

# **Valuation of Water Quality in Livestock Regions: An Application to Rural Watersheds in Iowa**

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Proposed Running Head: Valuing Water Quality in Livestock Regions

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**ABSTRACT**

This paper investigates rural residents' perceptions of the risk to water quality from large confinement facilities and their willingness to pay to delay nitrate contamination from these facilities. Rural residents are concerned about the environmental impact of confinement facilities and are willing to pay as much as \$82 annually to delay nitrate contamination in their water for 20 years. These contingent valuation results are consistent with the result obtained in similar studies that used hedonic valuation methods.

**Key Words:** contingent valuation, livestock production, nitrate contamination, rural development, water quality.

## **Introduction**

Value-added agriculture in the form of increased livestock feeding is often touted as a viable development strategy for rural, agriculturally dependent areas. Economic impact studies have suggested that livestock expansion strategies have the potential to add new jobs and incomes in rural areas (Hayes, Otto and Lawrence, 1996). In the case of the pork industry, which is currently experiencing dramatic structural change, any major expansion is likely to be in the form of a large-scale confinement production. These operations can be as large as 3,500 sows and have feeding facilities for as many as 75,000 hogs per year. These large-scale facilities can produce abundant amounts of manure and odor, creating a nuisance for nearby residents. In addition, several highly publicized spills at facilities in North Carolina and Iowa, and recent reports indicating a higher potential for groundwater contamination in Iowa (Perry, 1996) have reinforced the concerns about the vulnerability of water resources to nitrate runoff from hog waste.

Recent studies have attempted to quantify the external costs of large-scale livestock production with somewhat mixed results. Studies from North Carolina (Palmquist, Roka, and Vukina, 1997) and Michigan (Abeles-Allison and Connor, 1990) indicate adjacent property values were adversely affected, while results from Minnesota (Taff, Tiffany, and Weisberg, 1996) curiously indicate no adverse effect. Each of these studies use a hedonic framework based on the market price of residential housing. These studies incorporate into the hedonic price equation measures of proximity to livestock facilities and test whether these proximity measures significantly improve the explanatory power of their models.

The hedonic price methodology is useful in deriving the external costs or benefits associated with livestock production. Unfortunately, the current applications of this method

have not allowed researchers to distinguish which factors of livestock production are most bothersome. That is, what portion of the change in housing price is attributable to the odor nuisance, what portion to the potential change in water quality, and what portion to the change in other environmental disamenities? Since many of the potential disamenities associated with large-scale livestock production may require wholly different solutions, it is useful to price various disamenities separately. For instance, odor control may require a different solution than water quality assurance. Knowing the value of odor control and water quality assurance can help local governments identify specific concerns and determine if the cost of addressing these concerns is worth the potential benefit.

The objective of this paper is to use the contingent valuation (CV) methodology to determine the willingness to pay (WTP) of rural Iowa residents to delay nitrate contamination in their water supply. Two small watersheds in predominantly agricultural areas of southern Iowa were selected for this CV study. Both areas are heavily dependent upon surface water for household consumption and both have been concerned with agricultural pollutants for sometime. Like many rural areas in the Midwest, Clarke and Adams Counties are very interested in promoting development to offset population and economic losses in the agricultural sector. Their economic development experiences, however, have been markedly different. Clarke County, located along an interstate, has been more successful in attracting employment opportunities than the more remote Adams County. These differences were expected to create a potential contrast in attitudes toward agricultural development from the expansion of large confinement livestock operations.

The reliability of the CV methodology remains a subject of debate as highlighted by Diamond and Hausman (1994), Hanemann (1994), and Portney (1994). Two issues are of

particular concern. First, CV estimates seem to be subject to what has been labeled the “embedding effect” where estimates for distinctly different quantities of a good do not differ as expected. For instance, McFadden (1994) found that the difference in willingness to pay for preserving a single wilderness area did not differ from the value of preserving multiple wilderness areas. Second, seemingly irrelevant changes in the survey instrument can produce distinctly different estimates. For instance, McFadden (1994) finds that estimates of willingness to pay differed depending on whether open-ended, single-referendum, or double-referendum type questions were asked. Diamond and Hausman (1994) conclude that the problems with CV estimates does not arise from a flaw in the methodology, but instead, from an absence of preferences for the good being valued, which is often the nonuse value of an unfamiliar environmental commodity. However, when respondents are more familiar with the good, CV methods can provide useful information to policy makers.

