The Impact of Swine Production on Land Values in Illinois[1]

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THE IMPACT OF SWINE PRODUCTION ON LAND VALUES IN ILLINOIS

Abstract: Based on a spatiotemporal hedonic farmland price model and county-level data in Illinois from 1979 to 1999, we examined the impact of swine production on farmland values. Our results show that, in addition to the conventional determinants of farmland values, an increase in swine production intensity has a negative relationship with farmland values while an increase in swine operation scale had a positive association with farmland values at the county level in Illinois. We also estimate the impact of changes in the Illinois swine industry over the period 1980-1999 on farmland values at the state level and find that changes in swine inventory and scale of swine operations have led to changes in farmland prices from $-10.56 to $62.96 per acre. In general, the changes in Illinois swine industry increase farmland values in Illinois.

Keywords: farmland value, swine production, spatial econometrics, panel data, hedonic price model, Illinois.

JEL Codes: Q10, Q24, Q19, C21, C23.

Introduction

Illinois is one of the largest producers of pork in the United States and the swine industry is vitally important to the state. According to Illinois Agricultural Statistics (USDA, 2001), though there has been a decline in hog numbers and in national rank over the past two decades, Illinois produced 8.266 million market hogs in 2000, ranking 4^{th} nationally in the number of hogs marketed. Swine production is also the third largest source of farm cash income in Illinois ($825.9 million in 2000, accounting for 11.8% of all farm commodities). As in many other agricultural and livestock sectors, the structure of the Illinois swine industry has been undergoing a major shift, featuring the rise of large-scale production operations. The number of swine farms has declined steadily from 34,000 in 1977 to only 5,100 in 2000. However, the number of hogs marketed was 10-10.5 million in 1977 declining to only 8.266 million in 2000, indicating that with the decrease in number of hog operations, the size of hog farms has increased dramatically. The largest operations have gained the most market share and the very smallest have shown the greatest losses. In 2000, the large (more than 2,000 head of pigs) Illinois hog farms (10.6% of farms) produced 60% of Illinois hogs while small (less than 500 head of pigs) farms (62.8% of farms) produced only 8% of the hogs (USDA, 2001).

Despite the fact that the swine industry provides high quality nutrition for humans and creates enormous economic value to society, this industry is an object of public concern because of its potential harmful impacts on the environment, human health, and surrounding property values (Schiffman et al., 2000; Thu et al., 1997; Wing and Wolf, 2000; and Palmquist et al., 1997). The industrialization of the swine industry in recent years has aggravated this concern as a result of recent trends in swine production toward larger, more concentrated operations. In Illinois, large expansions and new constructions of swine operation are often met with opposition from environmental groups and neighbors. Opposition from neighbors is often due to their concern over the impact of swine operation on their property values. The objective of this paper is to examine this issue by focusing on the impact of the Illinois swine industry and its industrialization on farmland values.

Factors associated with swine production that may affect surrounding property values are odor and gas emissions, the potential for ground and surface water contamination, the positive value of manure as a nutrient source for crop production, and potential to improve employment opportunities in the nearby areas. Using a hedonic model, Abeles-Allison and Conner (1990) investigate 288 residential sales around eight nuisance hog operations in Michigan between 1986 and 1989. They found an average drop in sale price of $430 per house for every thousand hogs added within a five-mile radius. However, the results of their study should not be generalized because the data used are limited to house sales and the sales are around swine farms that have been regarded as a nuisance. Palmquist et al. (1997) conduct similar research on the impact of swine operations on residential property values in North Carolina. They construct an index of swine manure production and show that proximity to large swine farms and the amount of nearby manure jointly cause a statistically significant decrease in house prices of up to 9%. Additionally, Taff et al. (1996) examine residential property values in two counties of southwestern Minnesota. The measures employed to indicate feedlot proximity include distance from the feedlot, total animal units within a defined distance, and location downwind from any feedlots (mainly swine or poultry operations).

Contradicting the results of the other two studies, this study shows that feedlot proximity is associated with higher house sale prices. The authors argue that perhaps workers may be willing to pay more to live close to their work. Another possible explanation is that the income effect from the swine operations may drive up local property markets.

According to economic theory, land prices reflect not only the current use of land, but also competing potential uses. Swine production facilities, may affect the productivity of land, which has long been recognized as a determinant of land value differentials across space. Second, swine operations may also affect the potential land use in nearby areas for residential homes or for other urban development-related purposes. The magnitude of the impact depends on the intensity of livestock production and the proximity of the land to those production facilities. Existing economic studies on farmland prices are numerous, but the impact of swine facilities has been usually neglected. The only known attempt to investigate the impact of confined animal feeding operations (CAFOs) on nearby farmland values is by Hamed et al. (1999) who use a hedonic price model to investigate the impacts of land characteristics, distance to nearest CAFO, class of land, access to a primary road, and the existence of a house on the property value. Data used in their analysis were collected on 99 rural land, non-family real estate transactions of more than one acre and 39 of the properties included a house. They show that CAFOs in Missouri have a negative impact on nearby land values if the land has a house on it. Conversely, they find no impact of CAFOs on land values on land with no residential structure.

There are numerous economic studies of farmland prices (e.g., Oltmans et al., 1988; Just and Miranowski, 1993; Chavas and Thomas, 1999; and Shi et al., 1997). The most relevant to our research is by Oltmans et al. (1988). The authors analyze the trend of farmland price changes in Illinois from 1975-84 using a hedonic pricing method. They construct four farmland price indices for seven Illinois regions and the state as a whole over the time period 1975-84 based on the hedonic model. Specifically, land price is modeled as a function of the size of the tract sold, a dummy variable for improved land, soil productivity rating, distance to the nearest market, distance to Chicago, distance to the nearest city, and a time dummy variable for each year. Since the method takes into account the impact of the characteristics of land parcels sold, hedonic price indices better reflect the change in land prices. However, the potential impact of the swine industry on land prices is not discussed in their analysis.

