Asymmetric Willingness-To-Pay Distributions for Livestock Manure

Abstract

New regulations are forcing some farms to export livestock manure to off-farm acres. The regulation compliance cost depends on the willingness of neighboring crop producers to accept or pay for the manure. This study estimates a manure willingness-to-pay distribution for crop producers using a contingent valuation mail survey. A flexible parametric distribution is borrowed from the crop yield literature, which shows that manure willingness-to-pay is left-skewed. Most crop producers will pay a positive price close to the savings in commercial fertilizer, but approximately 25% require a payment before accepting manure.

Asymmetric Willingness-To-Pay Distributions for Livestock Manure

The last two decades have ushered in new regulations on how animal feeding operations handle manure. Virtually all livestock manure is applied to crops after some period of storage and treatment. Manure is costly to transport, and if unregulated, many livestock operations would choose to over-apply manure close to the farm. Continuous over-applications of manure lead to nutrient runoff, polluting surface and ground waters. In response, new regulations have been passed to minimize nutrient runoff by requiring manure applications to be consistent with crop uptake.

While many states have passed their own regulations, the Environmental Protection Agency's Concentrated Animal Feeding Operations rule (hereafter, CAFO rule) has received the most attention. The new CAFO rule regulates more livestock operations, and is more specific in how those farms must apply manure. For example, the CAFO rule states, "*Today's rule requires Large CAFOs to determine and implement site-specific nutrient application rates that are consistent with technical standards...The permitting authority may use the USDA Natural Resource Conservation Service (NRCS) Nutrient Management Conservation Practice Standard, Code 590*" (Federal Register, page 7209).

The NRCS Code 590 provides three options for applying manure to land, each of which can be described generally as follows. First, the nitrogen application must not exceed the nitrogen needs of the crop.[1] Second, since the phosphorus-to-nitrogen ratio in manure is generally higher than the ratio consumed by crops, supplying all the crop's nitrogen needs with manure results in a buildup of phosphorus in the soil. If the soil phosphorus buildup becomes too large, producers must either reduce their per acre application rate or temporarily cease manure applications (National Resource Conservation Service).

As regulations force the per acre application rate of manure to fall, more acres are needed to dispose of the same amount of manure. For farms that are limited in land, manure must be exported to off-farm acres. This typically involves a livestock producer transporting manure to another livestock or crop producers' land for application. To avoid confusion with the terms "livestock producer" and "crop producer", we refer to the exporter of the manure as the *deliverer* and the importer of manure as the *receiver*. Please note that in some cases the deliverer may pay the receiver to accept the manure, in which case the price is negative. In the Southeastern United States, surveys have found that 40% of swine farms may be land constrained (Carter-Young et al.) under new CAFO regulations. Similar results have been found for Oklahoma (Oklahoma State University 2004). Since the transportation costs of manure are large, these land-constrained farms will face the highest compliance costs.

The new regulations have received much debate, mainly regarding their benefits and costs, both of which are difficult to estimate. Many studies have focused on estimating the costs of new manure management standards to livestock farms (Feinerman, Bosch and Pease; Fleming and Long; Economic Research Service; Environmental Protection Agency). Estimating compliance costs require assumptions about farm types, transportation costs, nutrients generated in manure, cropland surrounding the farm and the willingness of neighboring crop producers (receivers) to pay for or accept manure. This last item—willingness of receivers to pay for manure—is the item in which the least is known. As no study has measured receivers' willingness-to-pay for manure, studies must employ best-guesses about whether deliverers must pay to export manure or whether they will receive a positive price for the manure. For example, the Environmental Protection Agency assumed all receivers would accept manure but would neither require a payment nor pay for the manure. Transportation costs of manure were then estimated based on the surrounding cropland area (Environmental Protection Agency).

In a similar study, the Economic Research Service also assumed receivers would not require a payment nor would they pay for manure, but allowed the percent of receivers accepting manure to vary. The authors state that "Crop producer willingness to accept manure has a profound impact on net costs" (Economic Research Service, page 20). When less than 10% of receivers were willing to accept manure, costs for hog farms were as high as $20 per animal unit, but when this percentage approached 100% costs turned negative (positive profits were made from complying with the regulations). In a study of dairy and poultry farms, Feinerman, Bosch and Pease calculated costs assuming 50%, 75% and 100% of receivers would accept manure, where the price receivers pay depends on the nutrient content of the manure and the price of commercial fertilizer.

Clearly, research is needed on the willingness of receivers to pay for livestock manure and the factors that enhance the marketability of manure. Two items are of particular interest. First is the percent of receivers that would accept manure at a price of zero. The second relates to the substitutability of manure for commercial fertilizer. Often, as in Feinerman, Bosch and Pease, studies assume that if a receiver will accept manure, she will pay the full "nutrient value", which is essentially the savings in commercial fertilizer. Yet, there are many reasons why receivers may not view manure as a perfect substitute for commercial fertilizer. Manure may contain undesirable foreign material, be associated with an undesirable odor, alter the soil PH and may release nutrients at a different rate, leading receivers to discount manure relative to commercial fertilizer. Receivers may also associate manure with greater regulation and environmental problems.