### **Survey Methodology**

The survey instrument was sent to a random sample of 1000 residents, 500 each from Clarke and Adams Counties in Iowa (O’Gorman, 1995).<sup>1</sup> In addition to demographic and economic variables, respondents were asked how they felt about the importance of environmental issues at the national and local level. Respondents were asked their reaction to the potential siting of a large scale hog facility in their area, and a series of three questions designed to determine their willingness to pay to delay nitrate contamination in their water. A total of 447 surveys were returned, of which 332 were complete and consistent for a final response rate of 33.2%.<sup>2</sup>

Analysis of the data indicated there were no statistically significant differences between the residents of Clarke and Adams Counties in their responses to questions regarding concern for

water quality from the potential siting of a large confinement facility near their homes. Respondents from both counties indicated high levels of concern over the potential contamination of local drinking water. The level of concern about potential nitrate contamination however was related to occupation, age, and source of drinking water. In response to various attitudinal questions, farmers and retirees, municipal water users, and respondents 60 years of age or older expressed a higher degree of concern about drinking water contamination.

The survey instrument questioned respondents about their ranking of environmental issues as a national and local policy issue. Over half of the survey respondents indicated that environmental concerns were a high or top priority as a national and local policy issue. Rankings of environmental issues varied according to occupation and gender. Male respondents and farmers considered environmental issues to be much less of a priority than other respondent classifications. This is an interesting paradox since farmers indicated a greater concern over the potential for water contamination from large-scale confinement operations.<sup>3</sup>

### **Empirical Method**

The survey mechanism asked respondents a series of three referendum questions in order to determine how much they were willing to pay to delay nitrate contamination in their drinking water for 10, 15, and 20 years assuming new and existing hog facilities would result in contamination beyond legal limits within five years. Bid values were held constant for all three questions on a survey but varied across surveys.<sup>4</sup> While follow-up questioning can improve the efficiency of willingness to pay estimates, anchoring effects can reduce these efficiency gains and cause bias. Anchoring occurs when a respondent's follow-up responses to subsequent bids are influenced by the initial bid posed by the survey instrument. In order to control for

anchoring, questions were asked in the one-way up and one-way down formats and the data were analyzed following Herriges and Shogren (1996).

We assume that the initial minimum time delay that an individual is willing to accept for a given program is a function of the amount he would have to pay for the program, the length of time he plans to remain in the area accruing benefits from the program, and other socio-economic factors such as gender, age, education, number of children, occupation, and income. Define the minimum initial time delay as  $T = f(X; \beta, \varepsilon)$  where  $X$  is a vector of regressors,  $\beta$  is a parameter vector and  $\varepsilon$  is a random disturbance. Define  $T_i$  to be the time delay proposed by the  $i$ th question where  $i = \{1, 2, 3\}$ . The probability that a respondent says yes to the first question is  $\Pr(T = f(X; \beta, \varepsilon) \geq T_1)$ . Furthermore, assume that a respondent anchors to  $T_1$  in question 1 when responding to questions 2 and 3 because of uncertainty regarding  $T$  (Boyle, Bishop and Welsh, 1985 or Mitchell and Carson, 1989). Specifically, the individual's responses to the follow-up questions are assumed to be evaluated based on a weighted average of the initial time preference and  $T_1$  such that  $\tilde{T} = (1 - \gamma)T + \gamma T_1$  where  $\tilde{T}$  is the individual's updated, anchored time preference and  $\gamma$  is a weighting factor that lies on the unit interval. When  $\gamma = 0$ , the respondent places no importance on the initial question when responding to follow-up questions. When  $\gamma = 1$ , the respondent anchors completely to the initial question and places no importance on his initial preferences when responding to follow-up questions. Therefore, the probability the respondents says yes to the  $i$ th question is

$$(1) \quad \Pr(\tilde{T} = (1 - \gamma)f(X; \beta, \varepsilon) + \gamma T_1 \geq T_i) = \Pr\left(f(X; \beta, \varepsilon) \geq \frac{T_i - \gamma T_1}{(1 - \gamma)}\right)$$

for  $i = \{1, 2, 3\}$ .