Our study employs a hedonic model to measure the impact of swine production and its industrialization on land values in Illinois using county level panel data for the period 1979-1999. The analysis provides two important contributions. First, findings of extant empirical studies are ambiguous, suggesting that the impact of swine production on property values can be case-specific. Second, although swine production in Illinois has experienced significant transformations in recent years, no previous empirical studies have addressed these impacts.

Our research contributes to the existing farmland value literature through its methodologically improvements incorporating both spatial and temporal dimensions into a hedonic property price model. In addition, it addresses the fact that swine production is often thought to be an environmental disamenity. By evaluating the relationship between differences in swine population and operation scale and their resulting capitalization in farmland prices, the dollar consequences of the environmental externalities as captured by the surrounding farmland values and arising from swine production can be measured, as differences in land prices reasonably indicate consumer's willingness to pay for differences in environmental conditions.

The Spatial-Temporal Hedonic Land Price Model

In a typical hedonic price model, the price of a differentiated commodity such as a house can be explained by its characteristics. These characteristics include structural, neighborhood, location, and environmental characteristics, among others. When applied to the land market, hedonic approaches assume that a given land tract can also be identified by a unique set of attribute levels, and that the value of the tract is an aggregation of the values of the individual attributes. According to previous studies on farmland values of Illinois (Oltmans et al., 1988), these attributes include tract size, class of land, soil productivity rating, and distances to the nearest agricultural product market, to Chicago and to the nearest city.

Since swine operations may affect the air, water, and soil quality of nearby land and hence affect the productivity of land, while simultaneously influencing the potential of land for uses other than farming, a hedonic land price model needs to include attributes reflecting these influences. Variables considered in our study to measure the impacts of hog farming activities are hog inventory intensity and the average scale of a swine operation. One expects that the higher the hog inventory intensity and the swine operation scale, the higher the impact of swine production on land transactions will be. In addition, since the literature also shows that inflation plays a role in farmland value dynamics (Canning and Leathers, 1993; and Chavas and Shumway, 1982), we include a lagged consumer price index variable in the hedonic price model to capture the impact of inflation. We also employ population density and annual personal income per capita in this model as control variables.

Property values can be spatially autocorrelated. Ignoring neighborhood effects or spatial dependencies in hedonic models not only affects the magnitude and significance of the estimates but may also lead to misinterpretation of standard regression diagnostic tests (Kim et al., 2003). To help illustrate the possible spatial dependences and trend in farmland values among Illinois counties, Figures 1 and 2 show the 1979 and 1999 farmland price characteristics in Illinois. Visual inspection of both figures suggests that farmland prices might be spatially autocorrelated among Illinois counties. Further examination of the Moran's *I* test statistics also strongly indicates that spatial autocorrelation may indeed exist in farmland prices among Illinois counties from 1979 to 1999 (Table 1). The results in Table 1 show that farmland prices are positively associated spatially among Illinois counties ($P < 0.01$) with no exceptions over the study time period. Figures 1 and 2 also suggest a spatial trend in farmland prices. Among other things, this trend reflects the influence of metropolitan areas on land prices. Clearly, farmland prices decrease as the distance of a county to Chicago increases. Similar spatial patterns can be also found in relationships between farmland prices and distances to St. Louis and other Illinois major cities. To capture these spatial trends and the influences of big cities on farmland prices, three variables are included: 1) distance to Chicago; 2) distance to St. Louis; and 3) distance to cities of population over 50,000.

There are two basic approaches for incorporating spatial elements into an econometric model: the spatial-lag model and the spatial error model (Anselin, 1988). These two approaches are closely related mathematically, but their basic assumptions and subsequent economic interpretations are different. Following Kim et al. (2003), the spatial-lag hedonic farmland price model implicitly assumes that the spatially weighted average of farmland prices in neighboring counties affects farmland prices of each county (indirect effects) in addition to the standard explanatory variables of farmland characteristics of a county (direct effects). In contrast, the spatial error model does not include such indirect effects arising from spatial autocorrelation but assumes that there are one or more omitted variables in the hedonic price model and that the omitted variables are spatially correlated. The error term of the hedonic price model can be spatially autocorrelated because of the spatial pattern in omitted variables. Because the fundamental spatial differences among counties in our hedonic farmland price model have been captured by variables such as distances to major cities and soil productivity rating, we specify our hedonic farmland price model with a spatial-lag representation.

In addition to the spatial dimension, our data set also involves a considerable temporal dimension as the data set covers county-level observations over the period of 1979 to 1999. The existing literature also shows that farmland prices can be serially dependent (Falk and Lee, 1998) and undetected temporal dependency may lead to overstatement of the reliability of the coefficient estimates (Pindyck and Rubinfeld, 1991). No doubt, the inclusion of the temporal dimension considerably increases the technical complexity in the specification of spatial econometric models (Pace et al, 1998; and Anselin, 1988). In order to appropriately address the spatial and temporal issues arising from the use of time-series and cross-section data set, we expand the spatial weight matrix from an $N \times N$ dimension to an $NT \times NT$ dimension to control the spatial relationships among observations of different locations, where N is the number of counties and T is the length of time series. Second, we incorporate a first-order autoregression or AR(1) process into our land price model. We consider only the first-order serial correlation because the AR(1) model for the disturbance has been shown to be a reasonable model for underlying highly complex processes (Greene, 1997). The simplicity of an AR(1) specification is particularly important for the hedonic price model to be empirically feasible when both spatial and temporal dependences are simultaneously represented. Another model specification problem that may result from the use of time-series and cross-sectional data is heteroscedasticity. To avoid additional complexities in our land price model, we simply assume no heteroscedasticity among the disturbance variances across different counties. This assumption is justified in our study for several reasons. First, because of multicollinearity, models with heteroscedasticity corrections such as GLS may lead to the exclusion of time-invariant variables such as soil productivity rating and distances to major cities, which are important determinants of the variation in farmland values among Illinois counties. Second, the presence of heteroscedasticity may produce inefficient estimators but will not affect their unbiasedness or consistency. Moreover, in large samples, the results of the estimators such as least squares will not be misleading (Greene, 1997).

