Evaluating the Effect of Proximity to Hog Farms on Residential Property Values: A GIS-Based Hedonic Price Model Approach

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Abstract: *The decline of small-scale farms and the dramatic increase in the size of corporate animal operations in recent years has sparked controversy over the impacts of confined animal feeding operations on surrounding residential communities. This study examines the applicability of geographic information systems (GIS)-based hedonic price modeling for evaluating impacts to residential property values from feeding operations, particularly hog operations. Residential property attributes were derived and compiled in a GIS. These attributes were used to construct a hedonic model to examine the relationship between distance to hog farms and property sales prices. Results indicate a negative and significant impact on property value from hog operations. A comparison of the results from this study with those of several other GIS-based hedonic models indicates that GIS-based hedonic price modeling is a promising method for assessing property value damages associated with animal operations, for evaluating potential impacts when siting new operations, and for developing setback guidelines.*

Introduction

The corporatization of livestock production during the 1990s has led to rapid growth of large-scale confined-animal feeding operations (CAFOs), especially in the pork industry. The result has been a decrease in the total number of hog farms in the United States and a tremendous increase in the size of individual operations. This trend has sparked a controversy about the relative benefits and costs of large-scale industrial hog farms.

A major concern for local communities is the impact of nearby CAFOs on surrounding residents. These impacts might include offensive odors (Swine Odor Task Force 1995; Chapin et al. 1998; Tyndall and Colletti 2000), physical and mental health problems (Schiffman *et al*. 1995; Thu *et al*. 1997; Wing and Wolf 1999), and degraded water quality (Hallberg *et al*. 1992; Hallberg 1996; Jackson 1996). The costs of such negative impacts on surrounding communities are not reflected in market prices for pork. One possible approach to account for externalities associated with CAFOs is through evaluation of property values of residential parcels surrounding the operations.

In this paper we describe the use of GIS techniques to derive additional parcel attribute data for constructing a hedonic price model of the impact of proximity to hog farms on residential property values. We include a brief discussion of model construction and potential applications. A more detailed discussion of the econometric techniques and analysis can be found in Ansine (2000).

Hedonic Price Models

The goal of this study was to evaluate the influence of proximity to swine facilities on the selling price of residential properties. Previous studies have used the hedonic pricing method (HPM) to approach the impact of CAFOs on property values (Abeles-Allison and Connor 1990; Taff *et al*. 1996; Palmquist *et al*. 1997; Mubarak *et al*. 1999; Bruton 2001; Herriges *et al*. 2003). A hedonic model attempts to explain the selling price of a house in terms of its physical attributes and its surrounding environment. If successful, it can reveal whether an environmental characteristic (such as proximity to a CAFO) has a significant effect on price, and how much the house's value is affected by a marginal increase or decrease in this environmental attribute.

The hedonic price model can be expressed as

$$P = f\,(C, E) \tag{1}$$

where P is the selling price of the house, *C* is a set of physical attributes that contribute to the price of a house (e.g., number of bedrooms, square footage, lot size), and *E* is a set of environmental attributes that can include factors that surround or define the house's physical location, such as its proximity to schools, parks, shopping, and livestock farms (Goodman 1978).

Hedonic price models are commonly estimated by the method of ordinary least squares (OLS). In this method, a multiple linear regression equation is constructed of the form

$$\hat{y} = b_0 + b_1x_1 + \ldots + b_px_p \tag{2}$$

For this study, _ represents the price of a residential property, $x_1 \ldots x_p$ are attributes or characteristics of the property (e.g., number of bedrooms, number of bathrooms, lot size), $b_1 \ldots b_p$ are regression coefficients, and p is the number of attributes or predictors. The regression coefficients represent the contributions of the attributes to the price of the property. Thus, using

the HPM, individual attributes of a residential property can be evaluated for their influence on the selling price.