Specifying a functional form for  $T$  and the distribution of  $\varepsilon$ , we can operationalize the model in equation (1). Define  $f(X; \beta, \varepsilon) = X\beta + \varepsilon$  where

$$(2) \quad X\beta = \beta_0 + \beta_1 \ln B + \beta_2 M + \beta_3 A + \beta_4 E + \beta_5 C + \beta_6 H + \beta_7 R_5 + \beta_8 W + \beta_9 F + \beta_{10} \ln I .$$

$B$  is the proposed payment required to implement a program that would delay nitrate contamination.  $M$  is a dummy variable that is equal to one if the respondent is male and zero if the respondent is female.  $A$  is the respondent's age.  $E$  is the respondent's years of education.  $C$  is the number of children under the age of 18 currently living in the respondent's household.  $H$  is a dummy variable that is equal to one if the respondent owns his own home and zero otherwise.  $R_5$  is the expected probability that the respondent will remain in the same community for five years.  $W$  is a dummy variable that is equal to one if the respondent's water source is municipal or rural and zero for other sources of water.  $F$  is a dummy variable equal to one if the respondent is a farmer and zero otherwise, and  $I$  is the respondent's income.<sup>5</sup> Assume  $\varepsilon$  is normally distributed with a mean of zero and variance of  $\sigma^2$ . The parameters in equation (2),  $\gamma$ , and  $\sigma^2$  can be estimated using maximum likelihood techniques.

The maximum likelihood estimates for equation (2) determine the likelihood that an individual says "no" to all three time delays; "yes" to a 20 year delay but "no" to a 15 or 10 year delay; "yes" to a 20 and 15 year delay, but no to a 10 year delay; and "yes" to all time delays. This estimation procedure is similar to an ordered probit specification with the exception that the thresholds are adjusted to account for potential anchoring. The estimates are based on an artificial index; therefore, the coefficients cannot be directly interpreted as the willingness to pay or marginal effects. A respondent's median bid for a time delay of  $T_j$  is implicitly defined by  $T_j - X\beta = 0$ . Solving for the WTP bid and substituting in the means of the socio-economic variables, the median bid for an average respondent and a time delay  $T_j$  can be written as

$$B(T_j) = \exp\left(\frac{T_j - (\beta_0 + \beta_2 \bar{M} + \beta_3 \bar{A} + \beta_4 \bar{E} + \beta_5 \bar{C} + \beta_6 \bar{H} + \beta_7 \bar{R}_5 + \beta_8 \bar{W} + \beta_9 \bar{F} + \beta_{10} \overline{\ln I})}{\beta_1}\right) \text{ where}$$

$T_{10}$  is a 10 year delay,  $T_{15}$  is a 15 year delay,  $T_{20}$  is a 20 year delay, and bars indicate sample averages.  $B(T_j)$  is the bid value that makes the average respondent equally likely to accept or reject the proposed time delay. Setting equation (2) equal to zero and using the implicit function theorem, the marginal change in the median willingness to pay for a delay of  $T_j$  years given a

change in  $X$  is  $\frac{\partial B(T_j)}{\partial X} = -\frac{\frac{\partial X \beta}{\partial X}}{\frac{\partial X \beta}{\partial B}}$ . For instance,  $\frac{\partial B(T_j)}{\partial I}$  is interpreted as the change in the

willingness to pay bid required such that the average respondent is equally likely to accept or reject the proposed time delay given a marginal change in income.