Conversely, manure contains organic material, providing more than just nitrogen, phosphorus and potassium, inducing a premium over commercial fertilizers. What portion of the commercial fertilizer savings will receivers pay for manure, and how does this portion vary across the population of receivers? What portion of receivers must receive a payment (pay a negative price) before accepting manure? This study answers these questions using a contingent valuation analysis of Oklahoma receivers.

This research estimates a probability distribution of manure willingness-to-pay (WTP) across receivers, where WTP is negative if the receiver requires a payment before accepting manure and is positive if she will pay for the manure. Most surveys eliciting WTP contain discrete dependent variables, which are subsequently analyzed using probit or logit models, both of which assume that WTP is symmetrically distributed.

In the case of manure, assuming symmetry in the WTP distribution may not be valid. Conversations with swine producers in North Carolina and Oklahoma reveal that they believe most receivers will pay a small price for manure or accept it for free, but a significant portion requires a payment before accepting manure. Indeed, in a survey of thirty-six Oklahoma swine farmers, 64% said manure buyers would not require a payment nor would they pay for manure (i.e. WTP = 0), 28% said buyers would require a payment to accept manure and 8% of buyers would pay a positive price for manure. This suggests that WTP for manure is left-skewed, with the mass of the WTP distribution at a low price but a left-tail extending over negative WTP values (Oklahoma State University 2004).

For these reasons, assuming a normal or extreme-value distribution for WTP may not be valid, yet we do not wish to impose a left-skew distribution either. Swine producers' perceptions may be wrong, and WTP could instead be symmetric or right-skewed. Thus, the WTP distribution used should be flexible, allowing skewness to be estimated directly from the data. In a review of the literature, little work has been conducted on parametric WTP distributions that allow asymmetry of either direction. Occasionally a log-normal or exponential distribution is used (Lusk), but this is usually to avoid negative WTP values and would impose a specific type of skewness. However, a large volume of research has been conducted on asymmetric distributions in the crop yield literature that can easily be extended to the stated preference area.

In particular, the Johnson S_U (JS_U) distribution initially developed by Ramirez and later refined by Ramirez, Misra and Nelson is appealing. The JS_U form allows for left-skewed, right-skewed or normal distributions, the decision of which is data-driven. The usefulness of the JS_U model is further enhanced by the fact that, even when the distribution is non-normal, the mean and variance of WTP follows simple deterministic equations, allowing for easier interpretation of parameters.

This study demonstrates how the JS_U distribution can be extended to discrete dependent variables and used to provide WTP estimates. When extended to the manure case, the JS_U model rejects normality and favors a left-skewed distribution. Results show that assuming normality would over-predict the true WTP for livestock manure, thereby underestimating manure regulation compliance costs. Finally, a simple method for incorporating the WTP estimates into manure management cost models is provided, which hopefully will lead to more accurate manure regulation compliance cost estimates. The next section provides a description of the survey data, and is followed by a methodology and then a results section. The last section provides a summary and discussion.

Survey Data

In August of 2003, a stated preference survey was mailed to 513 crop producers in Oklahoma. The database of producers had been maintained by Oklahoma State University for many years and was used to conduct surveys on rental rates of agricultural services. Producers on this list originally agreed to be in a mailing list, so they represent producers who are more willing to respond to surveys than the general population. This introduces a sample selection bias, where the direction of this bias is unknown. Most crop producers also managed a cow-calf and/or stocker operation. Very few raised swine, sheep, poultry or dairy cattle, and most of those that did probably used them for youth livestock shows.

The purpose of the survey was to measure crop producers' (receivers') willingness-to-pay for manure from other livestock farms. Eliciting the demand for manure through simple survey questions is a difficult task, as the good "manure" is not well-defined. Manure varies substantially in its moisture and nutrient content, odor, organic material and temporal availability across and even within a livestock species. Also, the nutrients contained in manure may be released more slowly than commercial fertilizers, which may positively or negatively influence crop yields. Many of the complexities of manure demand were eliminating by using a contingent valuation question as shown in figure 1.

