Toward the Efficient Production of the Discommodity of Animal Odor: A Hedonic Price Approach to Economies of Scale

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Abstract:

Controversy surrounding confined animal feeding operations (CAFO) is becoming more commonplace. In several regions of the country CAFOs and local residents have had disputes over odors emanating from these operations.

Viewing the CAFO as jointly producing products with utility (e.g., meat) and disutility (e.g., foul odor), it is possible to determine an efficient level of production for both products that is market-based. The authors propose a hedonic price model based upon real-estate transactions adjacent to CAFOs to establish a market-based estimate of the degree and extent of odor disutility. Using the results of the hedonic model, the authors suggest that a simple model of odor dispersal can be used to address the issue of economies of scale and the production of the disutility odor. Specifically, the final outcome should reveal if there is more or less disutility produced with an industry that is intensively or extensively managed.

Key Words: Hedonics, confined animal feeding operations, animal odor, economies of scale

Introduction

The current trend in North American agriculture to larger farms has been documented by many sources (Suits, 2000; Knutson et.al., 1998). For example, in the swine industry, the number of swine farms (operations) with 200 – 500 sows has been declining since the 1970's the number of operations with greater than 1,000 has risen dramatically. In 1978, 33% of operations had greater than 1,000 head and 7% had greater than 5,000 head. In 1992 those percentages had risen to 69% and 28% respectively (USDA). Similar trends are already well established in the poultry sector and are also appearing in the dairy sector. These larger operations have led to new challenges for managers/owners. One area of particular interest and concern is the growing problem of waste disposal and obnoxious odors that originate from the large-scale confined animal feeding operations (CAFOs).

There have been several well-publicized cases of hog manure leaking or spilling into nearby waterways and groundwater supplies. In several regions of the country, CAFOs and local residents have had major disagreements over the odors emanating from area cattle, hog or poultry operations. The causes for these conflicts are many and varied: new CAFOs moving into an area with an established human population, small operations growing into large operations and residential populations growing into the areas of existing CAFOs. The conflict between CAFOs and local residents will likely intensify in the future as the trend toward larger operations continues and firms take advantage of cost savings with increased size.

One of the first steps to determine an efficient resolution to this problem is to better understand the degree to which effluent from CAFOs is "bad." If one takes the simple view that a typical operation jointly produces two products, one with value to society (e.g. meat) and one with a cost to society (e.g. odor), it becomes possible to determine an efficient level of production for both products based on market equilibrium.

There is some regulatory interest in establishing odor models based on mechanical smellers to help define the areas affected by the discommodity of obnoxious odor. Presumably, the goal of this effort is to use these models to regulate CAFOs size, location, and method of operation to comply with state and federal odor guidelines. As with other command and control approaches to environmental regulation, using a non-market approach to this problem will not likely lead to efficiency in the production of either the commodity or discommodity by the CAFOs. Regulation may be inefficient if it either affects residential areas not affected by odors, or if it fails to regulate areas that are affected by livestock operations, where the extent of discommodity is revealed by residential property values.

A more appealing approach to the question of efficient CAFO size and method of operation would be market based. Using records of real estate transactions in areas adjacent to established CAFOs it is possible to determine the level of disutility caused by odor. Using these data to delineate affected areas, one can use a simple spatial model of odor abatement to objectively determine the efficient economies-of-scale for the abatement of odor.

Literature Review

The swine-odor problem is finding its way into headlines and public debates. Most of the growth came from operations housing hundreds or thousands of pigs at one site. By having so many animals under one roof, it is difficult to manage wastes and keep things clean. At the same time, development in once-rural areas is bringing more people into contact with farms. In many communities, complaints about problems associated with swine waste odor began to make the news (Okun, 1999) Citizens are concerned with the industry's impact on the health of nearby residents, the environment and the overall quality of life in the community.

Hog odor is a damaging and divisive issue facing the pork industry today. (Warrick and Stith, 1995) Over the past few years, there has been an increasing interest in the swine industry in many states, especially concerning odor-related issues. Some of the reasons for this emphasis are:

- *Historically in the prairies, the majority of the rural population consisted of "mixed farms" with small livestock operations. Now farms are more specialized and rural residents may have little or no experience with livestock and associated odors.*
- *The size of the livestock farms has increased considerably in the last decade.*
- *Non-farmers are moving into rural communities. This results in an increased sensitivity toward the introduction of new intensive livestock operations into the area.*
- *Some areas of the world have become densely populated with livestock resulting in negative environmental impacts.*
- *The public has an ever-increasing awareness of environmental issues and this includes odor-related issues.*
- *Those who have never had any experience with hog operations may base much of their comprehension of livestock production on other people's opinion and not on real facts.*

Not surprisingly, perceptions of bad odors vary from person to person. As with many personal preference issues, it is not yet clear why people feel that some odors are worse than others. For some people, the simple presence of a detectable odor, no matter how meager, will constitute a problem. People complain that swine odor adversely affects the quality of their lives, may cause unknown long-term health problems and reduce real estate property values. These affects have been particularly noticeable in North Carolina.