Table 1 reports the means and standard deviations of the regressors. Just over one in three of respondents were willing to pay for a 10 year delay. Fewer than 10% were willing to pay for a 15 or 20 year delay. Almost half were not willing to pay to delay nitrate contamination. Respondents were almost equally distributed between counties. Almost two-thirds of the respondents were male. The average age was about 52 years. Average education was equivalent to more than a two-year associate degree, but not quite a four-year college degree. The average number of children under 18 was just over two-thirds. Just over 80% of respondents owned their own home. Respondents were on average 80% certain that they would remain in the area for five years. Nearly three-fourths used municipal or rural water. Almost 11% were farmers, and average income was just over \$30,000.

## Results

We find that residents of Clarke and Adams Counties are willing to pay to delay nitrate contamination in their water source. Statistically significant differences between counties were not detected.<sup>6</sup> Table 2 reports the median bids and marginal effects for time delays of 10, 15, and 20 years. At the bottom of Table 2,  $\gamma$  is reported along with the maximized values of the log-likelihood function. The maximized values of the restricted log-likelihood function when  $\beta_2$  through  $\beta_{10}$  are constrained to zero is also reported along with a likelihood ratio test for these restrictions. Diagnostic tests indicated no significant concerns with multicollinearity among the regressors. Anchoring was significant and indicated that respondents weighted their initial bid just as much as their original preferences which may suggest a high degree of uncertainty regarding their preferences. By controlling for this anchoring, the willingness to pay estimates reflect the respondent's initial assessment of the proposed time delay.

The estimated median willingness to pay was just over \$50 a year for a 10 year delay, just under \$65 a year for a 15 year delay, and just over \$80 a year for a 20 year delay. While these estimates were statistically different from zero, the values, while increasing as expected, were not statistically different from each other. This result combined with the fact that over 80% of the sample either accepted or rejected all time delays indicates that respondents were generally either for or against the program at the proposed bid values.

Male respondents were less willing than female respondents to pay for a delay in nitrate contamination. On average, their median WTP bids were \$34 to \$56 lower than female respondents. This suggests that female respondents are more concerned about the potential for nitrate contamination than their male counter parts.

The education level of a respondent positively influences their willingness to pay to delay nitrate contamination. An additional year of schooling results in an increase of \$7 to \$12 in the

median WTP bids. This implies that respondents with higher levels of education may be more aware of the risks associated with nitrate contamination from large confinement operations.

The likelihood of a respondent remaining in the area for another five years positively influences the median willingness to pay to delay nitrate contamination. Residents that are 1% more likely to remain in the area for five years are willing to pay an additional \$0.70 to \$1.13.

Income also positively affects the median WTP bids. An additional \$1,000 in income results in higher WTP bids of \$1.22 to \$1.97 per year. Respondents who have higher incomes are better able to afford an increase in their water bill and are more willing to do so in order to protect their drinking water.

The WTP estimates can be aggregated to the county level to estimate the total value that residents in the two counties are willing to pay for water quality protection. One interpretation is that these amounts represent the value residents would be willing to pay for technologies to protect water quality. Adams County, with an adult population of 3,677 in 1990, could expect revenue amounts of \$186,461 to \$301,073 per year. The more populous Clarke County, with 6,119 adults, could expect revenues of \$310,294 to \$501,024 per year. These estimates may be inflated if the survey respondents were not answering as individuals as requested, but rather, were considering their household when answering the survey. The estimates could also be interpreted as the value the communities assign to the perceived environmental cost and the amount that livestock benefits need to exceed for an expansion to be implemented.