Receivers were told that the manure would be applied to their crop by the livestock producer (deliverer). This eliminates the need to discuss transportation costs. The value of manure relates directly to its ability to substitute for chemical fertilizer. As chemical fertilizer savings rises and falls, we would expect the value of manure to rise and fall accordingly. To gauge receivers' willingness-to-pay for manure, it is imperative that they be given information on chemical fertilizer savings. Receivers were told that with the manure application, they would save a certain amount on commercial fertilizer costs. This eliminates the need to discuss the crop type or nutrient content of the manure. The amount of fertilizer savings varied randomly across each survey as $10 per acre and $20 per acre. This range was chosen because commercial fertilizer costs for wheat, the major Oklahoma crop, are estimated to be around $16 per acre (Oklahoma State University 2003). Receivers were then asked one of two questions (1) if they would accept the manure if given a certain payment or (2) if they would pay a certain amount for the manure. Each survey had an equal chance of containing each question.

The "price" of the manure on each survey could then take a negative value if the receiver was told she would receive a payment and a positive value if the respondent was told she must make a payment to receive the manure (see table 1). This allows us to model the distribution of willingness-to-pay (WTP) as taking on positive and negative values. The amount a receiver could be paid for accepting manure was chosen from a uniform distribution between $10 and $1 per acre, while the price a receiver would have to pay varied from $0-$15 per acre if the fertilizer savings were $10 per acre and $0-$25 per acre if the per acre fertilizer savings were $20.

The manure was described as either (1) dry swine manure (2) liquid swine manure or (3) dry poultry manure. The manure may or may not be tilled into the soil. Each manure and tillage option had an equal chance of appearing on any given survey. See table 1 describing the contingent valuation variables used in the survey. When asked if they would accept the manure receivers could respond stated "yes" they would accept the manure at the price listed in the survey, "no" they would not accept the manure or "no answer." The "no answer" option was administered as suggested by the NOAA panel guidelines for value elicitation, which is described in Haab and McConnell and shown in figure 1. Since the receiver simply responds "yes", "no" or "no answer" to one hypothetical opportunity, this is a dichotomous choice question, which is the preferred tool for contingent valuation (Haab and McConnell).

The value receivers place on manure is revealed through their answers to the dichotomous choice questions. Suppose a receiver is told the manure application would save her $20 per acre in chemical fertilizer costs, and she can purchase the manure for $10 per acre. If she indicates "no" she would not purchase the manure, this implies she values the manure at less than $10 per acre, and places a discount on manure more than $10 per acre, relative to chemical fertilizer. Similarly, if she indicates "yes" she would purchase the manure at $20 per acre, this implies that she assigns manure no discount relative to chemical fertilizers.

There are many reasons why a receiver would give a discount to manure. While interpretation of the dichotomous choice question will vary across surveys, pretests suggested receivers would interpret the fertilizer savings as the additional per acre monetary expenditures that would have been made for the current crop year without manure.[2] It was not interpreted to include any discounted savings from future years. Pretests also revealed that some thought yield may differ with livestock manure, even if the same nutrient application was made, but that the yield difference would not be "too large." Some receivers may feel that yields will be lower when the same amount of nutrients are applied through manure instead of chemical fertilizer, and the price of manure must be less than fertilizer savings before they would accept it.

Receivers may also be concerned with odor; compaction of soil from the manure application equipment; pathogens, plant diseases, weeds and pests transported with the manure and concerns about regulatory oversight may also cause WTP to be less than fertilizer savings. On the other hand, manure may release nutrients more slowly than chemical fertilizers, and may contain organic materials and trace elements that enhance the soil fertilizer, and making manure more desirable than chemical fertilizer.

The price a receiver will pay for manure may depend on her experience with manure applications. Manure may receive a high discount for receivers who have only used commercial fertilizer, due to the uncertainty of manure performance as a fertilizer. But over time, if the manure nutrients prove effective, they would pay a higher price. The survey contained a question that allow us to identify which respondents have applied manure to their crop in the past. The variance of willingness-to-pay may be lower for those with manure experience as well.

Stated preference surveys are always subject to hypothetical bias. Receivers may find it easy to say they will pay for manure, but when real money is involved their enthusiasm wanes. Two safeguards against hypothetical bias were included. First, a short cheap talk script was administered where hypothetical bias was described to the receiver (as shown in figure 1). The receiver was then asked to try to avoid the hypothetical bias. The cheap talk script has been shown to eliminate hypothetical bias in some situations, and almost always reduces stated values. (Cummings and Taylor; Lusk).

Second, the discrete choice question was followed with a certainty question, as shown in figure 1. If the receiver stated "yes" she would accept the manure at the listed price, she was asked to indicate on a scale of one to ten how certain she was that she would accept the manure at the listed price if actually given the opportunity. An answer of one refers to "very uncertain" while an answer of ten refers to "very certain." A lower certainty rating has been shown to induce greater hypothetical bias (Johannesson et al.). Moreover, Champ and Bishop eliminated hypothetical bias by changing “yes” answers to “no” if the subject responds “yes” to the hypothetical question but indicates a certainty level less than eight. In this study, some models are calibration using the Champ and Bishop method. While further studies are needed to fully validate these two methods, we believe that they are the best available methods for addressing hypothetical bias.

