Living with Hogs in Iowa: The Impact of Livestock Facilities on Rural Residential Property Values

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Abstract

To better understand the magnitude of the effects of livestock feeding operations on residential property values, we constructed a new dataset that merges data on home sales with data on the location and size of livestock feeding operations in five rural counties of Iowa. We estimated a hedonic model to explain variations in residential sales price with standard house attributes, such as number of bedrooms and square feet of living space, as well as the effects of distance and density of livestock feeding operation. We find that livestock operations have an overall statistically significant effect on property values. Predicted negative effects are largest for properties that are downwind and close to livestock operations. In addition, feeding operations that are moderate in size have more impact than do large-scale operations, most likely reflecting age, type, and management practices of the moderate-sized operations. The limited size of the estimated effects suggest that common sense rules—such as not locating feeding operations close to and upwind of residences—combined with modest compensatory payments could help rural residences co-exist with modern feeding operations.

Keywords: hedonic model, livestock, property values.

LIVING WITH HOGS IN IOWA: THE IMPACT OF LIVESTOCK FACILITIES ON RURAL RESIDENTIAL PROPERTY VALUES

Introduction

The methods used to raise hogs in Iowa have undergone dramatic changes in the past twenty years. In 1980, approximately 65,000 farmers in the state raised hogs, with an average of 200 hogs residing on each farm. In 2002, the number of farms with hogs had fallen to about 10,000, and the average number of hogs per farm had risen to over 1,400.[1] In the not-so-distant past, the presence of livestock on farms was the norm. When living or traveling in rural areas, one expected to smell the smells, hear the noises, and see the sights that accompany such operations. Complaints between rural neighbors about livestock operations made little sense when everybody had livestock. But the dramatic increase in the concentration of ownership now means that far fewer rural residents have a large financial interest in livestock. What once was the smell of money is now the smell of somebody else's money and an externality to be dealt with. Moreover, there is a concern that the increased concentration of the industry may be accompanied by an increased risk of environmental damage due to manure spills and further degradation of local air quality as the result of odor emanating from large-scale hog facilities.

Accompanying the changes in the industry's structure has been an increase in complaints about livestock operations. State and local agencies have responded by enacting regulations for large-scale confinement units. Since 1995, the Iowa legislature has passed three progressively stricter bills regulating livestock operations. The most recent bill, Senate File 2293, provides for a lower size threshold at which a construction permit is required, calls for larger separation distances for livestock operations, and regulates air quality by limiting emissions from confinement operations.[2] In addition to such legislative action, since the Iowa Supreme Court in 1998 limited the immunity granted to farmers raising livestock, there have been several instances in which individual landowners have filed lawsuits against hog facilities. The best-known case involves four farm couples—two of whom had raised livestock—who sued Iowa Select Farms in 2002 for the production of offensive odors, noxious gasses, and excessive flies on the company's 30,000-head hog facility in Sac County, Iowa. The plaintiffs were awarded $1.06 million in actual damages plus $32 million in punitive damages.[3] The case was settled out of court in 2003, but the terms of the settlement are confidential.

The problem facing both regulators and the judicial system is that little information exists on the extent of damages caused by livestock facilities, making regulation and assessment of damages in civil suits that much more difficult. Palmquist, Roka, and Vukina 1997 (PRV hereafter) represents one of the few studies available. Using data on 237 rural residential properties in southeastern North Carolina, PRV conducted a hedonic price analysis. The authors found that proximity to hog facilities caused a statistically significant reduction in rural housing prices, with an impact of as much as 9 percent for a facility located within ½ mile of a home. A limitation of the PRV study is that the authors did not have information on the exact location of the hog operations. Instead, the authors were forced to rely on an index of manure production within three radii of each home sale (0 to ½ mile, ½ to 1 mile, and 1 to 2 miles) provided by the state veterinarian's office. This precluded the authors from controlling for whether facilities were upwind or downwind of the residential site or the specific distance to the nearest facility. Moreover, the authors did not control for the potentially positive impact that growth in the local livestock industry might have on the demand for housing in the region.

The purpose of this paper is to address some of the limitations inherent in data available for the PRV study by using GIS (geographical information systems) data on the location of livestock facilities in Iowa. Specifically, we conducted a hedonic analysis of the impact of livestock facilities on rural residential property values. We collected data on 1,145 actual home sales in five counties (Franklin, Hamilton, Hardin, Humboldt, and Webster) for the period from 1992 through the summer of 2002. We merged these data with information from the Iowa Department of Natural Resources (IDNR) on the location and size of livestock operations requiring either a construction permit or a manure management plan to determine how close each home was to livestock facilities. The livestock operations database used in the analysis includes facilities regulated according to the 1998 law, House File 2494, which required operations with an animal weight capacity in excess of 200,000 pounds (400,000 for bovine facilities) to file a manure management plan. Construction permits were required for facilities over 625,000 pounds of bodyweight (roughly 4,167 finishing hogs) that used formed storage.[4] For each residence, we identified the nearest livestock operation, recording the operation's distance from the home, its size (live weight), and whether it was upwind of the home during the winter (i.e., northwest) or summer (i.e., south) seasons. We also computed the number of operations within a 3- and 10-mile radius to control for concentration effects and the indirect impact of industry growth on housing demand.

Literature Review

Hedonic price models have long been used to value not only the physical attributes of housing units (e.g., square footage, number of bathrooms, and air conditioning) but also the surrounding location and environmental amenities (e.g., local school quality, crime rates, and air quality).[5] Drawing on seminal work by Rosen (1974), hedonic property value studies start with the notion that the price of a home (P) reflects the bundle of attributes associated with it; that is,

$$P = P\left(z_1, z_2, \ldots, z_K\right) \tag{1}$$

where $\boldsymbol{z} = \left(z_1, z_2, \ldots, z_K\right)$ is a vector of housing attributes. The hedonic function in equation (1) is a housing market equilibrium resulting from the interplay between consumers' demands for various bundles of attributes and suppliers' costs of providing such bundles. As such, it can be used to value marginal changes in a given attribute (say, z_k) using

$$MV_k\left(\boldsymbol{z}\right) = \frac{\partial P\left(\boldsymbol{z}\right)}{\partial z_k}. \tag{2}$$

However, one must be careful in using the hedonic function to measure large (i.e., non-marginal) changes in the set of housing amenities, as this may result in a change in the market equilibrium. According to PRV (p. 115), if the changes are localized (and hence not likely to alter substantially the local housing market), the hedonic function can be used to value changes in local environmental amenities. Moreover, they argue that this is likely to be the case in considering the impact of locating a new hog facility.