We can also use our regression results to calculate the additional property taxes a family would be willing to pay in order to delay nitrate contamination. The relocation of a large-scale confinement operation could threaten water supplies reducing the value of residential property. The WTP estimates are one indication of this potential change in property values because they

represent the increase in taxes respondents are willing to pay in exchange for water quality assurance. For example, suppose there is an owner occupied home with a 50 year old mother, a 50 year old father, and one child under 18 years of age. Also assume that both the mother and father have two years of education beyond a high school diploma, are 80% certain they will remain in their community for five more years, use municipal water, and have an annual family income of just over \$32,000. These assumptions and the regression equation imply that this family would be willing to pay between \$118.13 and \$190.75 in additional annual property taxes. If these annual property taxes were capitalized into the value of the family home over the life of the program, the value of a median price home would fall by between 2.9% and 6.8% in Adams county, and 2.3% and 5.4% in Clarke county, assuming a discount rate of 8.5%.<sup>7</sup>

These percentages are similar to those found by Palmquist, et.al. in their study of the effects on property values from the environmental impacts from swine operations in North Carolina (Palmquist, et al, 1995). Their percentages ranged from 7.06% to 1.9% at low levels of hog proximity when a new 2400 head-finishing unit located within half a mile to two miles of a median priced home. The Palmquist study included the effects of odor and other disamenities as well as changes in water quality associated with hog confinement facilities, therefore, a direct comparison with our results is not possible. However, our results support their findings that residential property values are likely to be negatively impacted by large hog confinement operations. Abeles-Allison and Connor (1990) also found that proximity to large hog confinements adversely affected property values in Michigan. Since their study focused on areas with multiple odor complaints, their results are likely to be related more to odor than to water quality, though potential changes in water quality are not completely controlled for in their

analysis. Therefore, our results suggest that part of the negative impact found by Abeles-Allison and Conner is possibly attributable to the potential for changes in water quality.

## **Conclusions**

This study investigated rural residents' perceptions of the risk to their water from the potential siting of a large hog confinement facility in their area and their willingness to pay to maintain water quality. The results indicate that rural residents are very concerned about the environmental impact of confinement facilities and that they are willing to pay higher water bills to delay contamination. Greater education and income levels were positively associated with willingness to pay estimates, as was the length of time a resident expected to remain in the community. Male respondents were much less inclined to pay for water protection than females. From a community perspective, the aggregated WTP values provide some idea of the value of water quality assurance.

Rural residents do value water quality, and local governments need to consider their concerns when evaluating the benefits of economic development associated with attracting large scale livestock operations. As the debate over the potential economic benefits and environmental consequences of large scale confinement operations continues, it is critical that rural residents remain informed and consulted about proposals for the siting of these types of facilities in their area. Although the results can be generalized only to Clarke and Adams Counties, the absence of any difference between these two counties suggests that similar opinions may be found in other rural counties.

Finally, our results can be contrasted with previous attempts to ascertain the external costs and benefits of livestock production using hedonic pricing equations combined with residential property values. One drawback to this hedonic valuation method is that it is hard to

distinguish what factors of livestock production are most concerning to neighbors. Carefully focused contingent valuation surveys provide an alternative method for evaluating the value residents' place on the odor nuisance, the potential for groundwater contamination, and other potential disamenities. These surveys can also help to determine the degree to which respondents view alternative disamenities as joint products. Also, future studies may find useful comparisons between contingent valuation and hedonic pricing methods when evaluating the effects of livestock confinement. These comparisons may help to further identify the advantages and limitations of each method.

### **Footnotes**

<sup>1</sup> A copy of the survey instrument is available from the authors on request.

<sup>2</sup> Out of the 447 surveys returned, 21 responses were inconsistent because they implied contradictory choices. For example, the respondent might have indicated that he was willing to pay \$75 for a 10-year delay, but not for an even longer delay of 20 years.

<sup>3</sup> One potential explanation for this paradox suggested by an anonymous reviewer is that many of the farmers in our survey could be small hog producers "masking concerns of economic survival in terms of water quality." Unfortunately, the survey did not ask farmers detailed enough information to test this hypothesis.

<sup>4</sup> Specifically, 25% of the surveys asked if a respondent was willing to pay an additional \$35 a year on their water bill or in local taxes, 25% were asked \$75, 25% were asked \$150, and the remaining 25% were asked \$300.

<sup>5</sup> Taking the natural log of the bid value and income allows for non-linear income effects that improve the fit of the model.

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<sup>6</sup> The test for differences between counties was constructed using a log-likelihood ratio test.

Estimating coefficients for each county separately led to a maximized log-likelihood of -340.68.