A total of 513 surveys were administered. With 294 surveys returned, we experienced a very high response rate of 57%. This high response rate is likely attributable to the brevity of the survey and the fact that the database contained receivers who at one time indicated they were willing to participate in Oklahoma State University surveys. Those who indicated “No Answer” to the discrete choice question were recoded as a “No” (Haab and McConnell). After eliminating surveys that did not provide answers the discrete choice question, 288 surveys remained.

Estimation Methodology

Data from the survey described in the previous section are used to estimate a manure willingness-to-pay function. The estimation methodology is similar to that of Lusk and Qaim and De Janvry. The decision to accept or not accept manure is modeled as a random utility function in money-metric form, such that a utility of one corresponds to one dollar. Willingness-to-pay (*WTP*) for manure for respondent i is given by

(1) $WTP_i = X_i\beta = \beta_0 + \beta_1 SAVINGS_i + \beta_2 DRYSWINE_i + \beta_3 LIQUIDSWINE_i +$

$\beta_5 INCORPORATE_i + \beta_6 PREVMANURE_i + \varepsilon_i.$

In (1), *SAVINGS* is a dummy variable that equals one if fertilizer savings are \$20 per acre and zero otherwise. The intercept β_0 then refers to WTP when saving are \$10 per acre, and $\beta_0 + \beta_1$ is the WTP when savings are \$20 per acre, assuming all other variable values are zero. The variables *DRYSWINE* and *LIQUIDSWINE* are dummy variables for dry swine manure and liquid swine manure, with dry poultry manure constituting the baseline. The variable *INCORPORATE* is a dummy variable for when the respondent is told the manure is incorporated into the soil by the livestock producer (deliverer) and *PREVMANURE* is a dummy variable for receivers who have applied livestock manure to their crop(s) within the last ten years.

The random error ε_i is expected to be heteroskedastic and skewed. Receivers who have applied manure in the past may display more homogenous preferences, so the variance of the error term is stated as

(2) $E(\varepsilon_i^2) = (\alpha_0 + \alpha_1 PREVMANURE)^2$.

Typically, the distribution of ε_i is assumed to take the extreme-value or the normal distribution. This study uses a non-normal distribution for ε_i where the skewness is determined by the data, the function in (1) still denotes the expected WTP and the function in (2) still denotes the variance of WTP. The Johnson S_U distribution described by Ramirez, Misra and Nelson meets these requirements well. This distribution assumes the ε_i is a transformation of normality, with the specific transformation being

$$\begin{aligned}
&\varepsilon_i = WTP_i - X_i\beta = \frac{\sigma\{\sinh(\Theta V) - F(\Theta,\mu)\}}{\Theta G(\Theta,\mu)} \\
&V \sim N(\mu,1) \\
(3)\quad &F(\Theta,\mu) = \exp(\Theta^2/2)\sinh(\Theta\mu) \\
&G(\Theta,\mu) = \left[\frac{\{\exp(\Theta^2)-1\}\{\exp(\Theta^2)\cosh(-2\Theta)+1\}}{2\Theta^2}\right]^{1/2} \\
&\sigma = \alpha_0 + \alpha_1 PREVMANURE
\end{aligned}$$

where sinh(.) and cosh(.) are the sine and cosine function, respectively. This model is exactly as described in Ramiriz, Misra and Nelson, so most of the details can be found there. As Ramirez, Misra and Nelson show, the beauty of this error distribution is that WTP_i can be skewed to the right or the left and it can exhibit kurtosis, both of which are determined by the parameters Θ and μ. Kurtosis is increasing in the absolute value of Θ (the sign of Θ is irrelevant), and a positive (negative) μ implies a right-skew (left-skew) distribution. The expected value of ε_i is zero and its variance is still given by (2).

The estimation method must be modified from Ramirez, Misra and Nelson to accommodate discrete dependent variables. Let P_i be the price of manure on the i^{th} survey, which can be negative if the receiver is offered a payment to accept the manure. A person answers "yes" she will accept manure whenever $WTP_i > P_i$ or $\varepsilon_i > P_i - X_i\beta$. The probability of a yes response then equals

$$(4)\quad \Pr\left(WTP_i > P_i\right) = 1 - \int_{-\infty}^{P_i - X_i\beta} \varphi\left(\frac{V-\mu}{1}\right)\left(\frac{dV}{d\varepsilon}\right)d\varepsilon$$

where φ is the standard normal probability distribution function. The term $\left(\frac{dV}{d\varepsilon}\right)$ can be solved for by first letting $\sinh(\Theta V) = \varepsilon\frac{\Theta G(\Theta,\mu)}{\sigma} + F(\Theta,\mu) = A$. Using the formula for the inverse hyperbolic sine function, V can then be expressed as $V = \ln\left(A + \sqrt{A^2+1}\right)/\Theta$. Taking the derivative of V with respect to ε then allows us to write (4) as

$$(5)\quad \Pr\left(WTP_i > P_i\right) = 1 - \int_{-\infty}^{P_i - X_i\beta} \varphi\left(\frac{V-\mu}{1}\right)\left(A + \sqrt{A^2+1}\right)^{-1}\left(1 + 0.5\left(A^2+1\right)^{-1/2}2A\right)G(\Theta,\mu)\sigma^{-1}d\varepsilon\,.$$