The empirical literature that employs hedonic analysis to value environmental amenities is substantial in both the size and scope of amenities being valued. For example, Smith and Huang (1995) use meta-analysis to summarize nearly 40 studies of the impact of air quality on housing prices. Perhaps more relevant to the current analysis are those studies focused on Locally Undesirable Land Uses (or LULUs), including landfills, hazardous waste sites, and incinerators.[6] For example, Kohlhase (1991), Kiel (1995), McCluskey and Rausser (2001), and Smith and Desvousges (1986) all estimate the impact of hazardous waste sites on residential property values and typically find that home values are significantly reduced by proximity to such disposal sites. Similar results emerge in studying the impact of incinerator sites (Kiel and McClain 1995a,b) and landfills (Thayer, Albers, and Rahmatian 1992; Reichert, Small, and Mohanty 1992).

As previously noted, however, there are relatively few studies that focus on the impact of livestock facilities on property values, with PRV being perhaps the most well-known to date. An earlier hedonic analysis by Abeles-Allison and Conner (1990) also found a significant impact of hog facilities on property values in Michigan. However, the analysis was subject to potential sample selection bias, as properties studied were limited to those located near hog facilities for which multiple complaints had been received. Taff, Tiffany, and Weisberg (1996) and Mubarak, Johnson, and Miller (1999) conducted property value studies in Minnesota and Missouri, respectively, but were hampered by limited information on the characteristics of the properties being sold. Moreover, in the Missouri study, over 60 percent of the parcels did not include a home; those that did include a home did not control for the homes' structural characteristics. The Minnesota study, on the other hand, used only house sales data but included property located in cities or townships with populations of 2,500 people or less. It therefore did not distinguish between rural and urban sales, and it had very little information on the characteristics of the properties sold.[7] To our knowledge, the only other hedonic study that controls for the presence of livestock facilities is a recent paper by Ready and Abdalla (2003), which analyzes single-family home sales in Berks County, Pennsylvania. In this study, the authors estimate a hedonic price function, including as housing amenities the proximity of each home to open space and disamenities, such as landfills, regional airports, and large animal production facilities. The authors find that a large animal production facility located at a distance of 500 meters (or roughly 0.3 miles) depresses the sales price of a home by 6.4 percent. However, the authors do not control for the direction of the housing unit relative to the livestock facility.

Data Collection

The study area (shaded in Figure 1) includes five counties in North-Central Iowa: Franklin, Hamilton, Hardin, Humboldt, and Webster.[8] We chose this area because there is a wide range of livestock operations in the region. As the inset map in Figure 1 indicates, the areas with lower density are the two western counties, with Webster and Humboldt counties having only 16 and 24 operations, respectively. Hamilton County, on the other hand, has 138 operations, Franklin has 76, and Hardin has 95. Moreover, the counties differ in terms of the mix of operation sizes. Whereas Franklin County has the largest share of moderate-sized facilities (i.e., hog facilities with less than 3,000 head),

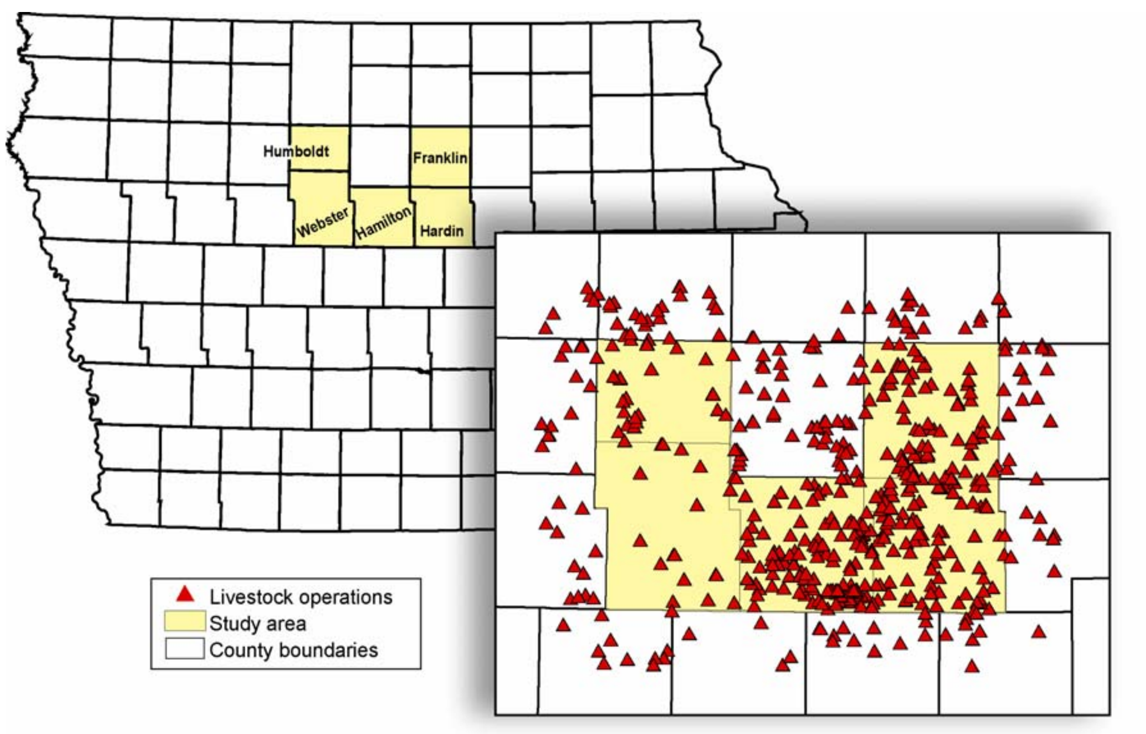

FIGURE 1. Study area

Hamilton County has the greatest number of larger facilities (i.e., over 3,000 head).[9] Over 90 percent of the facilities are hog operations, mostly growers, and the majority of them were built in the early to mid-1990s.