Previous hedonic price studies of housing indicate that variables such as the number of bathrooms, the age of the structure, heated living space, and the lot area are consistently significant in explaining sales prices (Palmquist *et al.* 1997). Thus, construction of a hedonic model to evaluate the effects of swine operations on nearby property values requires access to physical characteristics of the property that contribute to selling price, as well as an ability to calculate distances to swine facilities and to other features (e.g., schools and parks) that affect the desirability, and thus the selling price, of the property.

The increasing availability of various residential property attributes and georegistered locations in GIS format via county tax roll databases presents an opportunity to construct and analyze much more detailed and extensive hedonic price models than is possible without this technology. For example, without the aid of GIS technology, Abeles-Allison and Connor (1990) collected data on 300 residences, Taff *et al.* (1996) collected data on 292 residential properties, and Palmquist *et al.* (1997) collected data on 237 home sales. In contrast, using GIS, Herriges et al. (2003) collected and analyzed attribute data on 1,145 house sales in proximity to 550 livestock facilities in 5 counties in Iowa, and Ready and Abdalla (2003) used data from 8,090 residential properties in Berks County, Pennsylvania.

In this study, we developed a hedonic price model relating residential sales prices to a number of property attributes. GIS was employed to compile and analyze attribute data, as well as to derive new attribute data using centroid and distance calculation functions.

Study Area And Data Collection

We chose North Carolina for our study site because a rapid increase in the number of hog operations in recent years has created concerns among residents and sparked controversy between citizens' groups and facility operators. Between 1989 and 1997, the number of hogs in North Carolina nearly quadrupled, from approximately 2.5 million to 9.6 million (National Agricultural Statistics Service) (Figure 1). Production of feces and urine from this number of animals has been estimated at more than 20,000 tons per day, or nearly 20 million tons a year (Ansine 2002).

The North Carolina Department of Environment and Natural Resources collects data on active animal operations in North Carolina that require a permit from the Division of Water Quality. These data include location in latitude/longitude coordinates; type of facility; design capacity; and dates of registration, certification, and permit. In order to select a county for study, ArcView GIS software was used to create a point theme of swine facility locations, which was superimposed on a county base map of North Carolina (Figure 2).

Craven County was selected for study because the county maintains an extensive tax assessor's property parcel GIS database, and the number and distribution of swine operations is sufficient for analysis, though not so dense as to complicate the statistical

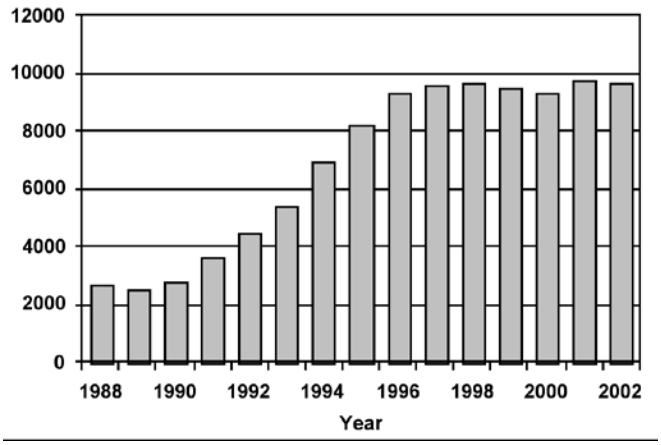

Figure 1. Total Annual Number of Market Hogs in North Carolina, 1988 to 2002
(Data from USDA National Agricultural Statistics Service)