While (5) contains a highly non-linear integral, the *quadl* numerical integration tool in MATLAB is able to integrate it well. The log-likelihood function can then be constructed as

$$(6)\quad LLF = \sum_{i=1}^{N} Y_i \ln\left(\Pr\left(WTP_i > P_i\right)\right) + \sum_{i=1}^{N}\left(1 - Y_i\right)\ln\left(1 - \Pr\left(WTP_i > P_i\right)\right)$$

where Y_i equals one if the respondent indicates she would accept the manure application and zero otherwise. The log-likelihood function was maximized using the unconstrained optimization algorithm *fminunc* in MATLAB. Due to the non-linearity of the objective function, extra care must be taken to ensure the solution is optimal. Parameter estimates were sensitive to starting values, especially those of Θ and μ, so fifty randomly generated starting values were used to identify the optimal parameters.

Estimation Results

See table 2 containing the maximum likelihood estimates of four models. The first model (second column) constrains Θ and μ to equal zero, which amounts to assuming normality in WTP. This model is uncalibrated, which means the survey responses were not modified based on the subject's answer to the certainty question. The non-normal-uncalibrated model in the third column is the same except that the values of Θ and μ are unrestricted, allowing a normal, left-skewed or right-skewed WTP distribution. The fourth column contains estimates for the non-normal-calibrated model, where all "yes" answers are changed to "no" if the person indicated a certainty level less than eight.[3] Finally, the fifth column is referred to as a non-normal-composite model and, as will be discussed, provides a weaker calibration that is akin to a composite model.

The regression results for mean willingness-to-pay (WTP) are interpreted as follows. The intercept indicates receivers' per acre WTP for dry poultry manure when commercial fertilizer savings are \$10 per acre. The dummy variables *DRYSWINE* and *LIQUIDSWINE* show how WTP changes for dry swine and liquid swine manure, respectively. The increase in WTP when commercial fertilizer savings increase \$10 to \$20 per acre is given by the coefficient on

SAVINGS. *INCORPORATE* shows the effect on WTP when manure is incorporated into the soil (without charge) and *PREVMANURE* illustrates the difference in WTP for receivers who have previously applied manure from other livestock farms.

First, compare the parameter estimates from the uncalibrated normal and non-normal models (columns 2 and 3). The asymptotic test-statistics for Θ and μ in the non-normal model indicate that they are indeed different from zero, leading us to reject normality in favor of a left-skewed distribution.[4] The difference between the two distributions is stark, as demonstrated by figure 2. At a savings of \$15 per acre, figure 2 shows that the normal model says some receivers will pay more than \$40 per acre, while the non-normal model has a maximum WTP close to \$20. It is very unlikely that buyers would assign a large premium to manure over commercial fertilizer, so clearly the non-normal model's predictions are better in this respect.

The intercept in the normal model is much larger than the non-normal model, implying its mean WTP estimate is larger. Since Wald tests favor the non-normal model, we conclude that the assumption of normality in this case would lead to an overestimation of true WTP. This naturally leads to an underestimation of manure regulation compliance costs. The non-normal model only requires estimation of two additional parameters, and even though estimation entails numerical integration at each observation, today's computers provide fast convergence (less than five minutes). Thus, in instances when normality is questionable, one should consider using the more flexible JS_U distribution.

The remainder of this section focuses on the results of non-normal models only, with particular attention to developing accurate WTP estimates. The uncalibrated [non-normal] model suggests dry swine manure is the most marketable manure, while the calibrated model has no clear preference for dry swine or dry poultry manure. In both models liquid swine manure is discounted by approximately $4.50-$5.00 for each acre the manure is applied. The fact that manure is incorporated has no significant impact on WTP, while previous experience with manure significantly increases WTP. The calibrated model—less subject to hypothetical bias—will have a lower mean WTP by construction. In this case, mean WTP is reduced by approximately $18 per acre—a substantial reduction.

Notice that the calibrated model produces some results more consistent with *a priori* expectations. There is little reason to suggest dry swine manure is better than poultry manure, holding the nutrient content constant, and the calibrated model reflects this. Also, it was expected that receivers with previous manure experience would display less WTP variance—the calibrated model reflects this as well. However, the calibrated model does not reflect the expectation that WTP should increase with fertilizer savings.