Almost overnight, North Carolina acquired a billion-dollar swine industry (Swine Odor Task Force, 1995). During 1994, North Carolina became the second largest swine producing state in the United States, behind only Iowa (Swine Odor Task Force, 1995). Hog inventories in North Carolina have more than doubled, growing from 2.8 million in 1991 to 7 million in 1994 eclipsing any previous rate of growth in U.S. history (Palmquist, Roka and Vukina, 1997). While the rapid growth of the swine industry is providing income and employment opportunities for some, there are also serious environmental concerns to consider. Presently, significant public attention is directed toward the offensive odor release from hog facilities and manure handling systems. Residents living in close proximity to large hog operations claim that odor can adversely affect the quality of their lives and may pose long-term human health risks. Some residents claim that they have suffered tangible economic damages from a decline in their real estate property values (Palmquist, Roka and Vukina, 1997).

The swine industry has spent large amounts of money to define the problem and discover practical, affordable solutions. For example, the North Carolina Pork Producers Association has agreed to fund research that attempts to capture, measure and analyze odors from hog farms (Warrick and Stith, 1995). Part of the ongoing regulatory problem with animal odor is that swine producers are not currently regulated by federal statues or by the air pollution control agencies of any of the states. This is in large part due to the subjective nature of determining when an odor is obnoxious. However, many state government officials have expressed concern over the complaints they have received from their citizens related to the odor issues.

The question of whether an odor is “bad” can be approached from the perspective of a free market. The choice of a residential property signals a preference for particular attributes. Knowledge of the market price for a good of bundled attributes makes it possible to assign a monetary value for each of the attributes. One of these desired features may be the absence of swine odor.

The hedonic pricing method (HPM) is frequently used to measure the value of natural and environmental resources, especially when they contribute to the market value of houses and property values that derive some of their value from the presence of the characteristics of the surrounding area.

The HPM has its genesis in the notion that goods and services are demanded for their desirable and attractive characteristics and the stream of benefits they provide. This idea finds its earliest expression in the work of Lancaster (1966), Rosen (1974), and Griliches (1971). In the theory developed in these papers, the present discounted value of a good derives from the stream of benefits provided by the characteristics of the good over time. Goods and services are transacted in markets and thus have a market price, and the HPM can be used to derive the marginal valuation – the implicit price - for each of the individual attributes that comprise the good. These values, when taken together, determine the price of the good. Using houses as an example, the HPM can be used to identify the value of attractive environmental surroundings; their absence, or the presence of undesirable characteristics, like noise or odor. Assuming separability of preferences, the HPM makes use of observed market behavior to estimate the implicit prices of similar, closely related goods that are distinguished by the presence or absence of certain characteristics.

The HPM has been used to estimate the implicit price of various characteristics of a good or service. The relationship can be expressed in its usual functional form as

$$Py_i = Py(q_i1,q_i2,\ldots q_in) \qquad 1.$$

where Py_i is the price of the good and $q_i1..qin$ represents the characteristics of the good or service. As noted above the model usually assumes that the underlying preference function,

$$u = u\ (q1,\ q2,\ldots qn), \qquad 2.$$

where the qi are the identifiable characteristics of the good, is weakly separable in those characteristics (Freeman, 1993). If the good is housing, the q_i might be living space in square feet, lot acreage, number of bedrooms or bathrooms, presence or absence of a garage, and neighborhood or environmental amenities. Location near a desirable school or a park may positively affect the market price of the house, and an objectionable or undesirable environmental presence, such as offensive odor from a nearby swine operation, would reduce it. *Ceteris paribus*, one would expect that, for two otherwise similar houses, with the same characteristics, one located within smelling distance of a pig farm would sell for a lower price than one not located near an operation. The same has been shown to hold true in cases of, for example, airport.

The HPM needn't, and typically will not, take a linear functional form. As Freeman (1993) notes, a linear functional form will not allow estimation of a demand equation because it would have a constant implicit price for a given characteristic. Each individual demand would have the same implicit price for a characteristic.