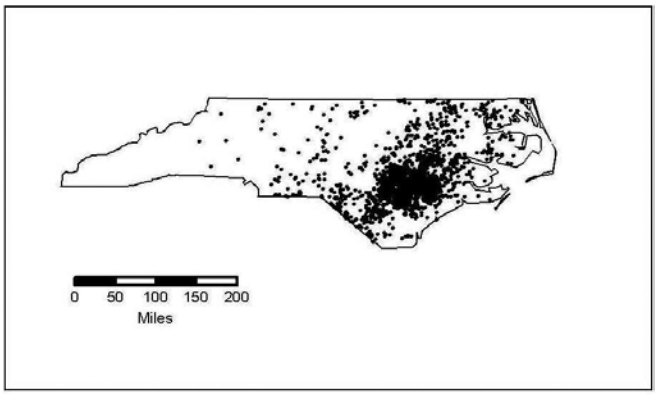

Figure 2. All Hog Operations Permitted by the State of North Carolina as of 2001

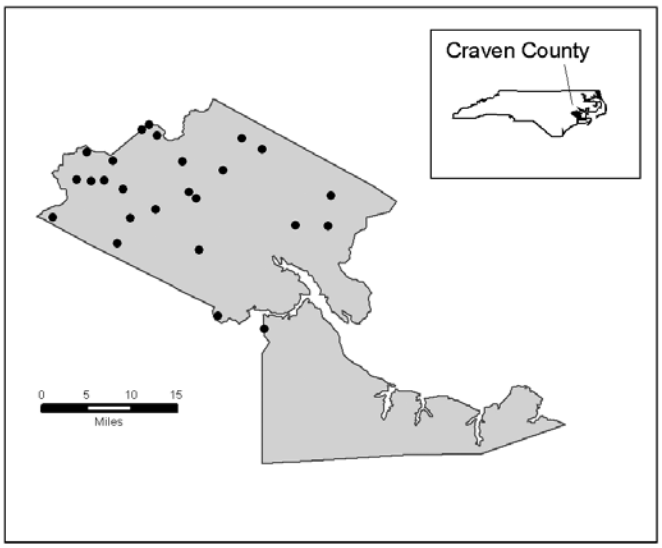

Figure 3. Hog Farm Locations in Craven County, North Carolina

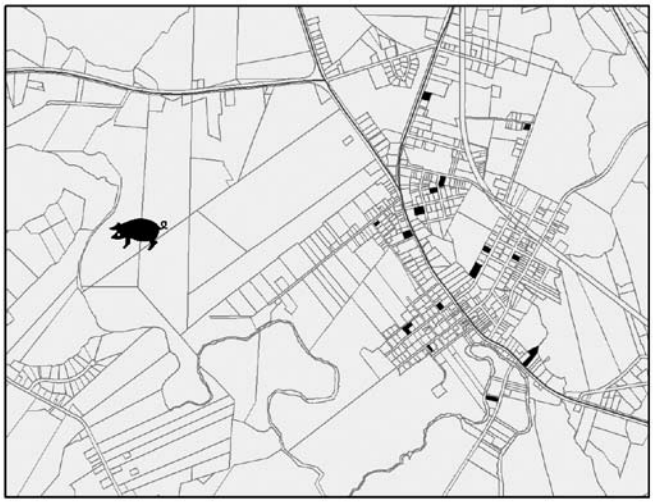

Figure 4. Example of Residential Property Parcels Near a Hog Farm

analysis (Figure 3). The data set consists of 26 hog operations ranging in design capacity from 720 to 7,680 hogs (data from North Carolina Department of Environment and Natural Resources Division of Water Quality).

Parcel data were selected for house sales transactions that occurred between January 2000 and July 2001. After removing parcels with missing data, apparent data entry errors, or very large lot sizes (suggesting homes sold in conjunction with farm or timber tracts), the final data set consisted of 810 parcels (Figure 4).

Parcels in black represent those screened from home sales data for hedonic modeling.

Additional parcel attributes were generated from the selected parcels and swine facility data by applying geometric and distance functions in ArcView. Separate polygon themes were created from the parcels data for a number of different land uses, including schools, parks, highways, police and fire departments, hospitals, and gas stations. Using ArcView's ReturnCenter function, center point themes were created for residential parcel polygons and for parcel polygons in each land use theme. Using ArcView's Distance function, distances were calculated from each swine operation and from each point in each land use layer to each residential parcel center point. Thus, distance from each land use type was added as an attribute of each parcel used in the analysis.