Both the calibrated and uncalibrated models place an upper bound on WTP at $18-$25 per acre when fertilizer savings are $15 per acre (see figure 2). Some receivers do indeed place a premium on manure relative to commercial fertilizers. Of the 288 subjects, 13 indicated they would pay a price higher than the fertilizer savings, and seven of those indicated a certainty level of eight or more. While some receivers place a premium on manure, other receivers place a discount. The distribution of WTP across receivers contains many receivers who require a payment before accepting manure.

However, due to imperfect survey design, all the models discussed thus far likely overestimate both the number of receivers who assign this discount and the size of the discount. Prior to administering the survey, almost all subjects were expected to accept manure if paid $10 per acre, and pretests supported this expectation. Although all seven subjects who were offered a hypothetical payment of $10 per acre accepted it, three subjects rejected a hypothetical payment of $9, and four rejected a payment of $8. This forces the left-tail of the distribution to the left of -$10. A larger survey with a wider range of payments is needed to better identify the lower bound for WTP. Until this larger survey is conducted, the only remedy is to truncate the WTP distributions from below.

Two adjustments are made to the uncalibrated and calibrated models to provide a final WTP distribution. First, a composite model is constructed from the two models by providing a weaker calibration. In the calibrated model, "yes" answers accompanied by a certainty level less than eight were recoded as "no". This essentially assumes that researchers believe that these people are lying when they say yes, and their value of Y_i is changed from $Y_i = 1$ to $Y_i = 0$. In the composite model, instead of changing $Y_i = 1$ to $Y_i = 0$, we recode the data as $Y_i = 0.5$. This is akin to assuming that there is a 50% chance that those who say "yes" but have a certainty level less than eight are lying. This composite is constructed under the perception that the calibrated model under-predicts WTP (given its extended left-tail shown in figure 2). In fact, other studies have demonstrated situations where this calibration provides downward-biased estimates of true WTP (Blumenschein et al.; Norwood). Since uncalibrated models are upward-biased, this composite model should better describe true WTP.[5]

The parameter estimates for the composite model are shown in the last column of table 2. Next, this composite model is truncated from below, under the pretense that no receiver would require a payment in excess of $20 per acre to accept manure.[6] This composite-truncated distribution is illustrated at the bottom of figure 2. Next, the composite-truncated model is used to provide a simple framework for incorporating WTP estimates in manure management cost models. The composite-truncated model is used because it accounts for hypothetical bias, contains bounds on WTP--which to us appear reasonable--and have coefficients which display desirable properties in an engineering-cost model. See table 3 where the WTP distribution is divided into intervals of WTP. The WTP distributions are listed for two values of fertilizer savings: $15 and $25 per acre. Savings of $15 per acre is between the two values of savings used in the survey of $10 and $20, while savings of $25 entails extrapolating outside the range of data. Assuming that fertilizer savings are $15 per acre, 25% percent of receivers require a payment before accepting manure, and 23% have a positive WTP, but will not pay the full fertilizer savings. Approximately 35% of receivers are in the $10-$20 interval which contains fertilizer savings, implying that most receivers would not assign a large discount or premium to manure. Finally, 17% of receivers are willing to pay a premium for manure.

Next, the distribution of WTP is shown for the case where fertilizer savings equal $25 per acre. This is extrapolating outside the data, as the largest savings were $20 per acre. This shows the WTP distribution does shift towards the right, but the shift is not very large, as the percent of receivers requiring a payment before they accept manure decreases from 25% to only 20%. Manure will usually be applied such that the manure nutrients supply the crop nutrients needs for at least one year. For most crops, this will save the receiver between $10 and $25 per acre. For example, crop budgets suggest the yearly per acre fertilizer costs for wheat, corn, alfalfa and grain sorghum are $16.68, $19.03, $20.50, $9.50, respectively (Oklahoma State University 2003). Thus, table 3 can be used to provide simple WTP estimates for manure for most crop enterprises.

Summary and Discussion

While many studies have focused on measuring the cost of complying with new manure management regulations, no study has of yet estimated the crop producers' willingness-to-pay

(WTP) for other farms' livestock manure. This study conducted a contingent valuation analysis of manure WTP across Oklahoma crop producers (receivers). Typically, studies assume symmetric distributions for WTP, whether it be an extreme-value or normal distribution. In this case, the prior expectation is that WTP is asymmetric, with the bulk of evidence pointing towards a left-skewed distribution. To allow skewness to be determine by the data, a flexible distribution developed by Ramirez and Ramirez, Misra and Nelson in the crop yield literature was modified for use in WTP estimation.

Receivers were given a hypothetical situation where they could allow a manure application to their crop, where this manure application would save them $10 or $20 per acre in chemical fertilizer costs. Receivers were then asked if they would purchase the manure at a given price, or accept it if paid a given amount. A certainty question and cheap talk script was used to correct for hypothetical bias.