Functional forms for the hedonic price model that have been proposed or used in the literature are numerous. In effect, there are few restrictions in choosing a functional form and goodness-of-fit is the most commonly used criterion in practice for deciding the functional form (specification) of a hedonic price model (Freeman, 1993; and Kim et al., 2003). For convenience interpreting estimated parameters, our land price model employs a log-log functional form. Based on the above arguments, and expanding existing models to account for potential spatial and temporal dependences, we employ the following hedonic farmland price model:

$$\ln P_{it} = \$_0 + \rho\,(W \otimes I_T) \ln P_{it} + \$_1 \ln Size_{it} + \$_2 \ln Class_{it} + \$_3 \ln SPR_i + \$_4 \ln Dich_i$$

$$+ \$_5 \ln Dist_i + \$_5 \ln Dici_i + \$_6 \ln CPI_{t-1} + \$_7 \ln SII_{it} + \$_8 \ln ASOS_{it} + u_{it} \qquad (1)$$

$$u_{it} = \lambda u_{i,t-1} + v_{it}, \quad v_{it} \sim N(0, \sigma_v^2)$$

$$E[u_{it}u_{is}'] = \sigma_v^2 \Omega(\lambda), \; t \neq s$$

and $$\Omega(\lambda) = I_N \otimes \left\{ \frac{1}{1-\lambda^2} \begin{bmatrix} 1 & \lambda & \lambda^2 & \cdots & \lambda^{T-1} \\ \lambda & 1 & \lambda & \cdots & \lambda^{T-2} \\ \lambda^2 & \lambda & 1 & \cdots & \lambda^{T-3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \lambda^{T-1} & \lambda^{T-2} & \lambda^{T-3} & \cdots & 1 \end{bmatrix} \right\}$$

where, P = average sales price per acre at the county level, dollars;

Size = average number of acres in the tract sold, acres;

Class = ratio of the improved land to the total land sold, percent;

SPR = soil productivity rating;

Dich = distance to Chicago, kilometers;

Dist = distance to St. Louis, kilometers;

Dici = distance to nearest city of a population over 50,000, kilometers;

CPI_{-1} = Consumer price Index for the Midwest region, 1982-1984=100;

SII = swine inventory intensity, measured as number of hogs per square miles;

ASOS = average swine operation scale, measured as number of hogs per operation;

W = row standardized spatial weight matrix, based on queen adjacency relations among counties;

I_T = identity matrix with dimension T equal to the number of time periods;

$\otimes$ = Kronecker product;

ρ, λ = spatial and temporal autoregressive coefficient, respectively; $|\rho|$ and $|\lambda|<1$;

u, v = disturbance terms;

i, t = subscript indexes for county and year, respectively.

Data

There are 102 counties in Illinois. Farmland transactions data are available from all counties except Cook County, where Chicago is located. The data are taken from transfer declarations commonly referred to as "green sheets" filed with the Illinois Department of Revenue and have been screened to include only "arm's length"[1] transfers of 5 or more acres. The data cover 1979-1999, and are aggregated by county giving a sample size of 2121. Farmland prices, the dependent variable in our hedonic price model, are acreage weighted average price per acre at the county level[2]. These land prices are in nominal terms and we used the January, 1982 producer price index (PPI) for farm products (January, 1982 PPI = 100) to adjust the data. Statistics on average numbers of acres in the tract sold (the size variable) and proportion of the improved land to the total land sold (the class variable) are also from the transactions database. Improved land is defined as parcels with buildings or other permanent structures.

Soil productivity ratings (SPR) were originally derived by Grano (1963), who estimated a weighted average SPR for each township in Illinois, except for Cook County, assigning each township an average productivity index value ranging from 5 to 100 based on the relative ability of a soil type to grow crops. Each county is assigned an average SPR based on data provided by the Illinois FBFM by county.

The distance measures used in our analysis were obtained using ArcView GIS (version 3.2) based on the shape files of Illinois counties and cities including St. Louis, MO. The distance measure represents the length of a straight line between the geographic centroid of a county and the city of interest (Chicago, St. Louis, and the nearest city with a population over 50,000 during the study period). While these distance measures may not fully reflect the transportation convenience to those cities, they are the most reasonable approximations for the influences of those cities on farmland values at the county level.

The county-level annual personal income per capita data were obtained from the Bureau of Economic Analysis, US Department of Commerce[3]. These income figures were nominal data and were adjusted for inflation with consumer price index (CPI) for the Midwest urban area. CPI and producer price index (PPI) for farm products are from the Bureau of Labor Statistic, U.S. Department of Labor. Population density measures are based on 1990 census data published by US Census Bureau. The base periods of the CPI and PPI are 1982-1984 and 1982, respective. Swine inventory intensity (SII) measures were calculated from the number of hogs in inventory divided by the area of a county. Annual hog inventory statistics are published by Illinois Department of Agriculture, available in various bulletins[4]. Average swine operation scale (ASOS) measures were computed based on Census of Agriculture 1978, 1982, 1987, 1992, and 1997. In these census reports[5], numbers of swine farms and swine inventories in each Illinois county for the census years were reported, and linear interpolations/extrapolations were used to derive the ASOS measures for other years in the study period.

The spatial weight matrix (W) is a result of the ArcView GIS (version 3.2) script application. Based on the Illinois county polygon shape file, a 101×101 weight matrix W representing the first order contiguity (on a queen criterion) among the 101 Illinois counties (Cook County was excluded for reasons already noted) was developed. The use of first-order contiguity implicitly assumes that a county's farmland prices directly affect the land prices of its neighboring counties only. This appears to be reasonable in our farmland value case. The definitions and descriptive statistics for the variables used in the estimation are summarized in Table 2.