Livestock Facilities Data

Information on each livestock facility in the study area was obtained from the IDNR. The available data included the GIS files on the location of the operations as well as the live weight and animal type in production. We identified two types of operations using the IDNR data: facilities that need a construction permit and facilities that need to file a manure management plan with the agency. In general, according to the 1998 Iowa law, any operation with an animal weight capacity of more than 200,000 pounds (400,000 pounds bovine) must obtain a manure management permit. If a facility uses earthen storage structures for manure, such as a lagoon, it must also obtain a construction permit. If a facility uses formed storage, on the other hand, it needs a construction permit only for operations with 625,000 or more of animal weight capacity (1.6 million pounds or more for bovine).

In total, 550 livestock facilities are included in our analysis.[10] Table 1 provides summary statistics for these facilities. Because of the structure of the confinement operation dataset, the facilities included tend to be quite sizable.[11] As Table 1 indicates,

TABLE 1. Livestock facilities summary statistics

Characteristic	Mean	Median	Range
Live weight (thousands of pounds)	727	600	120 to 41,044
Manure index (millions of pounds per year)	17	14	3 to 973
Percentage of operations by type			
Hogs	98		
Cattle	1		
Hen	2		
Percentage of operations by county			
Franklin	14		
Hamilton	25		
Hardin	17		
Humbolt	4		
Webster	3		
Other	37		

their live weight ranges from 120,000 to 41,044,000 pounds, with a median of 600,000 and an average of 727,000.[12] Over 97 percent of the facilities are hog confinement units, 1 percent are cattle operations, and the remaining 2 percent are egg laying facilities.

In order to provide some comparability to PRV, we also considered manure production as an alternative measure of size in our hedonic analysis. A manure index was formed for each facility based on type of facility and using the algorithms developed by Lorimor, Powers, and Sutton (2000). Manure production levels, as excreted, for facilities included in the study ranged from 3 to 973 million pounds per year, with a median and mean, respectively, of 14 and 17 million pounds per year.

Residential Property Sales Data

Data on house sales were obtained from each county assessor's office. We restricted sales to rural residential, owner-occupied homes sold via "arms length" transactions between 1992 and 2002.[13] As in the case of PRV, we excluded properties with more than 10 acres in order to avoid units that were being marketed in part because of their agricultural production capabilities. We also excluded properties whose sale prices were less than 50 percent of their assessed values and/or sold for less than $5,000. In total, 1,145 sales were available for the analysis. Table 2 details the number of sales and earliest sale date by county.

The variables used in the hedonic regression analysis fall into three broad categories: (*a*) the physical attributes of the home and lot (e.g., square footage and number of bathrooms), (*b*) the attributes of the surrounding community, and (*c*) the attributes of the livestock facilities in close proximity to each home. The physical characteristics available for each home varied by county. In total, 11 characteristic were formed using the overlap in information across the five counties, including the size of the lot, the age of the home,

TABLE 2. Rural residential property sales by county

County	Earliest Sales Date	Number of Sales
Franklin	January 1993	141
Hamilton	January 1992	190
Hardin	January 1995	177
Humboldt	March 1995	71
Webster	January 1992	566

and the year in which it was sold, the size of the living area and any additions to the home, and the number of bathrooms, decks and fireplaces. These characteristics, listed in the first part of Table 3, are similar to those used in PRV and other hedonic studies of residential properties. Each of these characteristics, with the exception of the age of the home, is expected to have a positive impact on the price of the home.

The second broad category of explanatory variables (listed in the second section of Table 3) characterizes the amenities of the housing unit in terms of the surrounding community. These include the distance to the nearest large town (i.e., with population of 2,500 or more) and nearest high school, as well as the median income and population density for the corresponding township. The two distance variables required locating each household spatially. For two counties, Webster and Hardin, GIS files with parcel locations were available. For the other three, we used Digital Orthophoto Quarter Quads (DOQQs) of the State of Iowa combined with paper or online maps to create the GIS data layers.[14,15] An application called PCMiler was then used to calculate the distance from each home to both the local high school and the closest town with a population of more that 2,500 within the 10-mile buffer.[16] In general, we expected that an increase in either of these distances would negatively affect a home's sale price.

We also associated each home with the appropriate township and used the 2000 census to obtain median family income and population density (see Figure 2 for town and home locations). Population density is quite variable among the townships considered, ranging from less than 10 people per square mile to over 100. Median income is quite variable too, ranging from $32,000 to over $60,000. In the hedonic regression analysis, we anticipated that both median family income and population density would have a positive influence on sales price.