Hypothesis tests reject normality in favor of a left-skewed WTP distribution. The distribution of WTP was centered around fertilizer savings for most receivers, but a significant portion of receivers had a negative WTP. Assuming that the non-normal model is indeed superior, the assumption of normality would overestimate true WTP. Liquid manure was discounted relative to dry manure. If the manure is applied at agronomic rates, liquid manure decreases mean WTP by about $4-$5 per acre. Results suggest livestock producers (deliverers) wishing to export manure should try to identify receivers who have previously accepted manure, as they demonstrated a greater WTP for manure.

Much research has focused on how compliance costs for new manure management regulations may vary across farms. Land availability and the willingness of receivers in the surrounding area to accept manure are two key variables explaining variations in compliance costs. Until now, no study has measured the variability in WTP for livestock manure. This study provides a complete WTP distribution researchers can use to capture the lower and upper bounds on compliance costs across regions. Results show that preferences for manure are heterogeneous. Many receivers are not only willing to accept livestock manure, but a portion will pay a premium over commercial fertilizers. However, a significant portion of receivers are very wary about accepting manure, and may require a large payment before they are willing to accept it. The good news for livestock farms is that once receivers have experience with manure, their willingness-to-pay for manure rises.

This introduces a dynamic element into manure management. If a receiver finds little initial demand for her manure, she can pay to have the manure accepted on off-farm acres. Then, once the manure receiver gains experience with manure as a fertilizer, she may be able to negotiate a higher price in the future. Lastly, results suggest that researchers should pay more attention to non-normality in non-market valuation. It would be desirable for popular software packages to incorporate the Johnson S_U distribution as a standard program, so that non-normality can be easily tested before WTP estimates are published.

Footnotes

1. The nitrogen needs of a crop is always greater than the nitrogen removed at harvest. Thus, there is always some nitrogen that was applied but not harvested. Nitrogen needs are defined here as the nitrogen *application* required to achieve a targeted yield.

2. The pretests included approximately twenty students who had some managerial oversight on a crop farm.

3. That is, if a subject said "yes" she would purchase the manure at the listed price, but gave an answer to the certainty question shown in figure 1 less than eight, this answer was changed to "no."

4. As Ramirez, Misra and Nelson explains, likelihood ratio tests cannot be used for the joint hypothesis $\Theta = \mu = 0$ because the model under the null hypothesis contains a nuisance parameter. While Wald tests are sometimes discouraged due to their sensitivity to scaling, note that all of the explanatory variables are dummy variables, making the scaling issue moot.

5. This composite model can be alternatively derived as follows. Consider the log-likelihood function value for an individual observation $LLF_i = Y_i \ln(\Pr(WTP_i > P_i)) + (1 - Y_i)\ln(1 - \Pr(WTP_i > P_i))$. Suppose this observation is such that $Y_i = 1$ but the subjects' certainty level is less than eight. In the uncalibrated model this formula is $(1)\ln(\Pr(WTP_i > P_i)) + (0)\ln(1 - \Pr(WTP_i > P_i))$ and for the calibrated model is $(0)\ln(\Pr(WTP_i > P_i)) + (1)\ln(1 - \Pr(WTP_i > P_i))$. If one constructs a composite likelihood function

that equals $LLF_{Composite} = (0.5)\ LLF_{Calibrated} + (0.5)\ LLF_{Uncalibrated}$, this is exactly that same as changing $Y_i = 1$ to $Y_i = 0.5$ when the certainty level is less than eight.

6. Let F(WTP) be the cumulative distribution function for WTP. The new truncated cumulative distribution is calculated as F(WTP) / [1 – F(-20)].

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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 per acre could receive a price between -$10 and $15	-10, -9, -8, ... , 0 , …13, 14, 15
Manure Price (2)	Producers given a situation with savings of $20 dollars per acre could receive a price between -$10 and $25	-10, -9, -8, ... , 0 , …23, 24, 25
Fertilizer Savings *SAVINGS*	Dummy variable taking the value of 1 if fertilizer savings are $20 per acre and 0 otherwise	$20 or $10
Liquid Swine Manure *LIQUIDSWINE*	Dummy variable taking the value of 1 to represent the qualitative characteristic of liquid swine manure and 0 otherwise (dry poultry manure is the omitted manure dummy variable)	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 (dry poultry manure is the omitted manure dummy variable)	1 or 0
Manure Incorporation *INCORPORATE*	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 *PREVMANURE*	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