Model Estimation

The land price model in equation 1 includes both spatial and temporal dependences. Our estimation strategy is first to remove the effect of AR(1) by the method shown in Judge et al. (1988) and Hsieh et al. (2001). Similar to Judge et al. and Hsieh et al., the inverse matrix of $\Omega(\lambda)$ can be written as:

$$\Omega^{-1}(\lambda) = I_N \otimes \begin{bmatrix} 1 & -\lambda & 0 & \cdots & 0 & 0 \\ -\lambda & 1+\lambda^2 & -\lambda & \cdots & 0 & 0 \\ 0 & -\lambda & 1+\lambda^2 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & 1+\lambda^2 & -\lambda \\ 0 & 0 & 0 & \cdots & -\lambda & 1 \end{bmatrix} \cdots = I_N \otimes (P(\lambda)'P(\lambda)) \qquad (2)$$

where $P(\lambda)$ is the transformation matrix:

$$P(\lambda) = \begin{bmatrix} \sqrt{1-\lambda^2} & 0 & 0 & \cdots & 0 & 0 \\ -\lambda & 1 & 0 & \cdots & 0 & 0 \\ 0 & -\lambda & 1 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & 1 & 0 \\ 0 & 0 & 0 & \cdots & -\lambda & 1 \end{bmatrix} \qquad (3)$$

Let y denote the land price variable and X denote an array of the explanatory variables in our land price model. Applying the following transformation to y and X:

$$y^* = (I_N \otimes P)^* y$$

$$X^* = (I_N \otimes P)^* X \qquad (4)$$

$$u^* = (I_N \otimes P)^* u$$

we obtain:

$$y^* = \rho(W\otimes I_T)y^* + X^*\beta + u^*,\ u^* \sim N(0,\ \sigma_u^2) \qquad (5)$$

where β is a vector of the coefficients to be estimated.

The transformed model (Equation 5) is a typical spatial-lag model in nature since spatial dependences among the two-dimensional observations are properly accounted for by $(W\otimes I_T)$. Anselin (1988) shows that, in the presence of a spatially lagged dependent variable, the ordinary least squares (OLS) estimator will be biased and inconsistent for the parameters of the spatial model, irrespective of the properties of the error term. As a result, the maximum likelihood (ML) estimator is commonly applied for spatial-lag models because of its attractive asymptotic properties. Following Hsieh et al. (2001), the ML estimates of Equation 5 can be obtained from maximizing the following log-likelihood function with respect to the parameters of λ, ρ, β, and σ^2:

$$\ln L = -(NT/2) \ln (2\pi) - (NT/2) \ln \sigma_u^2 + (NT/2) \ln (1- \lambda^2) + \ln |A|$$

$$- (1/2\sigma_u^2)(Ay^*-X^*\beta)'(Ay^*-X^*\beta) \qquad (6)$$

and $A = I_{NT} - \rho(W\otimes I_T)$

where NT is the number of observations (i.e., 2121 in our case). Since A is a 2121×2121 matrix, the computation of its determinant (the Jacobian term) is problematic. Thus, the dimension of the Jacobian term was reduced to 101×101by exploiting the properties of the Kronecker product[6]. Equation 6 thus:

$$\ln L = -(NT/2)\ln(2\pi) - (NT/2)\ln\sigma^2 + (NT/2)\ln(1-\lambda^2) + T\ln|I_N-\rho W|$$
$$- (1/2\sigma^2)(Ay^*-X^*\beta)'(Ay^*-X^*\beta) \quad (7)$$

where N and T are respectively the number of counties and time periods (i.e., 101 and 21 in our case). This decomposition of the Jacobian term greatly reduces the complexity of computing the spatiotemporal ML estimates.

The ML parameter estimation was conducted in SAS/ETS (version 8.2). For comparison, we also estimated the model with three different specifications. The OLS was used to estimate the traditional hedonic price model in which neither spatial nor serial dependences were considered while the ML estimator was applied for models excluding the spatial or the serial dependence components. The results of these estimations are reported in Table 3.

Results and Discussions

In general, all four specifications of the model produce similar results, with coefficient estimates that have reasonable signs, and generally good statistical significance (Table 3). However, it is clear from the results that the inclusion of spatial and temporal dependencies, the goodness-of-fit measure of the model improves substantially (adjusted R^2 and log likelihood values). Test statistics also indicate that spatial (λ)and temporal (ρ) dependences are present in our hedonic land price model. It is also notable that, for most variables, the OLS coefficient estimates (Table 3, Column 1) are larger in magnitude than the estimates from models with spatial and/or temporal dimensions, suggesting that ignoring the spatial and temporal effects tends to overestimate the impacts of the exogenous variables and the reliability of the estimates. Our results also show that models with only spatial or temporal effects have a larger ρ, or λ, than the spatiotemporal model, suggesting that excluding either of these two effects in the model also tends to bias up the effects of the other. Taking into account its theoretical and empirical superiority to others, we highlight the results of the spatiotemporal model (Table 3, Column 4).

Consistent with earlier literature (e.g., Oltmans et al., 1988; and Palmquist and Danielson, 1989), our results confirm that farmland values decline with parcel size and with distances to Chicago and to cities with population over 50,000 but increase with soil productivity ratings, class (an indicator of farmland improvement), population density, and personal income per capita. More germane, our results show that income and soil productivity are the most important determinants of farmland price differentials across Illinois counties. The estimated coefficients of distances from Chicago and cities with population over 50,000 reasonably exhibit the difference between a large municipality and an ordinary city in influences on Illinois land values. Our results show that the influence of Chicago is more than five times larger than the influence of other cities over 50,000. Distance from St. Louis is also shown to have a negative effect on farmland values, but this effect is not statistically significant. This result is not surprising because much of the impact of St. Louis on farmland values has been accounted for by other cities over 50,000 [7].