The third category of variables used in our hedonic regression analysis consists of measures of the proximity of each housing unit to livestock operations. We used Arc View 3.2 to analyze the spatial relationships between homes sold and livestock operations, constructing centroids for all property sales and livestock operations. We used these centroids to calculate distances between sales and livestock operation sites. In most hedonic studies, each sales property is associated with a single LULU site, typically the closest site. However, given the density of livestock facilities in some regions of the

TABLE 3. Description and summary statistics for variables used in hedonic analysis

Variable	Description	Units	Min	Max	Mean	Std. Dev.
Price	Market price	dollars	500,200	475,000	81,667.60	55,529.64
LSize	Lot size	acres	0.05	10	2.38	2.22
SYear	Sales year	years	1,992	2,002	1,997.16	2.76
Age	Age of home	years	0	142	52.62	32.59
LArea	Living area (without additions)	sq ft	224	500,112	1,171.67	503.84
AdArea	Area of additions	sq ft	0	1642	175.68	273.14
AC	Air conditioned	0/1	0	1	0.62	0.48
Baths	Number of bathrooms	number	0.5	6	1.58	0.68
Decks	Number of decks or enclosed porches	number	0	5	1.61	0.98
Fire	Number of fireplaces	number	0	3	0.39	0.54
AttG	= 1 if there is an attached garage; else =0	0/1	0	1	0.45	0.50
DetG	= 1 if there is a detached garage; else = 0	0/1	0	1	0.47	0.50
DistTown	Distance to nearest large town	miles	0.60	35.20	9.87	5.77
DistHS	Distance to nearest high school	miles	0.90	51.20	10.89	8.79
PDens	Population density by township	number/sq mi	4.00	116.76	29.54	26.90
MedInc	Median income by township	$1,000s /family	32.4	63.0	47.0	56.4
DI1	Distance to nearest livestock facility	miles	0.01	6.78	2.77	1.75
Size1	Size of nearest livestock facility	thousands of pounds	160	2,600	485.29	303.25
NW1	=1 if nearest livestock facility is northwest; else = 0	0/1	0	1	0.30	0.46
SO1	=1 if nearest livestock facility is south; else = 0	0/1	0	1	0.22	0.41
Mile3	Number of livestock facilities within 3 miles	number	0	27	2.48	3.39
Size3	Average size of facilities within 3 miles	thousands of pounds	0	1,649	342.18	331.77
NW3	Percentage of facilities within 3 miles that are northwest	percent	0	100	18.43	29.00
SO3	Percentage of facilities within 3 miles that are south	percent	0	100	16.72	27.78
Mile10	Number of livestock facilities that are within 10 miles	number	2	104	28.36	25.93

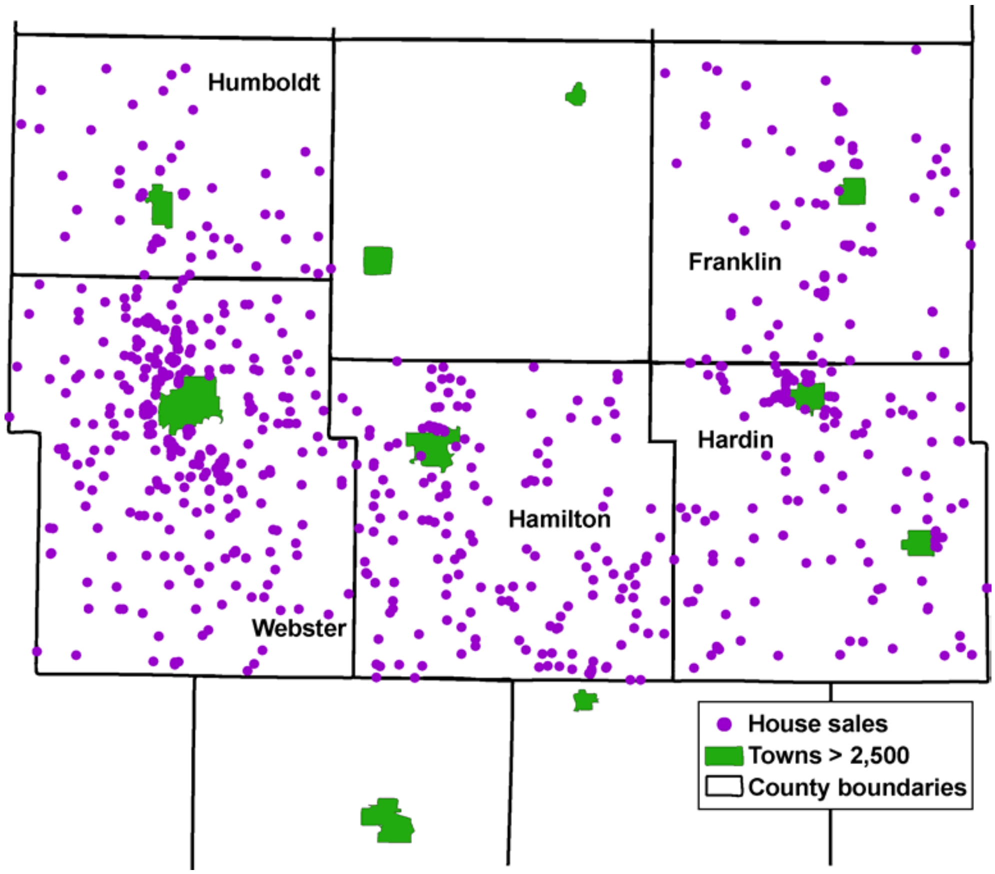

FIGURE 2. Residential sales locations

study site, we wanted to control for the possibility that a property could be affected by more than one facility. Three groups of livestock facilities were identified for each residential sales property: (*a*) the closest operation, (*b*) operations within 3 miles of the property, and (*c*) operations within 10 miles of the property. The dataset contains 47 property sales that have at least one confinement located at ½ mile or less, 149 properties with a confinement between ½ and 1 mile, and 491 properties with a confinement between 1 and 3 miles.[17] For the closest livestock operation, we calculated the distance to the property (*Dist1*), the size of the nearest livestock facility (*Size1*), and whether the facility was upwind of the property during the winter (*NW1*) or summer (*SO1*) seasons.[18] As Table 3 indicates, the average distance to the nearest livestock facility is 2.8 miles and ranges from just 0.01 to 6.8 miles. Roughly 30 percent of the nearest livestock facilities are upwind of the sales sites during the winter months and 22 percent are upwind during the summer months.

