"The siting of large-scale livestock facilities near homes disrupts rural life as the freedom and independence associated with life oriented toward the outdoors gives way to feelings of violation, isolation, and infringement."

--Pew Commission on Industrial Farm Animal Production

Valuing Localized Externalities:

Hog Operations in North Carolina

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April 2009

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Acknowledgments

I am especially grateful to my thesis advisor, Professor Christopher Timmins, for his dependable advice, patience with my constant emails, and support throughout this year. I am also incredibly grateful to my Econ198S and 199S professor, Peter Arcidiacono, for his guidance and insightful feedback during the research and writing process. I would also like to thank my fellow seminar classmates for their helpful comments on drafts and presentations. Special thanks to Joel Herndon, Mark Thomas, and Tatyana Kuzmenko for their invaluable computer expertise and assistance.

Abstract

In the early 1990s, eastern North Carolina experienced a boom in industrial hog production. Among the negative externalities generated by this activity, residential property value losses due to operation proximity are some of the most significant. This paper discusses the impact of hog operation presence on median housing values for census tracts and blocks (the smallest geographic unit the Census Bureau keeps data on). It concludes that measuring localized externalities at the tract level yields insignificant results, but that measuring these at the block level accurately shows the marginal impacts on housing values. At ½ kilometer, one operation can cause a 9% decline in value, or a drop equal to almost $7,000 in magnitude. Even without considering health, sociological, and political consequences, the economic drawbacks from these industrial-sized animal feeding operations gives a substantial reason to re-evaluate their siting, expansion, and ultimate necessity.

I. Introduction

Locally undesirable land uses, such as power plants, hazardous waste sites, and animal feeding operations, have become a nuisance in rural areas across the country. Waste materials from these facilities contaminate the surrounding air and water, usually leaving nearby residents with no compensation. Even though measuring the damage from these facilities can prove difficult, most research has found that health, social, and economic effects are negative in a localized area (within a couple of kilometers). Measuring economic externalities is made possible by house price capitalization, whereby the value (or disvalue) of an environmental characteristic can be extracted from its contribution to the value of a house.

One type of locally undesirable land use, confined animal feeding operations, congregates "animals, feed, manure and urine, dead animals, and production operations on a small land area," and produces a host of negative externalities (Environmental Protection Agency, 2009). Specifically, in North Carolina, industrial hog production has become increasingly concentrated into smaller geographic areas so that the economic effect of these facilities shows up in decreased housing values for those residents nearby.

The North Carolina hog industry has surpassed the tobacco industry in terms of the agricultural income that it generates for the state. North Carolina produces 19% of the total United States hog output, valued at over $2 billion, and ranks second only to Iowa. Corporations have touted the economic benefits of large-scale hog operations: greater tax revenues, more local products, job creation, and increased organic plant nutrients for crop production. During the pivotal decade of the 1990s, the North Carolina hog industry grew from 2.6 million hogs to almost 10 million today (Environmental Defense Fund). The industrialization of the industry that began in the late 1980s continued uninhibited well into the 1990s because local environmental groups began to take action only after major polluting incidents (Furuseth, 1997).

Manure disposal poses one of the greatest environmental challenges for the industry. The average total waste generated by hogs in North Carolina per day is thirteen million pounds (Duke Department of Sociology). Traditionally, farmers use open-air anaerobic lagoon pits to contain the waste. Ammonia and methane emissions may drift into the air of surrounding neighborhoods (EDF). Foul odors can spread for miles, excess nutrients may seep into and contaminate ground and surface water, workers may develop respiratory ailments, and toxins from waste can create health hazards for residents situated nearby. This paper tests for a negative relationship between median housing prices (at both the census tract and block level) and hog operations in order to measure the localized externalities.

Much debate still exists surrounding the level at which to measure localized externalities in hedonic analysis, so this paper uses both census tracts and blocks. Some studies use county-level data, while others use individual house prices. I use both tract-level and confidential block-level data, to see how the relationship changes with the level of geographic aggregation. My data contain information for the years directly before the boom in hog production and directly after, and should be able to fully capture any effects on housing values.