Restricting the coefficients to be equal across counties led to a maximized log-likelihood of -

348.69. The log-likelihood ratio test resulted in a  $\chi^2 = 16.03$  with 13 degrees of freedom. This

$\chi^2$  is not significant at the 10% level, and indicates that restricting coefficients to be equal across

counties does not significantly reduce the explanatory power of the model.

<sup>7</sup> The median price of residential housing from the 1990 census was \$28,700 in Adams county and \$36,400 in Clarke county.

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Table 1: Means/Percentages and Standard Deviations of the Regressors.

| Variable                                | Mean/Percentage | Standard Deviation |
|---|-----------------|--------------------|
| Unwilling to Pay to Delay Contamination | 45.29%          |                    |
| 10 year delay                           | 37.39%          |                    |
| 15 year delay                           | 7.90%           |                    |
| 20 year delay                           | 9.42%           |                    |
| Adams County Residents                  | 44.99%          |                    |
| Clarke County Residents                 | 55.02%          |                    |
| Male                                    | 62.31%          |                    |
| Age                                     | 51.5            | 14.7               |
| Education                               | 13.40           | 2.50               |
| Children Under 18                       | 0.68            | 1.13               |
| Homeowner                               | 84.20%          |                    |
| Remain for 5 Years                      | 81.99%          | 22.36%             |
| Municipal/Rural Water                   | 74.16%          |                    |
| Farmer                                  | 10.64%          |                    |
| Income                                  | \$32,135        | \$22,981           |
| Number of Observations                  | 329             |                    |

Table 2: Median Willingness to Pay and Marginal Effects.

|                                 | 10 Years            | 15 Years   | 20 Years   |
|---------------------------------|---------------------|------------|------------|
| Median WTP                      | \$50.71***          | \$64.44*** | \$81.88*** |
|                                 | (4.42) <sup>a</sup> | (7.06)     | (5.22)     |
| Male                            | -\$34.39**          | -\$43.70** | -\$55.53*  |
|                                 | (2.03)              | (2.03)     | (1.86)     |
| Age <sup>b</sup>                | \$0.69              | \$0.87     | \$1.11     |
|                                 | (0.11)              | (0.11)     | (0.11)     |
| Education                       | \$7.28**            | \$9.25**   | \$11.75**  |
|                                 | (2.04)              | (2.18)     | (2.09)     |
| Children Under 18               | -\$8.62             | -\$10.96   | -\$13.92   |
|                                 | (1.12)              | (1.11)     | (1.08)     |
| Homeowner                       | -\$14.23            | -\$18.09   | -\$22.98   |
|                                 | (0.67)              | (0.68)     | (0.67)     |
| Remain for 5 Years <sup>c</sup> | \$0.70*             | \$0.89*    | \$1.13*    |
|                                 | (1.80)              | (1.89)     | (1.83)     |
| Municipal/Rural Water           | -\$10.86            | -\$13.80   | -\$17.54   |
|                                 | (0.61)              | (0.61)     | (0.61)     |
| Farmer                          | -\$34.23            | -\$43.49   | -\$55.27   |
|                                 | (1.24)              | (1.27)     | (1.25)     |
| Income <sup>d</sup>             | \$1.22**            | \$1.55**   | \$1.97**   |
|                                 | (2.72)              | (2.77)     | (2.40)     |
| $\gamma$                        | 0.53                |            |            |
|                                 | (1.94*)             |            |            |
| Restricted Log-likelihood       | -376.55             |            |            |
| Log-likelihood                  | -348.69             |            |            |
| $\chi^2(10)$                    | 55.72***            |            |            |
| Number of Observations          | 329                 |            |            |

<sup>a</sup> Absolute t-statistics are reported in parentheses.

<sup>b</sup> Tens of years.

<sup>c</sup> For a one percentage point increase in the probability of remaining in the area for an additional five years.

<sup>d</sup> Thousands of dollars.

\*Significant at the 10% level.

\*\*Significant at the 5% level.

\*\*\*Significant at the 1% level.