While the nearest livestock facility is likely to have the most direct impact on the residential property value, the concentration of facilities in the region also may have an impact. In addition to computing the total number of facilities within a 3-mile radius of each property (*Mile3*), we also computed the average size of these facilities (*Size3*) and the percentage that are upwind during the winter (*NW3*) and summer (*SO3*) seasons. As Table 3 indicates, there is considerable variation in the concentration of facilities around the residential sales site. While on average there are 2.5 livestock facilities within 3 miles of the properties sold, this number ranges from 0 to 27 in the data set.[19]

Finally, we calculated the number of confinements in a 10-mile radius of each property centroid. We hypothesized that the presence of a large number of confinements within such a large radius might have a positive impact on local economic activity, while the distance from the residential properties would be too large for odor to affect sale values. As Table 3 indicates, the number of livestock confinements in the 10-mile radius averages 28.4 and ranges from 2 to 104.

Model Specification and Hypotheses

Theory provides little or no guidance in terms of the choice of functional form for the hedonic price function. Instead, it is standard practice to consider a variety of functional forms in order to determine the sensitivity of the results to form choice and to choose the form that provides the best fit to the data. We investigate four broad classes of models in the current analysis:

$$\text{Model 1: } P_i = \alpha' Z_i + \left(\beta' X_{1i}\right) DI_i^{-1} + \left(\delta' X_{3i}\right) Mile3_i + \gamma Mile10_i, \tag{3}$$

$$\text{Model 2: } \ln\left(P_i\right) = \alpha' Z_i + \left(\beta' X_{1i}\right) DI_i^{-1} + \left(\delta' X_{3i}\right) Mile3_i + \gamma Mile10_i, \tag{4}$$

$$\text{Model 3: } P_i = \alpha' Z_i + \left(\beta' X_{1i}\right) \ln\left(DI_i\right) + \left(\delta' X_{3i}\right) Mile3_i + \gamma Mile10_i, \tag{5}$$

and

$$\text{Model 4: } \ln\left(P_i\right) = \alpha' Z_i + \left(\beta' X_{1i}\right) \ln\left(DI_i\right) + \left(\delta' X_{3i}\right) Mile3_i + \gamma Mile10_i, \tag{6}$$

where Z_i denotes the vector of structural and location characteristics for each sales unit (i.e., the first two sets of variables in Table 3), X_{1i} denotes the vector of characteristics of the nearest livestock facility for each home (i.e., size and wind direction dummies), and X_{i3} denotes the vector of characteristics of the facilities within 3 miles of each home. The differences among the four groups of models lie in the forms of the dependent variable and the distance to the nearest livestock facility. Models 1 and 3 have the sales price enter linearly, whereas Models 2 and 4 use log-price as the dependent variable. In Models 1 and 2, the inverse distance to the nearest livestock facility is used, whereas in Models 3 and 4, the distance to the nearest livestock facility enters in logarithmic form.[20] In general, the results of the hedonic regression analysis were similar across these four classes of models. However, Model 4 (the double-log specification) provided the best fit.[21]

In addition to the basic model variations in equations (3) through (6), two alternative measures of size were used for each livestock facility: live weight (pounds) and manure production (pounds per year). Again, the qualitative finding reported as follows did not change with the choice of these size measures. However, the models that include the live weight measure dominated those based on manure production. In the results section, we report only the results based on live weight measure. Thus, using the notation for the variables listed in Table 3, the final model becomes

$$\begin{aligned}\ln\left(Price_i\right) = {} & \alpha_0 + \alpha_Z \widetilde{LSize_i} + \alpha_{YR} \widetilde{SYear_i} + \alpha_{AG} \widetilde{Age_i} + \alpha_{LA} \widetilde{LArea_i} + \alpha_{Ad} \widetilde{AdArea_i} \\ & + \alpha_{AC} AirC_i + \alpha_{Bt} \widetilde{Baths_i} + \alpha_{Dk} \widetilde{Decks_i} + \alpha_{Fr} \widetilde{Fire_i} + \alpha_{AG} \widetilde{AttG_i} + \alpha_{DG} \widetilde{DetG_i} \\ & + \alpha_{Tw} \widetilde{DistTown_i} + \alpha_{HS} \widetilde{DistHS_i} + \alpha_{PD} \widetilde{PDens_i} + \alpha_{MI} \widetilde{MedInc_i} \\ & + \left[\beta_0 + \beta_Z \ln\left(\widetilde{Size1_i}\right) + \beta_N \widetilde{NW1_i} + \beta_S \widetilde{SO1_i}\right] \ln\left(DI_i\right) \\ & + \left[\delta_0 + \delta_Z \ln\left(\widetilde{Size3_i}\right) + \delta_N \widetilde{NW3_i} + \delta_S \widetilde{SO3_i}\right] \widetilde{Mile3_i} \\ & + \gamma \widetilde{Mile10_i}\end{aligned} \tag{7}$$

where the tildes above each variable indicate that they are measured relative to the mean in the sample.[22]

There are a number of hypotheses of interest in terms of the hedonic price function. Specifically, we consider the following four hypotheses:

- $H_0^A : \beta = \delta = \gamma = 0$. This hypothesis corresponds to a test as to whether the livestock facilities have any effect on rural residential property values.
- $H_0^B : \delta = 0$. This hypothesis corresponds to a test as to whether concentration of livestock facilities in the region has any effect on rural residential property values, over and above the impact of the nearest facility.
- $H_0^C : \delta = \gamma = 0$. This hypothesis corresponds to a test as to whether only the nearest livestock facility affects a property.
- $H_0^D : \beta_k = \delta_k = 0 \,\forall\, k \neq 0$. This hypothesis corresponds to a test as to whether the characteristics of the livestock facilities (i.e., size and wind direction) have any effect on rural residential property values.

Results

Table 4 provides the results of estimating the hedonic price equation in (7). Coefficient estimates are presented for the unconstrained model and under each of the hypotheses outlined in the previous section.

