)\right] + \left[(1 - Y_i)\ln\left(1 - \Phi\left(\frac{X_i\beta - P_i}{\sigma}\right)\right)\right].$$

Using a likelihood ratio test, one can conduct hypothesis tests such as whether previous experience is significantly greater than zero ($H_0$: $\beta_6 = 0$ *vs.* $H_A$: $\beta_6 > 0$). Maddala indicates that a likelihood ratio test is defined as $-2log_e\lambda$ and is distributed as a Chi-square with $k$ degrees of freedom; where $k$ is defined as the number of parameters being tested and $\lambda$ represents the maximum likelihood function value of the restricted model divided by the maximum likelihood function value of the unrestricted model.

**Results**

The demographic information gathered in the survey provided insightful information into the Oklahoma farming situation and producer practices. Across the 292 survey responses, the overwhelming majority of crop producers surveyed managed a winter wheat operation either for grain harvesting, grazing, or dual purpose. Likewise, the most common livestock operation was cow/calf. As for questions regarding manure fertilization and acceptance, 75.2% of the respondents indicated that livestock manure had not been applied to any crop or pasture they managed in the last ten years. As indicated earlier in the study, this statistic alone could be an indicator of the challenges livestock producers face in moving crop producers toward technology adoption of livestock manure as a viable chemical fertilizer substitute. Approximately three-fourths of crop producers that accept manure prefer applications after harvest and prior to planting. Also, the majority of producers prefer soil incorporation of the manure but do not have a preference for solid or liquid manure.

The model parameters were estimated by maximizing (5), using an unconstrained optimization algorithm in MATLAB. Results are shown in Table 2. Surprisingly, none of the variable were significant. The *t*-statistic for each variable, including the intercept, did not exceed the critical value of 1.96. Hence, one may believe that the actual willingness-to-pay of crop producers' may not differ significantly from zero. However, realizing that a *t*-statistic can be unreliable in non-linear models, a likelihood ratio (LR) test was determined to jointly test for coefficient and model significance. The first hypothesis test is $H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$ *vs.* $H_A: \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq 0$. At the 5% significance level, the null hypothesis was rejected because the LR critical value of 37.7756 was significantly greater than the Chi-square critical value of 12.592 with six degrees of freedom. This suggests that the average willingness-to-pay does take on a positive value.

The next hypothesis test tested whether manure type, manure incorporation, or previous experience differed from zero. The hypothesis test is: $H_0: \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$ *vs.* $H_A: \beta_3 \neq \beta_4$

$\neq \beta_5 \neq \beta_6 \neq 0$. At the 5% level of significance, we failed to reject the null hypothesis due to a Chi-square value of 1.9949 and concluded that these attributes were not significant factors in determining the price of manure. This result is interesting given the survey results previously discussed in this section. Because of the large number of producers that responded with "no preference" to liquid or solid manure and incorporation of manure it is no surprise that these values do not differ from zero.

In attempt to determine if the intercept and savings were significant, another hypothesis test was conducted. A simple willingness-to-pay model was estimated that included only the savings dummy variable and the intercept, with the results shown in Table 2. Recall that the intercept represents the savings of $10 and the *dummysav* variable is the difference in WTP observed in producers receiving $20 in savings.

(6) $$WTP_i = \beta_1 + \beta_2[dummysav_i]$$

The hypothesis that WTP equals zero was tested ($H_0: \beta_1 = \beta_2 = 0$ *vs.* $H_A: \beta_1 \neq \beta_2 \neq 0$). The null hypothesis was rejected at the 5% level of significance. The LR test statistic was significantly large (35.7806), indicating that WTP was in fact greater than zero.

Given the coefficient estimates of the estimated model and the hypothesis test results, one last hypothesis test was conducted to see if the intercept was different from ten and if the difference in savings to the crop producers from $10 to $20 was zero as indicated in the model estimation. Thus, the hypothesis test appeared as $H_0: \beta_1 = 10 \quad \beta_2 = 0$ *vs.* $H_A: \beta_1 \neq 10 \quad \beta_2 \neq 0$. We failed to reject the null hypothesis at a 5% level of significance with a LR test statistic of only 0.0916.

**Extensions in Progress**

Several extensions to the previous model are in progress. First, the normality assumption regarding the error term is modified. While many producers may be willing to accept manure at a low price, there may be some portion of producers who would require a large payment before they would accept manure. For example, a few producers may be located near residential areas where odor problems could arise, suggesting a right-skewed distribution is warranted. This is accounted for by assuming errors follow a Johnson $S_U$ distribution as described by Ramirez, Misra and Nelson.