Method

Many aspects of a property can affect the selling price. Among the variables tested were physical characteristics of the property (number of bedrooms, number of bathrooms, size of lot, living area, and whether the home was a mobile home). Other aspects of the property considered were year of sale (2000, 2001) and time of sale (spring, summer, autumn, winter). In addition to proximity to hog farms, the effects of distances to other features were considered. These included schools, vacant lots, highways, sewage treatment, veterinary clinics, gas and oil storage, police and fire protection, banks, restaurants, golf courses, hospitals, retail food stores, lumberyards, trucking terminals, service gas stations, night clubs, marinas, mining and quarrying, manufacturing and processing, and agricultural fields. Different functional forms of the model were tested including linear, log-linear, log-log, and quadratic.

Model Results

It was determined that a log-log functional form with 7 variables produced the best results (R2 = 0.789):

$$lnSLSPR = 3.582 + 0.02717\ lnLOTSIZE + 1.109\ lnSQFTLA - 0.02425\ lnAGEOFHO + 0.349\ lnBTHRM_t - 0.485\ lnMH - 0.02790\ lnPKD - 0.03113\ lnD/D \quad (3)$$

Where:

SLSPR is the sales price of the house.
LOTSIZE is acres of land.
SQFTLA is living area (sq. ft.).
AGEOFHO is age of house (years).
BTHRM is number of bathrooms.
MH is mobile home (YES = 1 or NO = 0).
PKD is distance to nearest park (feet).
D/D is hog density/distance, the number of hogs in the nearest hog farm[1] divided by linear distance from the house measured in feet (swine/linear ft.).

While not used in previously published research, the variable D/D is particularly appealing because it captures the impact of both hog farm size (number of hogs) and proximity to the property in one variable. The D/D variable should exhibit a negative relationship with house sales price. This presumes that homeowners prefer to live farther away from hog farms and that proximity to farms with more animals is less desirable than proximity to farms with fewer animals.

The coefficient for D/D, -0.03113, represents the elasticity of D/D. This means that an increase in the D/D variable of 1% results in a -0.03113% change in the property value. An increase in D/D could result from either an increase in the number of hogs on a farm at a fixed distance from a property, or a decrease in the distance to a farm of fixed size. Thus, D/D can be used to evaluate the effect of either increasing farm size or decreasing distance to a farm. As an example, for a home valued at $114,000 (the median house price) at a distance of 1 mile from a farm with 5,000 animals, the marginal impact of adding an additional hog to the farm is a decrease in value of $0.71. Assuming the marginal impact is an average impact per hog, the value of the home would suffer a one-time loss of $3,550, or 3.1%.

[1]The number of hogs on each farm was calculated from the permitted steady state live weight (SSLW). SSLW is associated with the type of animals it processes (e.g., farrow to wean, feeder to finish). For this study, the number of hogs was calculated as the live weight divided by 135, the average live weight for feeder to finish hogs (SB1217 guidance document).

Comparison With Results From Other Studies

We could identify only three other studies in the literature exploring the use of GIS-based hedonic price models to examine impacts on property values from surrounding animal operations. Although these studies involved a diversity of models employing different sets of attributes, different functional forms, and different geographic locations, all of them demonstrated a similar measurable and significant negative impact to property values from nearby livestock facilities.

Kim (2004) performed a more complex hedonic analysis of hog farm impact to residential properties in Craven County. Kim's study, which included more environmental attribute variables, used a linear Box-Cox functional form and a stratified area sampling of assessed property values. Using concentric distance bands and accounting for spatial effects, this study demonstrated a decline in assessed property values by $0.47/hog at 0.75 mile from farms, $0.52 at 1 mile, and 0.42 at 1.25 miles. This equates to an impact of -$5,210, or 8%, on a median house value ($63,520) at 1 mile from a 10,000-head swine facility. Kim's results are in general agreement with the findings of this study, which modeled a decline of $0.71/hog at 1 mile.