It is interesting to note that inflation, measured as lagged consumer price index, has a significant negative impact on farmland price. Intuitively, land prices are expected to rise with inflation or anticipated inflation. However, according to Chavas and

Shumway (1982), inflation (or expected inflation) may lead to either higher or lower farmland prices depending on how it affects after tax net returns to agriculture, the proportion of net returns that goes to land, and the discount rate. If inflation affects only the discount rate, an increase in inflation tends to decrease land values. However, if inflation is partly due to a rise in food prices and other production factors, net returns from farming would increase with inflation. If variable input prices do not increase as rapidly as farm product prices, it is also likely for inflation to yield higher net returns from land and hence to drive up land prices. The impact of inflation on land values is thus an empirical issue and cannot be assumed a priori. Our results show that expected inflation might have led to reduced farmland values in Illinois. In the absence of further investigation it is unclear how inflation cause such changes in land values.

Our results show that both the spatial and the temporal autoregressive coefficient estimates (ρ and λ) are strong positive and significantly different from zero, indicating substantial spatial effects across Illinois counties and the presence of temporal dependence over time. Specifically, the spatial autocorrelation estimate, $\rho = 0.184$, can be interpreted to indicate that a 1% increase on the average in farmland prices around the neighboring counties will lead farmland prices in the observed county to increase by 0.184%. The serial autoregressive coefficient, $\lambda = 0.300$, indicates that the variables omitted from the regression, as well as some of those included, are correlated across periods, suggesting that an appropriate treatment of the serial correlation problem is important to the hedonic farmland price modeling.

Our most important results concern swine production intensity (SII) and average swine operation scale (ASOS). The estimated coefficients of these two variables are -

0.129 and 0.069, respectively, and both statistically significant at the 1% level. Literally, ignoring the spatial multiplier effect resulting from the presence of spatial dependence (Kim et al. 2003), our results suggest that if swine production intensity increases by 1% in a county, farmland prices of that county will decrease by 0.129%. Stated differently, more hogs imply lower average farmland prices. However, if the average swine operation scale increase by 1%, farmland prices increase by 0.069%, suggesting that, for a given number of hogs in a county, more concentrated operations are associated farmland with higher prices at the county level though the immediate impact of these operations on the values of the surrounding farmlands might be negative. Because the swine intensity and the operation scale variables have opposite signs, and the size of the effect of swine intensity is nearly twice that of operation scale, a simple increase in hog numbers while keeping the number of swine farms constant will only minimally decrease farmland prices (the price elasticity of hog numbers in this case is -0.06). However, the negative impact of swine production on farmland values can be ameliorated the increase in operation scale is twice as much as the increase in hog intensity. This finding is interesting because it suggests that swine production can be even beneficial to farmland values if the pace of scale increase is fast enough to compensate the negative effect of production intensity.

Is this a fact or fiction? Wood (1998) observed an interesting case of the two Carolinas regarding the relationship between hog production and land values. In 1978, North Carolina farmland values were 27.1% higher than land values in South Carolina while this farmland price gap between the two states became 45% in 1987 and 48% in 1998. During the same time period, North Carolina's hog inventory has grown from 2.3

million head in 1977, to 2.55 million in 1987, to 9.7 million in 1997 while South Carolina has seen its hog inventory drop from 525 thousand in 1977, to 450 thousand in 1987, and to only 290 thousand in 1997. As is well known, North Carolina has become a paradigm of large-scale hog farming and South Carolina has nearly gotten out of the swine industry entirely. Though it is difficult to draw any conclusion based on this data, the industrialization of hog production in North Carolina, in general, is not detrimental to the aggregate farmland values.

As mentioned earlier, the Illinois swine industry has experienced significant changes in scale of operation and in hog inventories in the past two decades. It is relevant to consider the effects of these changes in swine production capitalized on farmland values. Based on Table 3 and on Illinois state average data, in Table 4 we estimated the effects of swine production on farmland values in Illinois from 1980 to 1999. Our results show that in most of the years examined the changes in the Illinois swine industry had a positive effect on land values. These positive effects accrue from two sources. One relates to the decrease in swine production intensity and the other is from the increase in swine operation scale. However, there are also were a few years that the industry changes led to reduced farmland values. The size of the effect ranged from $-10.56 to $62.96 per acre, which accounted for 0.9% and 2.8%, respectively, of the land price in the corresponding year. It is worth noting that the values in Table 4 measured the externalities resulting from changes in swine industry rather than from direct externalities of the swine industry. Our results provide evidence that swine production has negative externalities because an increase in swine production intensity leads to reduced in farmland values. Therefore, these values can be interpreted as the capitalized value of the benefits from the decrease in negative externalities of swine production.

Conclusions

This study is relevant for policy makers. First, our results indicate that farmland values are affected by swine production and the magnitude of this effect is substantial. Our results showed that, in addition to the conventional determinants of farmland values, increases in swine production intensity have negative impact while increase in swine operation scale has a positive effect on farmland values at the county level in Illinois. We also estimate the impact of changes in Illinois swine industry over the period of 1980-1999 on farmland values at the state level and our results show that these changes may have led to changes in farmland prices from $-10.56 to $62.96 per acre. In general, the changes in Illinois swine were associated with increased farmland values in Illinois. These results have useful implications for government regulations on the size and location of swine operations, as well as for government policies aiming at supporting producers.

References

Abeles-Allison, M. and L.J. Connor (1990), "An analysis of local benefits and costs of Michigan hog operations experiencing environmental conflicts", Agricultural Economics Report number 536, Department of Agricultural Economics, Michigan State University, East Lansing, June.

Anselin, L. (1988), Spatial Econometrics: Methods and Models, Kluwer Academic Publications, Dordrecht.

Canning, P.N. and H.D. Leathers (1993), "Inflation, taxes, and the value of agricultural assets", Land Economics 69 (4): 389-403.

Chavas, J.-P. and C.R. Shumway (1982), "A pooled time-series cross-section analysis of land prices", Western Journal of Agricultural Economics 7(1): 31-41.