Also, the estimates shown in Table 1. do not account for hypothetical bias. The survey included a certainty question similar to the Champ and Bishop study that allow us to calibrate hypothetical values downward (see the last question in Figure 1). Specifically, if a producer indicated "yes" she would accept manure but answered less than 8 on the certainty question, we recode her answer to "no." Finally, the variance of WTP may be conditional on previous experience with manure. Crop producers with more experience with manure will probably place more similar values on manure.

Figure 2 shows the estimated WTP distribution using the Johnson $S_U$ error distribution, the certainty calibration and a heteroskedastic assumption. Statistical tests have not been conducted to determine the impact of non-normal errors, the certainty calibration, and heteroskedasticity on WTP, but Figure 2 strongly suggests a right-skew distribution for WTP.

## Summary

Little research has attempted to measure crop producers' willingness-to-pay for livestock manure. Interestingly, this preliminary research indicates that when fertilizer savings are $10 per acre, the average crop producer will pay approximately the same price as the nutrient value of the manure. At the least, this suggests that livestock manure may potentially serve as a viable substitute for chemical fertilizer. However, there is no significant difference between willingness-to-pay for manure with savings of $10 and $20. It appears that as the savings increase, the percentage of manure value that a crop producer is willing to pay declines. Further, the current results do not indicate that manure type, form, or experience play a significant factor in a producers' decision to accept manure application. More in depth analysis will seek to explain and clarify the lack of importance of these factors in the decision process.

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**Table 1. Contingent Valuation Variables Defined**

| Variable | Definition | Range of Values |
|---|---|---|
| Manure Price (1) | Producers given a situation with savings of $10 dollars could receive a price between -$10 and $15 | -10, -9, -8, …13, 14, 15 |
| Manure Price (2) | Producers given a situation with savings of $20 dollars could receive a price between -$10 and $25 | -10, -9, -8, …23, 24, 25 |
| Fertilizer Savings *dummysav* | Dummy variable taking the value of 1 if fertilizer savings represent $20 and 0 otherwise | $20 or $10 |
| Liquid Swine Manure *liqswine* | Dummy variable taking the value of 1 to represent the qualitative characteristic of liquid swine manure and 0 otherwise | 1 or 0 |
| Solid Swine Manure *dryswine* | Dummy variable taking the value of 1 to represent the qualitative characteristic of dry (solid) swine manure and 0 otherwise | 1 or 0 |
| Manure Incorporation *incorp* | Dummy variable taking the value of 1 if producer was told manure was incorporated (sub-surface) into the soil and 0 if it was spread across the top of the ground | 1 or 0 |
| Previous Experience *previous* | Dummy variable taking the value 1 to indicate that a crop producer had spread manure on his/her land in the last ten years and zero otherwise | 1 or 0 |

**Table2. Maximum Likelihood Parameter Estimates**

| | Model A | Model B |
|---|---|---|
| | Parameter (t-statistic) | |
| Intercept | 5.1207<br>(1.0510) | 9.6746<br>(3.8632) |
| Dummysav | 1.2643<br>(0.4016) | 0.9648<br>(0.2967) |
| Liqswine | 0.8812<br>(0.2283) | ____________ |
| Dryswine | 4.3809<br>(1.0844) | ____________ |
| Incorp | 0.6435<br>(0.2056) | ____________ |
| Previous | 3.0823<br>(1.4043) | ____________ |

## Figure 1.
## Sample Contingent Valuation Question

**In the next question, we would like you to tell us how you feel about substituting livestock manure for commercial fertilizer. Studies have found that people tend to overestimate their willingness to accept or pay money in hypothetical situations. When answering the question, please consider how you would react if you actually had to pay or accept real money that could be used for other goods and services.**

**7)** Suppose your crop has traditionally received commercial fertilizer but no livestock manure. You now have the opportunity to let a nearby producer apply swine manure to your crop. With the swine manure application, you would not need to apply commercial fertilizer and would save $20 per acre in commercial fertilizer costs. The manure is of the liquid form and is incorporated into the soil.

If the livestock producer offered to pay you $6 per acre to apply manure to your crop, would you accept the offer?

☐ Yes ☐ No ☐ No Answer

8) **If you checked "No Answer"** to the previous question, was this because?

☐ Rough indifference between a "yes" or "no" answer
☐ Inability to make a decision without more information
☐ Preference for some other mechanism for making this decision
☐ Other (please explain)

**9) If you checked "Yes" to Question 7**, on a scale of 1 to 10, where 1 means "very uncertain" and 10 means "very certain," how certain are you that you would accept $6 per acre for the manure application, if actually given the opportunity? (CIRCLE ONE NUMBER)

| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|
| very uncertain | | | | | | | | | very certain |

**Figure 2.**
**Probability Distribution Function For Willingness-To-Pay For Manure**
**(savings = $10 / acre)**