All of the structural characteristics of the home have the expected signs and are statistically different from 0 at the 1 percent level or better. For example, each year of age of the home reduces its value by roughly 0.4 percent, while a deck increases the home value by 5 percent, and each fireplace increases the value by 8 percent. Moreover, the coefficients change little across the various model specifications. Likewise, the location variables, with the exception of distance to high school, have the expected size and signs. Each mile away from the nearest large town diminishes the property value by approximately 0.7 percent, whereas homes in areas with greater population densities and/or higher median income levels are generally more valuable. The only unusual result among the non-livestock factors is the coefficient on the distance to the nearest high school. In general, one would expect that this coefficient would be negative, indicating that easy access to the education system would increase the value of a home. However, under all the model specifications considered, the coefficient on *DistHS* is positive and significant at a 5 percent level or higher.

TABLE 4. Parameter estimates

Variable	**Unconstrained**	$H_0^A: \beta = \delta = \gamma = 0$	$H_0^B: \delta = 0$	$H_0^C: \delta = \gamma = 0$	$H_0^D: \beta_k = \delta_k = 0 \;\; \forall k \neq 0$
Intercept	11.07***	11.11***	11.08***	11.11***	11.08***
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)
LSize	0.059***	0.061***	0.059***	0.062***	0.058***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
SYear	0.059***	0.059***	0.059***	0.059***	0.058***
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Age	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
LArea	0.00029***	0.00028***	0.00029***	0.00028***	0.00030***
	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)
AdArea	0.00034***	0.00035***	0.00034***	0.00034***	0.00035***
	(0.00005)	(0.00005)	(0.00005)	(0.00005)	(0.00005)
AirC	0.31***	0.31***	0.31***	0.31***	0.31***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Baths	0.17***	0.18***	0.17***	0.18***	0.17***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Decks	0.046***	0.046***	0.044***	0.044***	0.046***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
Fire	0.076***	0.081***	0.077***	0.076***	0.084***
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
AttG	0.16***	0.17***	0.16***	0.16***	0.16***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
DetG	0.09***	0.10***	0.09***	0.09***	0.09***
	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)
DistTown	-0.0065**	-0.0070***	-0.0068***	-0.0066***	-0.0070***
	(0.0025)	(0.0025)	(0.0026)	(0.0026)	(0.0025)
DistHS	0.0036**	0.0030**	0.0035**	0.0026*	0.0040**
	(0.0016)	(0.0016)	(0.0016)	(0.0016)	(0.0016)
PDens	0.0011**	0.0013**	0.0012**	0.0014***	0.0012**
	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
MedInc	0.015***	0.013***	0.014***	0.013***	0.014***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)

TABLE 4. Continued

Variable	Unconstrained	$H_0^A: \beta = \delta = \gamma = 0$	$H_0^B: \delta = 0$	$H_0^C: \delta = \gamma = 0$	$H_0^D: \beta_k = \delta_k = 0 \; \forall k \neq 0$
LN(DI1)	-0.009		-0.011	-0.038*	0.029
	(0.029)		(0.026)	(0.021)	(0.025)
*Size1*LN(DI1)*	-0.064		-0.086**	-0.075*	
	(0.042)		(0.040)	(0.040)	
*NW1*LN(DI1)*	0.052*		0.045	0.047	
	(0.029)		(0.029)	(0.029)	
*SO1*LN(DI1)*	0.036		0.031	0.033	
	(0.029)		(0.029)	(0.029)	
Mile3	0.0010				0.0080
	(0.0079)				(0.0066)
*Size3*Mile3*	-0.0060				
	(0.0169)				
*NW3*Mile3*	0.00043*				
	(0.00025)				
*SO3*Mile3*	0.00027				
	(0.00022)				
Mile10	0.0015		0.0018**		0.0011
	(0.0009)		(0.0008)		(0.0009)
LogLik	-638.9	-649.2	-641.3	-644.3	-645.5
χ^2		20.6***	4.8	10.8*	13.2**
Df		9	4	5	6
P-value		0.01	0.31	0.06	0.04

*Statistically different from zero at a 10% level. **Statistically different from zero at a 5% level. ***Statistically different from zero at a 1%level.

Turning to the livestock proximity factors, the unconstrained model in column 2 of Table 4 indicates that few of these coefficients are individually significant. The exceptions are the two wind direction variables associated with the winter season. Specifically, the coefficient on the interaction term *NW1*ln(DI1)* is positive and statistically significant at a 10 percent level. This indicates that for homes downwind of a livestock facility during the winter season, an increase in the distance to the facility is associated with a higher property value (i.e., proximity to the livestock facility is a disamenity). While a similar point estimate applies to the summer wind direction variable, it is not statistically significant. On the other hand, the coefficient on the interaction term *NW3*Mile3* is positive and significant at a 10 percent level, indicating that a higher number of facilities in the region is generally associated with higher property values. This may be capturing the positive impact of economic activity in the region on property values.

While the livestock factors are not measured precisely on an individual basis, it is apparent that they are significant as a group. In column 3 of Table 4, the hedonic price coefficient estimates are presented under the hypothesis that all of the livestock factors are 0. The associate likelihood ratio test statistic ($\chi^2_{df=9}$ =20.6) clearly rejects this hypothesis with a p-value of 0.01. Livestock facilities apparently do have a significant effect on rural residential property values in Iowa.

The lack of individual coefficient significance for the livestock variables may be due in part to the high degree of correlation among some of the explanatory variables. In particular, for many housing units the closest livestock facility is also the only livestock facility within a 3-mile radius, resulting in substantial correlation among the *ln(DI1)* and *Mile3* variables. Column 4 of Table 4 considers a simpler specification for the livestock variables, restricting the *Mile3* factors all to 0. This hypothesis is not rejected at any reasonable level. However, restricting both the *Mile3* and *Mile10* factors to be 0, as in column 5, is clearly rejected. Finally, ignoring the size and wind direction characteristics of the surrounding livestock facilities (as in the model presented in column 6) is also rejected as a restriction.