Chavas, J.-P. and A. Thomas (1999), "A dynamic analysis of land prices", Amer. J. Agr. Econ. (November 1999): 772-84.

Falk, B. and B.-S. Lee (1998), "Fads versus fundamentals in farmland prices", Amer. J. Agr. Econ. 80(November 1998): 696-707.

Freeman, A.M. III (1993), The Measurement of Environmental and Resource Values: Theory and Methods, Resource for the Future, Washington, D.C.

Grano, A.M. (1963), Regional Factors Affecting Farmland Values in Illinois, unpublished Ph.D. thesis, University of Illinois at Urbana-Champaign.

Greene, W.H. (1997), Econometric Analysis. 3rd ed., Prentice-Hall, Inc.

Hamed, M., T.G. Johnson and K.K. Miller (1999),"The impacts of animal feeding operations on rural land values", University of Missouri-Columbia Community Policy Analysis Center, Report R-99-02.

Hamed, M., T.G. Johnson and K.K. Miller. 1999. "The impacts of animal feeding operations on rural land values", University of Missouri-Columbia Community Policy Analysis Center, Report R-99-02.

Hsieh, W., E.G. Irwin, and D. L. Forster (2001), "Evidence of county-level urbanization spillovers from a space-time model of land use change", Working Paper, Department of Agricultural Economics, Ohio State University.

Judge, G., R.C. Hill, W.E. Griffiths, H. Luekepohl, and T.C. Lee (1988), Introduction to the Theory and Practice of Econometrics, 2nd ed. New York: John Wiley.

Just, R.E., and J.A. Miranowski (1993), "Understanding farmland price changes", amer. J. Agr. Econ. (February): 156-68.

Kim, C.W., T.T. Phipps, and L. Anselin (2003), "Measuring the benefits of air quality improvement: a spatial hedonic approach", Journal of Environmental Economics and Management 45(1): 24-39.

Oltmans, A.W., D.L. Chicoine, and J.T. Scott, Jr. (1988), "Farmland price indexes: an evaluation of alternatives for Illinois, 1975-1984", Ag-Econ AERR Staff Paper, University of Illinois at Urbana-Champaign.

Pace, R.K., R. Barry, J.M. Clapp, and M. Rodriquez (1998), "Spatiotemporal autoregressive model of neighborhood effects", Journal of Real Estate Finance and Economics 17(1): 15-33.

Palmquist, R.B. and L.E. Danielson (1989), "A hedonic study of the effects of erosion control and drainage on farmland values", American Journal of Agricultural Economics 71 (1): 55-62.

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

Pindyck, R.S. and D.L. Rubinfeld (1991), Econometric Models and Economic Forecasts. 3rd ed. McGraw-Hill, Inc.

SAS Institute Inc. (2003), SAS System for Windows (version 8.2).

Schiffman, S., J. Walker, P. Dalton, T. Lorig, J. Raymer, D. Shusterman, and C. Williams. 2000. Potential health effects of odor from animal operations, wastewater treatment, and recycling of byproducts. J. Agromed. 7: 7-81.

Shi, Y.J., T.T. Phipps, and D. Colyer (1997), "Agricultural land values under urbanizing influences", Land Economics 73 (1): 90-100.

Taff, S.J., D.G. Tiffany, and S. Weisberg (1996), “Measured effects of feedlots on residential property values in Minnesota: a report to the legislature”, Staff Paper P96-12, Department of Applied Economics, University of Minnesota, St. Paul, July.

TerraSeer, Inc. (2003), ClusterSeer®2.

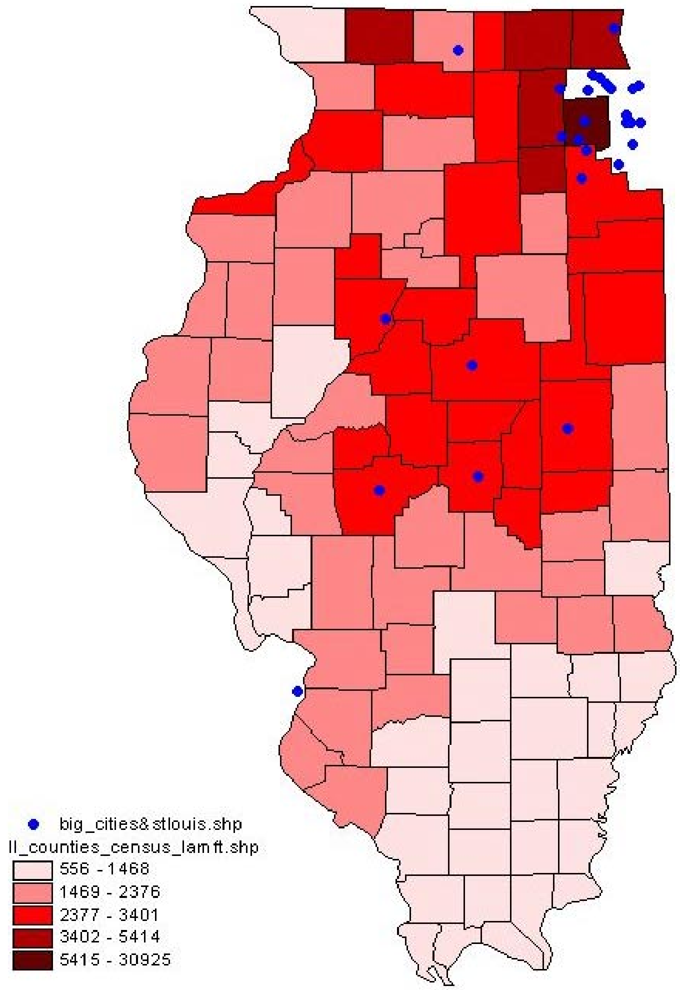
Thu, K., K. Donham, R. Ziegenhorn, S. Reynolds, P.S. Thorne, P. Subramanian, P. Whitten, and J. Stookesberry (1997), A control study of the physical and mental health of residents living near a large-scale swine operation. J. Agric. Saf. Helth. 3: 13-26.