Coefficients on hog operation presence are negative and significant using the block-level data, while the coefficients at the tract level are not significant. In terms of magnitude, one hog operation located at ½ kilometer from a house can lower the house's value by as much as $6,968. Knowing this information has useful implications for homeowners seeking damages and for policy makers deciding questions of industry expansion. Most importantly, my results show that using the most geographically-specific Census Bureau data available captures the extent of damages caused by very local undesirable land uses.

This paper is divided into five sections. Section II reviews relevant literature that has examined the impact of different types of locally undesirable land uses on residential property values. Section III discusses the sets of data used: Dun and Bradstreet data on hog operations back to 1990, census tract data from 1990 and 2000, and census block data from 1990 and 2000. Section IV discusses the theoretical framework of hedonic analysis as applied to housing values and the empirical methods used. Section V presents the results of tract-level and block-level analysis. The final section concludes the paper and discusses areas for future research.

II. Literature Review

While there have been a great number of studies conducted on measuring localized externalities, there has been limited research conducted on the effects of swine operations on residential housing values. None of the previous studies on confined animal feeding operations has used census block data, and none has tracked changes in housing values over time. Instead, most of the studies have combined data on housing sales with varying data on animal-herd numbers to run cross-sectional regressions. They have found mixed results depending on distance, operation concentration, and operation size.

The most well-known and comprehensive study, conducted by Palmquist, Roka, and Vukina used data on 237 home sales in the early 1990s, and data on the total number of herds within specified distance rings around each house because they did not have data on exact hog operation locations. A "herd" is one hog or more, so they used "market-herd equivalents" to develop a manure index as well. They found that "if a new operation locates within one-half mile of a house…house value drops by 4.75%" (Palmquist et al., 1997). The drop in value is dependent upon manure levels and previous concentration of operations in the area. Overall, they found that operation proximity does have a negative and significant impact on property values (Palmquist et al., 1997). They admit, however, that "data on hog farm locations would allow the inclusion of important variables such as exact distances between farms and residents" (Palmquist et al., 1997). I expand on their research by using data from thousands of housing values (instead of sales) *after* the boom in hog production, and data containing the precise location of the operations (exact latitudes and longitudes).

A more recent study on the topic is titled "Living with Hogs in Iowa: The Impact of Livestock Facilities on Rural Residential Property Values" by Herriges, Secchi, and Babcock. In this study, the authors used county assessor data on home sales (over 1,000) and the exact location and size of livestock feeding operations in five rural counties. They found that "predicted negative effects are largest for properties that are downwind and close to livestock operations" (Herriges et al., 2003). They also counter-intuitively found that "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" (Herriges et al., 2003). These authors used GIS data on the location of livestock facilities, but did not use panel data. They constructed centroids for property sales and livestock operations, and calculated distances between the two (Herriges et al., 2003). I use a similar technique by constructing centroids for census blocks and measuring the concentration of hog operations within specified distance rings.

Gallagher and Greenstone used census tract data and GIS techniques in their study titled "Does Hazardous Waste Matter? Evidence from the Housing Market and the Superfund Program." They used census tract data to estimate the local welfare impacts of hazardous waste site clean-ups. They showed that waste site clean-ups are associated with a small and statistically insignificant change in property value (Greenstone and Gallagher, 2008). My results show a similar story at the tract level, suggesting that this level of analysis is too large to measure localized externalities. The authors used GIS to draw circles around each Superfund site and incorporated data from all tracts that fell within a certain radius to calculate demographic and housing values. I perform a similar analysis at the block level by drawing radii around each centroid and counting the number of operations contained.

Glenn Blomquist's approach in the "Effect of Electric Utility Power Plant Location on Area Property Values" (1974) guided the (cross-sectional) census block portion of my research. I use the same dependent variable: mean property value (the block average of owners' estimates of market sale price of house and lot for all owner-occupied, single family dwelling units). He also mentions that zoning requirements are believed to limit too much variation in lot size - this makes using census block data less prone to omitted variables bias. He measured distance to power plants as the distance from the center of the block to the smokestack of a power plant, showing that this empirical method can correctly measure localized negative externalities.

The chart below summarizes some of the studies that most closely resemble mine.