Table 2. Manure Willingness-To-Pay Parameter Estimates

	Normal-Uncalibrated Model	Non-Normal Uncalibrated Model	Non-Normal Calibrated Model	Non-Normal Composite Model
	Parameter Estimates (t-statistic)			
Mean Equation				
INTERCEPT	7.8374***	-3.5917***	-21.5799***	-17.1003***
	(6.17)	(-2.74)	(-6.00)	(-10.60)
SAVINGS	2.2207**	5.8230***	1.1093	3.7668***
	(2.27)	(2.95)	(0.35)	(3.08)
DRYSWINE	3.0924***	2.5356**	-0.5927	1.3940
	(2.68)	(2.05)	(-0.36)	(1.16)
LIQUIDSWINE	-1.8434	-4.5469***	-4.9533***	-4.0473***
	(-1.42)	(-2.74)	(-4.56)	(-3.77)
INCORPORATE	1.3543	-0.8054	-1.7895	-0.0751
	(1.38)	(-0.69)	(-1.61)	(-0.1066)
PREVMANURE	3.1619***	2.4091**	6.7174***	7.6883***
	(2.25)	(2.06)	(3.74)	(7.19)
Variance Equation				
INTERCEPT	19.6416***	44.4976***	59.2469***	61.2823***
	(9.78)	(43.41)	(48.17)	(52.85)
PREVMANURE	2.7876***	0.6534	-3.9313***	-3.5721***
	(2.42)	(0.63)	(-4.02)	(-3.53)
Non-Normality Parameters				
Θ (leptokurtic)	-------------	1.2860***	-0.9861***	-1.0949***
		(12.35)	(-13.36)	(-9.65)
μ (leptokurtic and skewness)	-------------	-3.2878***	-4.0612***	-4.1731***
		(-3.00)	(-3.22)	(-4.20)
Log-Likelihood Function Value	*-172.3516*	*-167.9530*	*-175.1672*	*-180.82*
Sample Size	*288*	*288*	*288*	*288*

***, ** and * denote significance at the 1%, 5% and 10% level.

Table 3. Willingness-To-Pay Distribution Using the Truncated-Composite Model For Dry Manure

Per Acre Maximum Willingness-to-Pay is Between	Percent of Producers When Savings = $15 Per Acre	Percent of Producers When Savings = $25 Per Acre
-$20 and -$10	10%	8%
-$10 and -$0	15%	12%
$0 and $10	23%	19%
$10 and $20	35%	30%
$20 and $30	17%	31%

Notes: Assumes 25% of producers have previous experience with manure. This distribution is estimated using the composite model estimates from table 3, where WTP is truncated from below at -$20. For a savings of $15 ($25) per acre, the value of *SAVINGS* is set to 0.5 (1.5).

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

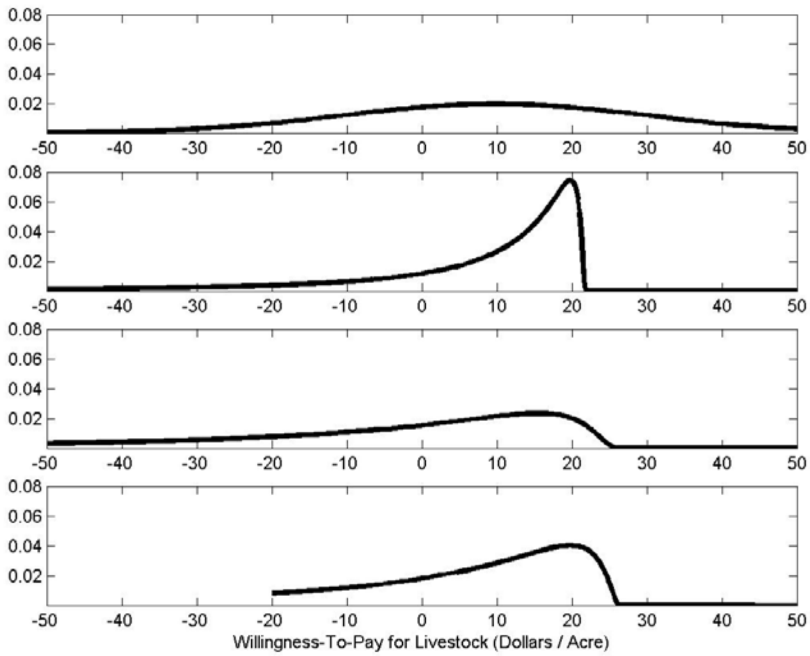
8) **If you checked "No Answer"** to the previous question, was this because?

☐ 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 1. Sample Contingent Valuation Question



Uncalibrated Normal Model (not truncated)

Uncalibrated Non-Normal Model (not truncated)

Calibrated Non-Normal Model (not truncated)

Composite Non-Normal Model (Truncated Above -20)

Figure 2. Manure Willingness-To-Pay Probability Distribution Functions

Notes: The value of *SAVINGS* and *PREVMANURE* in table 1 is set to 0.5 and 0.25, respectively. All other explanatory variables are set to zero. This assumes dry poultry manure, not incorporated in the soil, which saves the producer $15 in chemical fertilizer costs. It also assumes the producer has a 25% chance of having experience with manure.