To illustrate the implications of the livestock factors for housing prices, Table 5 presents the price elasticity of housing with respect to the distance to the nearest livestock facility. Using equation (7), this elasticity is given by

$$\begin{aligned}\eta_{DI1} &= \frac{\partial \ln(Price_i)}{\partial \ln(DI_i)} \\ &= \beta_0 + \beta_Z \ln\left(\widetilde{Size1}_i\right) + \beta_N \widetilde{NW1}_i + \beta_S \widetilde{SO1}_i\end{aligned}, \qquad (8)$$

and depends on both the wind direction and size of the nearest operation. In Table 5, we calculate this elasticity for three sizes of operations (250,000; 450,000; and 650,000 live weight) and three wind direction scenarios (*NW1*=1, *SO1*=1, and *NW1*=*SO1*=0). In general, if the nearest livestock facility is a disamenity, one would expect the elasticity η_{DI1} to be positive, indicating that the value of the rural residential property increases as the distance to the nearest livestock facility increases.

Several patterns emerge in terms of the distance elasticities in Table 5. First, point estimates for these elasticities are largest if the nearest facility is upwind in the winter months (i.e., northwest) and smallest if the facility is downwind from the property (column 4). Second, while the distance elasticities are generally positive, as expected, they are statistically significant only in two cases: when the livestock facility is moderately sized (250,000) and when it is upwind of the home. While this finding first seems counterintuitive, the size of the facilities may be serving as a proxy for other

TABLE 5. Price elasticities

Size of nearest facility (live weight)	Wind direction		
	NW=1	***SO=1***	***NW1=SO1=0***
250,000	0.098*** (0.034)	0.085** (0.036)	0.053 (0.039)
450,000	0.044 (0.029)	0.031 (0.029)	-0.009 (0.026)
650,000	0.024 (0.033)	0.011 (0.032)	-0.022 (0.027)

** Statistically different from zero at a 5% level. *** Statistically different from zero at a 1% level.

unobserved attributes of the confinement unit, including its age and the type of storage system. In particular, most of the largest facilities in Iowa are relatively new and rely on liquid manure storage systems. Additional research, including information on the management and infrastructure of each livestock facility, is needed in order to disentangle the dependence of the distance elasticity on facility size.

Finally, consider a rural residential property that currently has no livestock facility located within a 3-mile radius. Tables 6a through 6c provide the predicted reductions in property value that would result from a new livestock facility locating at various distances away from a residence.[23] For example, Table 6a considers locating the new facility ¼ mile away from the home. The pattern of results, not surprisingly, is similar to that found for the distance elasticities reported in Table 5. The impact is largest if the new facility is located upwind of the home and is moderate in size (i.e., 250,000 pounds live weight). Moreover, the property value reductions are statistically significant at a 95 percent confidence level only for the upwind and the moderate-sized facilities. In these cases, the new facility would reduce the property value on average by 26 percent if located northwest of the home and 22 percent if located south. For the average-sized facility of 450,000 live weight, the percentage reductions are substantially smaller (less than one-half) and statistically insignificant in all cases. Locating the new facility ½ mile away from the residence (as in Table 6b) reduces the impact by 30 to 40 percent, but the pattern remains the same in terms of statistical significance and the influence of wind direction and size. Finally, locating the facility 1½ miles from the property (Table 6c) further reduces the impact, with the property value reduction now ranging from roughly 0 to 6 percent.

Conclusions

Iowa is an ideal place to raise livestock. The state has relatively few people, abundant land, its crop sector imports fertilizer, and it has the lowest-cost feed. Yet, currently it is quite difficult to build a new livestock feeding operation in Iowa because of the opposition of rural residents. The estimated effects of proximity to livestock feeding operations on property values in this study help explain the stalemate in siting new

TABLE 6A. Percentage reduction in property value from a new facility located ¼ mile away[a]

	Wind Direction		
Size of Facility (live weight)	***NW=1***	***SO=1***	***NW1=SO1=0***
250,000	26** (5,49)	22** (1,45)	13 (-6,34)
450,000	11 (-5,29)	7 (-7,24)	-1 (-13,13)
650,000	3 (-15,22)	-1 (-16,17)	-8 (-20,6)

Note: 95% confidence bounds in parentheses.

**Statistically different from zero at a 5% level.

TABLE 6B. Percentage reduction in property value from a new facility located ½ mile away

	Wind Direction		
Size of Facility (live weight)	***NW=1***	***SO=1***	***NW1=SO1=0***
250,000	18** (4,33)	15** (1,31)	9 (-4,24)
450,000	8 (-4,20)	5 (-5,17)	-1 (-9,9)
650,000	2 (-11,16)	0 (-12,12)	-6 (-15,5)

Note: 95% confidence bounds in parentheses.

**Statistically different from zero at a 5% level.

TABLE 6C. Percentage reduction in property value from a new facility located 1½ miles away

	Wind Direction		
Size of Facility (live weight)	***NW=1***	***SO=1***	***NW1=SO1=0***
250,000	6** (1,12)	6** (0,11)	3 (-2,9)
450,000	3 (-1,7)	2 (-2,6)	0 (-4,3)
650,000	1 (-4,6)	-1 (-16,17)	-2 (-6,2)

Note: 95% confidence bounds in parentheses.

**Statistically different from zero at a 5% level.

operations in Iowa. The results suggest that there may be approximately a 10 percent drop in property value if a new livestock feeding operation is located upwind and near a residence. This drop in value helps explain opposition by rural residents to large-scale feeding operations. Livestock supporters often admit there could be circumstances whereby livestock facilities might affect property values, but they argue that the costs are worth bearing because of the need to support a competitive industry in the state. From their perspective, a 10 percent drop in the price of a $100,000 home is not large when compared to investment costs of more than $300,000 for a new operation. The siting stalemate reflects the political stalemate in Iowa. The state's political leaders do not seem to be able to resolve the problem because of the conflicting interests of important political constituents.

This is a classic problem in which a production externality cannot be internalized because of a lack of property rights. If rural residents were granted the right to be free of damage, then our estimate of the magnitude of the effects of livestock facilities on property values suggests room for mutually beneficial trading. If the willingness to pay to site a feeding operation in Iowa exceeds the willingness to accept the damage caused by the facility, then one would expect private negotiations to result in an agreement whereby livestock operators would pay residents for the right to locate their feeding operations nearby.