USDA, Illinois Department of Agriculture. 2001. Illinois Agricultural Statistics: Annual Summary. Bulletin 01-1. Illinois Agricultural Statistics Service. November, 2001.

U.S. Department of Commerce, Bureau of the Census (1984), 1982 Census of Agriculture. AC82-A-13 Volume 1, Geographic Area Series, Part 13, Illinois State and County Data.

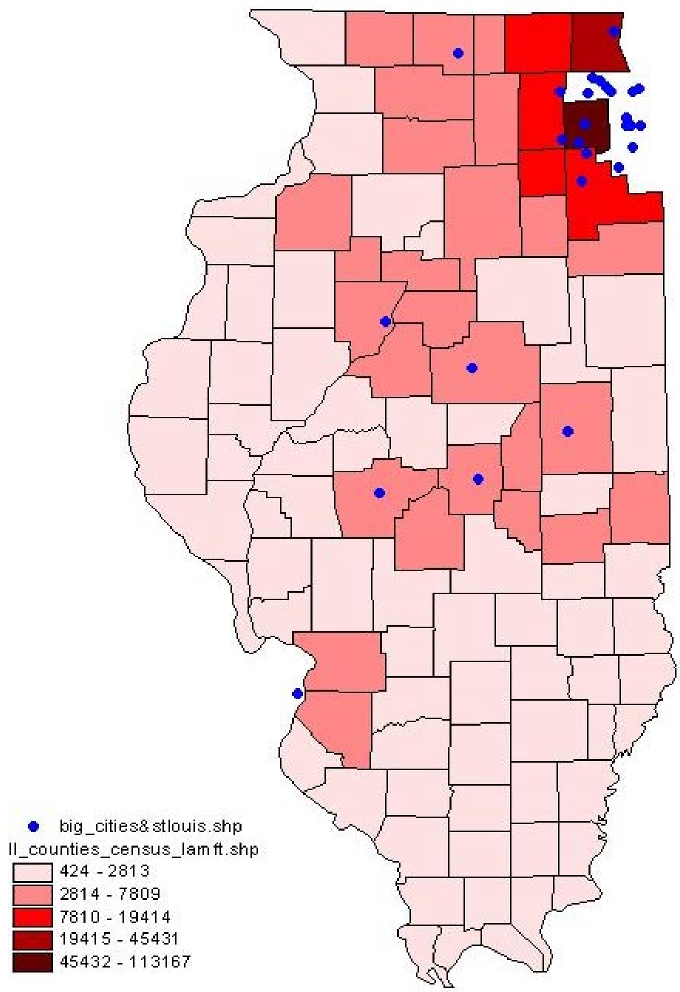
Wing, S. and S. Wolf (2000), Intensive livestock operations, health, and quality of life among eastern North Carolina residents. Environmental Health Perp. 108: 233-238.

Wood, C. (1998), "Modern hog production and land values", Ron Plain's Swine Economics Report, June 12, 1998.



Average price per acre

Figure 1 Illinois Farmland Price, 1979



Average price per acre

Figure 2 Illinois Farmland Price, 1999

Table 1. Moran's *I* Test for Global Spatial Autocorrelation of Farmland Prices among Illinois Counties

Year	Moran's *I* statistic	z-score (normality)	z-score (randomization)	P-value
1979	0.292	5.115	6.710	0.002
1980	0.209	3.711	5.085	0.002
1981	0.269	4.722	6.143	0.002
1982	0.284	4.976	6.159	0.006
1983	0.370	6.423	8.057	0.002
1984	0.320	5.582	7.274	0.002
1985	0.359	6.234	7.697	0.002
1986	0.347	6.043	7.649	0.002
1987	0.318	5.552	6.776	0.002
1988	0.345	6.007	7.686	0.002
1989	0.371	6.451	8.394	0.002
1990	0.337	5.862	7.545	0.002
1991	0.558	9.602	10.803	0.002
1992	0.255	4.488	6.081	0.002
1993	0.274	4.801	6.513	0.002
1994	0.430	7.447	9.355	0.002
1995	0.529	9.116	10.554	0.002
1996	0.288	5.046	6.783	0.002
1997	0.411	7.112	9.100	0.002
1998	0.491	8.481	9.737	0.002
1999	0.373	6.474	8.230	0.002

Note: 1. $\mathbf{H_0}$: farmland prices are spatially independent, the observations are assigned at random among location. ***I*** is close to zero, depending on sample size.
$\mathbf{H_1}$: farmland prices are not spatially independent. ***I*** is not zero.
2. The computation was carried out on the ClusterSeer® 2 software, a product of TerraSeer, Inc.

Table 2. Definition and Descriptive Statistics for Variables

Variable	Definition	No. obs	Mean	Std. dev.	Min	Max
Price	Acreage weighted average sales price per acre, dollars.	2121	2713	7567	89	155700
Size	Average number of acres in tract sold, acres.	2121	64.58	36.79	6	464.35
Class	Ratio of improved land to total land sold, %.	2121	46.3	19.9	0	100
SPR	Soil productivity rating	101	72.31	14.19	41.61	93.56
DICH	Distance to Chicago, kilometers.	101	284.56	126.02	34	535
DIST	Distance to St. Louis, kilometers.	101	216.01	101.83	31	450
DICI	Distance to nearest city over 50,000, kilometers.	101	58.06	41.32	1.47	159.2
CPI_{-1}	Lagged consumer price index for Midwest urban, 1982-1984=100.	21	117.69	27.05	64.7	159.3
PPI	Producer price index for farm products, 1982=100.	21	103.98	7.16	91	116.4
SII	Swine inventory intensity, hogs/mile^2.	2121	94.88	70.34	0	523.63
ASOS	Average swine operation scale, hogs/operation.	2121	383.88	265.68	0	3019
POP90	Population density, residents per square mile in 1990.	101	117.01	265.92	11	2340
INCOME	Annual personal income per capita, in current dollars.	2121	15318	5122	5323	44632