The coefficients of the q_i would be the implicit prices, or contributions to Py_i, of each characteristic, and Py_i is a function of the values of the characteristics.

The link between the Lancaster (1966) and Rosen (1974) papers and the HPM is the theory of value based on the marginal contribution of the characteristics of the good, in which the good as described by the characteristics of the good. These characteristics may vary from unit to unit, as between house to house. A change in an environmental variable will produce a change in the price of the house; when the environmental disamenity affects the entire region or area, all of the houses in it will, to the extent that they are affected by the disamenity, also experience a lower price.

The HPM has been used in many environmental applications; among the earliest and most notable are applications investigating the relationship between house values and air quality (Freeman 1974, Anderson and Crocker 1971). A recent application to valuation of residential property near swine farming operations is Palmquist, et.al. (1997).

Procedure

The hedonic model generically described above can be specified to estimate the effect of odors from pig operations value on residential property prices. One vector of independent variables would reflect the characteristics of the house, and another would account for distance of the house from nearby pig farms:

$$\mathbf{P_i} = (\mathbf{H}_i, \mathbf{D}_i, \mathbf{M_I}, e_i) \qquad 3.$$

Where $\mathbf{H}_i$ is a vector of characteristics of a particular house, such as the number of rooms, bedrooms, square feet of living space, and other such attributes; $\mathbf{D_i}$ is a vector of distance from the house to nearby pig operations that might affect the price of the house; **M**i is a vector of other characteristics and factors, such as those that may affect the volume of affected area (see p. 10), that may complicate the simple linear relationship between odor and distance; and e is a vector containing the usual independently distributed, uncorrelated error terms.

To consider the question of economies of scales in odor abatement, it is useful to start with a simple model of overlap and consider two polar cases. Assume one unit of animal waste fouls a fixed volume of air. Without going into the numerous factors, both chemical and physical that affect the size of the affected area, simply impose *ceteris paribus* and assume for a given environment one unit of waste will foul a finite volume of air. The size of this fouled area will be determined by society and reflected in market behavior.

If we assume the fouled area is of size X, then one can generalize two polar models of odor abatement. In the first model, assume the environmental factors that control odor abatement and/dispersion are nonexistent, or put another way, there exist no environmental processes to reduce or dissipate odor. In this case, two units of waste will affect an area of size 2X. The juxtaposition of waste will have no affect on the total area of fouled air. However, it is noteworthy to remember that the average distance from the waste to the edge of the affected area grows at $(A/N\Pi)^{.5}$.

The affected area then becomes:

$$A = NX \qquad 4.$$

where N = number of waste units, and

X = fixed volume of foul air per unit of waste.

In this case, the replacement of many dispersed waste units with a single concentration of waste will lead to no change in the size of fouled air.

In the second case, assume there exists some set of environmental factors that allow the volume of fouled air from one unit to overlap with that of another unit, with no displacement of fouled air. In this case, with perfect overlap of fouled air, placing all waste units in one spot could reduce the size of the affected area.

$$A = (N_T X)/N_o \qquad 5.$$

Where N_T = number of waste units

X = fixed size of fouled air per unit of waste

N_O = number of overlapping units, $N_O \geq 1$.

With complete overlap of all N_T units, A would reduce to X, the affected area of one unit of waste.

There is evidence to expect that A is neither completely overlapping, nor total devoid of overlap. The degree to which overlap occurs will determine the economy of scale in odor abatement.

Consider the following linear model of odor dispersal:

$$A = \phi + \alpha(N) + \in \qquad 6.$$

where ϕ = constant ;
α = degree of odor dispersion, ($0<\alpha<1$);
N = number of waste units (lbs of manure);
$\in$ = error term.

The variable A is estimated by the hedonic model and could be represented as a circle; the radius set where the effects of swine odor on pricing becomes negligible. Using Geographical Information System data, it may be possible to determine a more exact area, allowing for the effects of prevailing winds and geographical features. Furthermore, restrict the degree of odor dispersion to the unit interval. When $\alpha = 0$, there is complete odor overlap and when $\alpha = 1$, there is no odor overlap. By sampling a range of CAFOs one can test as $\alpha \to 0$, for improving economies of scale, using a simple hypothesis test, with the null hypothesis, $H_O : \alpha = 0$, and the alternative hypothesis, $H_A : \alpha \neq 0$, to determine the existence of economies of scale.

The authors are collecting swine operation data from several sources; most notably, the North Carolina Department of Environment and Natural Resources. These data will provide the physical location of operations and a measure of manure production. Real estate transactions data will be collected from several North Carolina county governments and include information on location and amenities.

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