The results suggest that the magnitude of the payments that would have to be made would be relatively modest if operators followed common sense siting rules. For example, we cannot reject the hypothesis that siting a facility out of the path of prevailing winds causes no damage. And the results are consistent with the expected finding that the greater the distance between the facility and the residence, the less the damage. Thus, if an operator would negotiate with residents located within a mile or so of a proposed site, the site were located no closer than ½ mile of a resident, and no residence was located downwind of the site, then we would expect the required payments to obtain the acquiescence of the residents to be relatively modest.

Of course, our point estimates are only our best prediction of the average damages. Actual damages depend on unmodeled effects such as local topographic features, site-specific management practices, the type of manure storage and land application techniques used, and other factors. Agreements between livestock feeders and rural residents would have to include good faith provisions in which operators followed prescribed management practices that are shown to reduce damage and subsequently residents agreed to allow the feeding facility to remain in operation.

More precise estimates of the effects of feeding operations on property values could be obtained by gathering more data about the attributes of the operations. In particular, our finding that proximity to moderate-sized operations (250,000 pounds live weight) results in greater damage to property values than proximity to large operations likely is a result of different management practices employed at smaller units. Greater knowledge of the management practices used on the various-sized units would allow us to better estimate the effects of size on damage.

Endnotes

1. As Palmquist, Roka, and Vukina (1997) note, similar trends toward industry concentration have emerged in North Carolina, the second largest pork producer in the nation. By 1993, 13 percent of the producers were responsible for 95 percent of the state's total swine production (Hurt and Zering 1993).

2. For the text of the bill, see <http://www.legis.state.ia.us/GA/79GA/Legislation/SF/02200/SF02293/Current.html>.

3. The case, heard by a Sac County jury, was *Blass et al.* vs. *Iowa Select Farms, Inc*.

4. Construction permits were also required for confinement feeding operations that used earthen storage and had an animal weight capacity of 200,000 pounds or more (400,000 or more pounds for bovine).

5. Freeman (2003, chap. 11) and Palmquist (1991) provide more complete overviews of theory underlying hedonic pricing analysis.

6. Farber (1998) provides a summary of recent studies of the impact of LULUs on property values.

7. Specifically, the house variables were the square footage, the age of the house, the number of bedrooms and bathrooms, and the assessor's estimate of the ratio of house value to property value.

8. Wright County was originally included in our study area but eventually was dropped because of problems in obtaining residential sales data for the county.

9. Specifically, among the counties with a high density of livestock operations, Franklin has over 36 percent of moderate-sized facilities, Hamilton has 22 percent, and Hardin has 29 percent.

10. In order to properly account for proximity to animal operations for rural residential properties that were close to the county boundaries, we added a 10-mile buffer around the study area and included livestock facilities found in the buffer. The averages in Table 1 include facilities in the five-county study area (349) and the buffer zone (201).

11. There are two limitations to the livestock facilities data available for our analysis. First, we have information on only those operations in the five-county study area that are sufficiently large to require a manure management plan and/or a construc-

tion permit. Thus, we are not able to control for the impact of smaller livestock operations on rural residential property values. However, we were able to obtain data on all of the livestock facilities for Franklin County. This additional information did not change qualitatively the regression results for Franklin County. Second, the IDNR data does not provide a time series on the size (i.e., live weight) of each of the livestock facilities. Instead, we assumed that the operation size and locations were those reported in the manure management plan or construction permit filing and were constant over the study period. This creates a potential measurement error problem, particularly for those housing sales during the early 1990s. However, sensitivity analysis, excluding homes sold prior to 1996, again did not change the nature of the results.

12. The largest operation in the data set corresponds to an egg laying operation.

13. Because each assessor's office had different filing systems, in some counties we were unable to obtain data for sales in the early 1990s.

14. DOQQs are available at <http://cairo.gis.iastate.edu/doqqs.html>.

15. Specifically, we used Sidwell's online maps (<http://www.sidwellmaps.com/>) for Franklin and Humboldt counties, and copies of the assessor's paper maps for Hamilton County. All data were analyzed in UTM Zone 15, NAD83.

16. We chose the 2,500 population cutoff in consultation with Daniel Otto, an Iowa State University Extension expert in economic and rural development. Towns over 2,500 were deemed large enough to serve as a hub of local economic activity, both in terms of employment and shopping.

17. It is worth noting that, according to Iowa law, operations built after January 1, 1999, have to comply with regulations on minimum distance to buildings and public use areas that range from 750 to 1,875 feet. Details about the regulation are available at the web site of the Iowa Department of Natural Resources, Water Quality Bureau.

18. The latter two wind direction variables were based on prevailing wind directions in Iowa (Mukhtar and Zhang 1995). Specifically, *SO1*=1 if the angle between the closest confinement and the house was between 135° and 255°, and *NW1* = 1 if the angle between the closest confinement and the house was between 270° and 360°.

19. There are 458 properties that have no confinements within a 3-mile radius and 524 that have one to five operations within it. The remaining 163 properties have between 6 and 27 operations in the 3-mile radius.

20. Note that both the inverse distance and log distance ensure that the impact of a negative externality diminishes with distance.

21. The choice between the linear and logarithmic price specifications (i.e., Models 1 and 3 versus Models 2 and 4) was the most straightforward. Following PRV

(endnote 4), the sum of squared residuals from the two specifications were compared, after first normalizing observed prices by their geometric means. Palmquist and Danielson (1989) show that this is equivalent to using the Box-Cox criterion. The differences between using inverse distance and log-distances to the nearest site were less substantial, but the log-distance specification (i.e., Model 4) consistently dominated in terms of log-likelihood.

22. For example, $\widetilde{Age}_i \equiv Age_i - \overline{Age}_i$ where $\overline{Age}_i$ denotes the mean house age in the sample.

23. For the purposes of this exercise, we use the simpler hedonic price specification in column 4 of Table 4.

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