Herriges et al. (2003) constructed a hedonic model using 550 livestock operations (> 90% were hog facilities) and 1,145 property sales distributed throughout five counties in Iowa. Five different model functional forms were tested. From the results of their study, the authors concluded that there may be an approximate 10% reduction in property value if a new livestock facility is located upwind and near a residence. Ready and Abdalla (2003) analyzed the impact of surrounding land uses and potential local disamenities on residential property values in Berks County, Pennsylvania. Using sales and attribute data for 8,090 single-family houses and 71 large-scale animal production operations, they concluded that the impact of a large-scale animal operation located at 800 meters was 4.1%, and that the impact did not vary significantly by type of operation (poultry, swine, beef/dairy).

Discussion: GIS And Hedonic Price Models

A Potential Method for Establishing Setbacks and Managing Buffer Zones

As the structure of the livestock industry has trended toward concentration of more animals in fewer operations, state and local governments have acknowledged the problems associated with large operations by enacting legislation imposing stricter regulations on CAFOs and increasing separation distances (Herriges et al. 2003). In North Carolina the following mandatory setbacks are imposed on new or expanded farms with 250 or more hogs: 1,500 feet from occupied residences, 500 feet from any residential property boundary to swine houses and lagoons, and 75 feet from any residential property boundary to sprayfield boundaries.

Based on the results of studies discussed here, it is quite apparent that significant externalities are associated with animal feeding operations, and that the relationship between externalities, farm characteristics, and community attributes can be quite complex. To be realistic, setback models must go beyond merely fixing set distances, but must incorporate a broad range of variables and considerations.

This study demonstrates that GIS-based hedonic price modeling may be a viable approach to establishing setbacks for animal production facilities. Hedonic models incorporating distance variables can be constructed without the need to devise objective measures of inherently subjective perceptions of negative qualities, such as odor or aesthetics. Peoples' willingness to pay, as indicated by property sales prices, reflects the full range of negative perceptions.

Negative impacts of animal facilities as reflected in lowered property values can extend far beyond established setbacks. For example, based on the results of this study and those of Kim (2004), to significantly avoid the negative impact of swine production, a setback or buffer of 1.75 to 2.5 miles would be recommended. Results of the studies of Ready and Abdalla (2003) and Herriges et al. (2003) would imply setbacks up to 1 mile and at least 1.5 miles, respectively.

A Potential Method for Assessing Damages

Establishing buffer zones large enough to avoid impact to property values is probably unrealistic, especially in regions with high property values. Even if such separation distances were feasible, such a policy could not remedy impacts that have already occurred. A growing number of nuisance lawsuits reflect the increasing and often hostile conflict between livestock production farmers and surrounding residential neighbors. Without a systematic method for determining loss, damages for reductions in property values are often awarded based on personal testimony and appraisals by the owners (Vansickle 2003). Compensatory and punitive damages awarded in lawsuits can be enormous (Lee 2004).

GIS-based hedonic price modeling could provide a means for equitable damage assessment, as well as for mutually agreeable negotiations between property owners and facility operators prior to establishing a facility. Modeling results suggest that, provided operators followed practical and reasonable siting rules, the magnitude of compensatory payments made to property owners could be modest relative to the cost of establishing a new operation (Herriges et al. 2003).

Summary And Conclusions

GIS technology has enabled applications of spatial analysis techniques that were previously impractical or not possible due to the great amount of data involved. The increasing use of GIS in county parcel database management has created an opportunity to assess the impacts of land use activities on surrounding property values. In particular, attribute data derived from a GIS parcel management system can be used for hedonic modeling of damages to property values associated with proximity to livestock production facilities. The results of this study indicate that GIS-

based hedonic price modeling may be a promising technique for establishing setback guidelines, for assessing property value damages resulting from animal operations, and for evaluating potential property value impacts to surrounding properties when siting a new CAFO.

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References

Winsbert Ansine is a recent graduate of the Florida A&M University Agribusiness program. He is currently employed with the Ministry of Education in Jamaica.

Abeles-Allison, M., and L.J. Conner. 1990. An analysis of local benefits and costs of Michigan hog operations experiencing environmental conflicts. *Agricultural Economics Report No*. 536. Department of Agricultural Economics, Michigan State University, East Lansing.