Authors	Year	Panel	Sample	Location	Hog Measure	Finding
Palmquist, Roka, Vukina	1992-1993	No	237 home sales	9 counties in Southeast North Carolina	Total "herds" at three distance rings around each home, index of hog manure at different distances	Up to 9% decrease depending on hog number and distance
Miller, Thomas, Ansine	2001-2002	No	810 parcels	Craven County, NC	Hog density (# in nearest farm)/distance (feet)	1% increase in D/D led to .031% decline in value
Herriges, Secchi, Babcock	1992-2002	No	1,145 home sales	Iowa – 5 counties	Location, live weight, manure index, concentration ratio	10% reduction if upwind and moderate in size
Abeles-Allison, Connor	1986-1989	No	300 homes	Michigan	Distance to farm, wind direction, number of animals	Value declines 43 cents for each additional hog
Ready and Abdalla	1998-2002	No	8090 homes	Penn.	Linear distance to house	4.1% decline at 800 meters

None of the previous studies has all of the following: 1) a very large sample size 2) panel data and 3) precise measures of location. While there are not a large number of studies conducted specifically on hog operations, the literature estimating the effects of localized environmental externalities is extensive enough to guide my research on swine operations and rural residential property values in North Carolina. Most previous studies, however, were conducted before or during the boom in hog production, and do not use a panel dataset to measure changes over time. My panel dataset contains information on both census blocks and tracts in the largest hog producing counties in North Carolina. My hog operation data contain information on exact operation locations, employees, and sales. Using confidential block data from two points in time and employing fixed effects to control for omitted variables, I determine the precise magnitude of the negative effect of operations on a very detailed level.

III. Data

Coastal Plains North Carolina is an important study location because of its comparative advantage in swine production due to poor soil resources, strong government support, comparatively few environmental regulations, proximity to East coast markets, and lower on-farm production costs (The Pig Site). Throughout the 1990s, hog farming became increasingly concentrated in narrower geographic areas. The facts below summarize the trends:

- From 1989 to 1995, the percentage of the state's hog population in ten Coastal Plains counties jumped from 39% to 67%
- By 1992, over 90% of the swine population was concentrated on just 802 farms
- In 1998, 92% of the states' 10 million hogs were raised on operations of at least 2,000 head (North Carolina Coastal Federation)

Hog Operation Data

My data on hog operations come from Dun and Bradstreet, a corporation whose database contains quality business information, services, and research on companies. The data contain not only information on the exact location of hog operations (geographic coordinates), but also figures for the number of employees and the amount of sales in each year beginning in 1990. It also contains yearly entry and exit information for each firm.

The Dun and Bradstreet hog data match the trends in the industry as described by current literature. In 1995, the Swine Farm Siting Act required waste lagoons and hog houses to be situated 1,500 feet from any occupied residence *but* only on all new or expanded hog farms raising more than 250 hogs. Most importantly, in 1997, House Bill 515 imposed a moratorium on the construction of new and expanded hog operations with

250 or more hogs until March 1, 1999 as well as imposed an additional setback requirement for hog houses and lagoons to 2,500 ft (Environmental Defense). Owen Furuseth found that the "ten counties of southeastern North Carolina captured 78% of the statewide expansion in swine populations during the past six years…In 1989 these counties contained slightly more than 39% of North Carolina's hog population (1.2 million head), but by 1995 their share had jumped to 67% (4.4 million animals)" (Furuseth, 1997). See Charts 1-3 in the Appendix to observe the trends as described by my data.

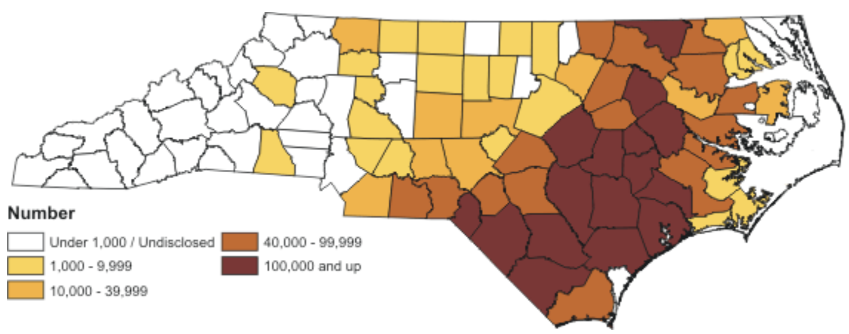
According to my data set, until 1997-1998, the total number of employees steadily increased, then leveled off. The total number of firms increased linearly throughout the decade. This is consistent with the observed decline in total number of hog farms across the entire state: my data captures only the explosion in production in the eastern portion of the state. Interestingly, average sales increased throughout the decade as expected, then precipitously declined after 1997. To evade the moratorium, farmers constructed smaller operations: this neatly explains both the trend of increasing firms and the trend of decreasing average sales. These three charts clearly capture the apparent trend in the industry over the decade.