Table 3. Model Estimation Results

Dependent variable: ln (land price / acre)				
Variable	OLS (1)	ML (spatial dependence) (2)	ML (temporal dependence (AR (1)) (3)	ML (spatial and temporal dependence) (4)
CONSTANT	2.667*** (3.43)	-0.03 (-1.105)	3.595*** (3.73)	1.127 (1.21)
ln (SIZE)	-0.525*** (-27. 40)	-0.517*** (-26.95)	-0.526*** (-29.14)	-0.524*** (-29.59)
ln (CLASS)	0.059*** (4.60)	0.061*** (4.72)	0.063*** (5.59)	0.065*** (5.88)
ln (SPR)	0.655*** (10.61)	0.581*** (9.37)	0.664*** (8.65)	0.604*** (8.19)
ln (DICH)	-0.444*** (-15.29)	-0.288*** (-8.95)	-0.455*** (-11.43)	-0.321*** (-8.39)
ln (DIST)	-0.066** (-3.12)	-0.025 (-1.15)	-0.066** (-2.45)	-0.030 (-1.16)
ln (DICI)	-0.041** (-3.27)	-0.060*** (-4.73)	-0.042*** (2.64)	-0.059*** (-3.84)
ln (CPI_{-1})	-0.267*** (-6.24)	-0.146*** (-3.40)	-0.220*** (-4.53)	-0.212*** (-4.51)
ln (SII)	-0.138*** (-9.87)	-0.122*** (-8.67)	-0.140*** (-8.49)	-0.129*** (-8.09)
ln (ASOS)	0.080*** (5.03)	0.058*** (3.61)	0.084*** (4.84)	0.069*** (4.08)
ln (POP90)	0.117*** (9.17)	0.108*** (8.43)	0.125*** (8.04)	0.118*** (7.86)
ln (INCOME)	0.849*** (11.08)	0.937*** (12.18)	0.725*** (8.32)	0.780*** (9.25)
ρ		0.211*** (11.17)		0.184*** (8.49)
λ			0.317***	0.300***
Adjusted R^2	0.780	0.792	0.837	0.842
Log likelihood	-760.15	-687.12	-527.73	-483.90
Number of observations	2121	2121	2121	2121

Notes: 1. *** indicates that the statistic is significantly different from zero at 1%, ** at 5%, and * at the 10% hypothesis level.
2. *t*-statistics are given in parenthesis.
3. The significance of the temporal autoregressive coefficient λ is based on likelihood ratio test.

Table 4. Estimates of the Influence of Swine Production on Farmland Values

Year	Farmland prices ($/acre)	Swine intensity[a]		Swine operation scale		Total effects: (3)+(5) ($/acre)
		Change in swine intensity (%)	Effect of (2) on land price ($/acre)	Change in swine operation scale (%)	Effect of (3) on land price ($/acre)	
	(1)	(2)	(3)	(4)	(5)	(6)
1980	1930	-5.30	13.20	6.52	8.69	21.88
1981	1898	-2.21	5.40	6.12	8.02	13.42
1982	2018	-13.16	34.27	5.77	8.03	42.30
1983	1752	-3.27	7.39	3.45	4.17	11.56
1984	1589	-0.74	1.51	3.34	3.66	5.17
1985	1587	-0.08	0.17	3.23	3.54	3.70
1986	1357	-7.60	13.30	3.13	2.93	16.23
1987	1176	8.58	-13.02	3.03	2.46	-10.56
1988	1210	3.38	-5.27	5.22	4.36	-0.92
1989	1143	1.87	-2.76	4.96	3.91	1.15
1990	1156	0.32	-0.47	4.73	3.77	3.30
1991	1244	3.07	-4.93	4.51	3.87	-1.06
1992	1315	-0.16	0.28	4.32	3.92	4.19
1993	1326	-7.43	12.72	11.50	10.52	23.24
1994	1317	-1.87	3.18	9.42	8.56	11.74
1995	1569	-10.49	21.25	8.17	8.85	30.10
1996	1582	-8.35	17.05	10.61	11.58	28.64
1997	1776	7.31	-16.75	7.08	8.67	-8.07
1998	2020	3.05	-7.96	7.36	10.26	2.30
1999	2251	-17.63	51.19	7.58	11.77	62.96

Note: 1. Farmland prices, changes in swine intensity, and changes in swine operation scale are in terms of Illinois state average.
2. Farmland prices are deflated with producer price index for farm products.
3. Estimates in column 4 and 5 are calculated as:
Change in swine intensity(or operation scale)*Elasticity of SII*Farmland prices.

[a]Swine intensity is defined as swine population (inventory) per square mile.

Endnotes

[1] "Arm's length" is broadly defined as a transaction arrived at in the open market, unaffected by abnormal pressure or by the absence of normal competitive negotiation.

[2] Illinois county level farmland prices data are at http://www.farmdoc.uiuc.edu.

[3] County-level personal income per capita data are at http://www.bea.gov/bea/regional/reis/.

[4] Illinois hog inventory data are published at http://www.agr.state.il.us/agstates.htm.

[5] The 1978 and 1982 Illinois and county census data are from 1982 Census of Agriculture (U.S. Department of Commerce, 1984); 1987, 1992, and 1997 data are at http://govinfo.kerr.orst.edu/php/agri/show2.php.

[6] Since $A = I - \rho(W \otimes I_T) = I_N \otimes I_T - \rho(W \otimes I_T) = (I_N - \rho W) \otimes I_T$, $|A| = |(I_N - \rho W) \otimes I_T| = | I_N - \rho W |^T | I_T |^N = | I_N - \rho W |^T$.

[7] In calculating distance to cities over 50,000, St Louis as well as Chicago are also on the list of these cities. Therefore, the two municipalities' influences on land values may have been mitigated by variable distance to other cities over 50,000.