Ansine, W. 2000. Hog externality and residential property values: A hedonic price approach using geographic information systems data. Unpublished thesis. Florida Agricultural and Mechanical University, Tallahassee, Florida.

Bruton, N.L. 2001. The environmental effects of the swine industry on residential property value in North Carolina. Unpublished thesis. Florida Agricultural and Mechanical University, Tallahassee, Florida.

Chapin, A., C. Boulind, and A. Moore. 1998. *Controlling odor and gaseous emission problems from industrial swine facilities*: A handbook for all interested parties. Yale Environmental Protection Clinic.

Goodman, A.C. 1978. Hedonic prices, price indices and housing markets. *Journal of Urban Economics* 5: 471–484.

Hallberg, G. 1996. Soil and water quality: Issues for the Farm Bill. *The Farm Bill—A Keystone of Environmental Policy. The Universities Council on Water Resources. Water Resources Update* 101: 39–45.

Hallberg, G.K., R.D. Woida, and Libra, K.D. 1992. The Iowa state-wide rural well water survey: Site and well characteristics and water quality. *Technical Information* Series 23. Iowa Department of Natural Resources, Geological Survey Bureau.

Herriges, J.A., S. Secchi, and B.A. Babcock. 2003. Living with hogs in Iowa: The impact of livestock facilities on rural residential property values. *Working Paper* 03-WP 342. Iowa State University Center for Agricultural and Rural Development.

Jackson, L. 1996. Water Quality. In: K. Thu, ed. *Understanding the impacts of large-scale swine production: Proceedings from an interdisciplinary scientific workshop*. Des Moines, Iowa. 29–30 June 1995, 10–39.

Kim, J. 2004. An assessment of the discommodity effects of swine production on rural property values: A spatial analysis. Unpublished Doctoral Dissertation, University of Illinois at Urbana-Champaign.

Lee, J. 2004. Hog odor battles head to court. *Des Moines Register*. 21 March 2004.

Mubarak, H., T.G. Johnson, and K.K. Miller. 1999. The impacts of animal feeding operations on rural land values. *Report* R-99-02. University of Missouri Columbia Social Sciences Unit.

Palmquist, R.B., F.M. Roka, and T. Vukina. 1997. Hog operations, environmental effects, and residential property value. *Land Economics* 73(1): 114–124.

Ready, R., and C. Abdalla. 2003. GIS analysis of land use on the rural-urban fringe: The impact of land use and potential local disamenities on residential property values and on the location of residential development in Berks County, Pennsylvania. *Staff Paper* 364. Pennsylvania State University Department of Agricultural Economics and Rural Sociology.

Schiffman, S.S., E.A. Miller, M.S. Suggs, and B.G. Graham. 1995. The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. *Brain Research Bulletin* 37(4): 369–375.

Swine Odor Task Force. 1995. Options for managing odor. North Carolina Agricultural Research Service, North Carolina State University.

Taff, S.J., D.G. Tiffany, and W. Weisberg. 1996. Measured effects of feedlots on residential property values in Minnesota: A report to the legislature. *Staff Paper Series* P96-12, 27. University of Minnesota Department of Applied Economics.

Thu, K., K.. Donham, R. Ziegenhorn, S. Reynolds, P.S. Thorne, P. Subramanian, P. Whitten, and J. Stookesberry. 1997. A control study of the physical and mental health of residents living near a large-scale operation. *Journal of Agricultural Safety and Health* 3(1): 13–26.

Tyndall, J., and J. Colletti. 2000. Air quality and shelter belts: Odor mitigation and livestock production, a literature review. USDA National Agroforestry Center, University of Nebraska, Lincoln.

Vansickle, J. 2003. Nuisance lawsuits on the rise. *National Hog Farmer*. http://nationalhogfarmer.com/ (15 March 2003).

Wing, S. and S. Wolf. 1999. Intensive livestock operations, health and quality of life among Eastern North Carolina Residents. North Carolina Department of Health and Human Services, Division of Public Health.