In most recent studies of the effect of confined animal feeding operations, the size of the herd or pounds of manure is used as the independent variable to serve as a proxy for negative externalities. The problem with this approach is that in some cases, "larger operations…tend to be newly built and employ best available technologies for dealing with waste and odor" (Putze). I do not have data on prevailing wind directions, size of the associated waste lagoons, water quality, or number of swine contained in each operation. I rely on the simple existence of a swine facility to measure its effects, and omit distinctions between small and large operations.

Housing Data

Data on median housing characteristics are drawn from the United States Census Bureau. First, I utilize census tract variables from both 1990 and 2000 for the largest hog producing counties in North Carolina: Beaufort, Bladen, Columbus, Craven, Duplin, Edgecombe, Greene, Halifax, Harnett, Johnston, Jones, Lenoir, Nash, Northampton, Onslow, Pender, Pitt, Robeson, Sampson, Warren, and Wayne. The darkest color in Figure 1 depicts the largest hog producing counties in the state, all located in southeastern North Carolina.

FIGURE 1: Largest Hog Producing Counties in North Carolina



Source: North Carolina Department of Agriculture

A census tract is a small statistical subdivision of a county. Tracts generally contain information for 2,500-8,000 people and, when first delineated, "are designed to be homogeneous with respect to population characteristics, economic status, and living conditions" (Census Bureau). This implies that in rural areas, such as Coastal Plains North Carolina, tracts will cover a relatively large geographical area. The Census Bureau collects the following information for each tract: median household income, median property value, median number of rooms per house, house age, ethnicity percentages, mean travel time to work, percentage of the population over 25 with a bachelor's degree, etc. All of these variables will impact housing values and need to be controlled for in any analysis.

The median housing values are owner imputed. Champ, Boyle, and Brown state that homeowner surveys of value are one commonly used method of collecting data on property values, with the only caveat that measurement error may be a significant concern. Owners' lack of information about neighborhood amenities might cause them to overestimate or underestimate the value of their houses for different purposes. In the census survey, housing value is not a continuous variable, and the participants could not answer the valuation question with "I don't know." County appraisers are required to consider the impacts of contamination and other externalities in the value estimation process, but owners are not (Kilpatrick, 2001). Because repeat sales data in rural areas is very difficult to obtain and because the turnover of houses is relatively infrequent (causing spatial imbalance), I use median housing values (Kim and Goldsmith, 2007). The two greatest benefits of using median housing values are that I utilize an incredibly large sample size and account for all houses in the study area.

Using Geolytics' Neighborhood Change Database, it is possible to compare census tracts across time, even though the delineated boundaries of the tracts may have changed significantly. The software takes the 1990 Census Bureau information but uses 2000 tract boundaries to recalculate the population and housing figures so that 1990 and 2000 tracts can be compared. Below are means for census tract data, with dollar amounts adjusted for inflation.

TABLE 1: Tract Means, 1990 and 2000

Variable	Mean 1990	Mean 2000
Tract Population	4801 (1,926)	5644 (2,700)
Percentage of Owner Occupied Houses	0.60 (.15)	0.59 (.16)
Median Household Income ($)	28,166 (9,058)	38,274 (8,825)
Average Household Income ($)	35,895 (9,364)	40,772 (9,478)
Percentage of Mobile Homes	0.19 (.12)	0.22 (.14)
Percentage of Population with a Bachelors Degree +	0.11 (.08)	0.14 (.09)
Percent Below Poverty Line	0.19 (0.09)	0.19 (0.09)
Median Property Value (all $2000)	68,077 (29,290)	81,164 (22,853)
Hog Operations	0.95 (1.77)	1.6 (2.77)
White	0.62 (.23)	0.58 (.23)
African-American	0.34 (.22)	0.35 (0.22)
American Indian	0.03 (0.12)	0.03 (0.11)

Note: Standard deviations are listed in parenthesis next to each mean. The inflation rate used was 31.8%.

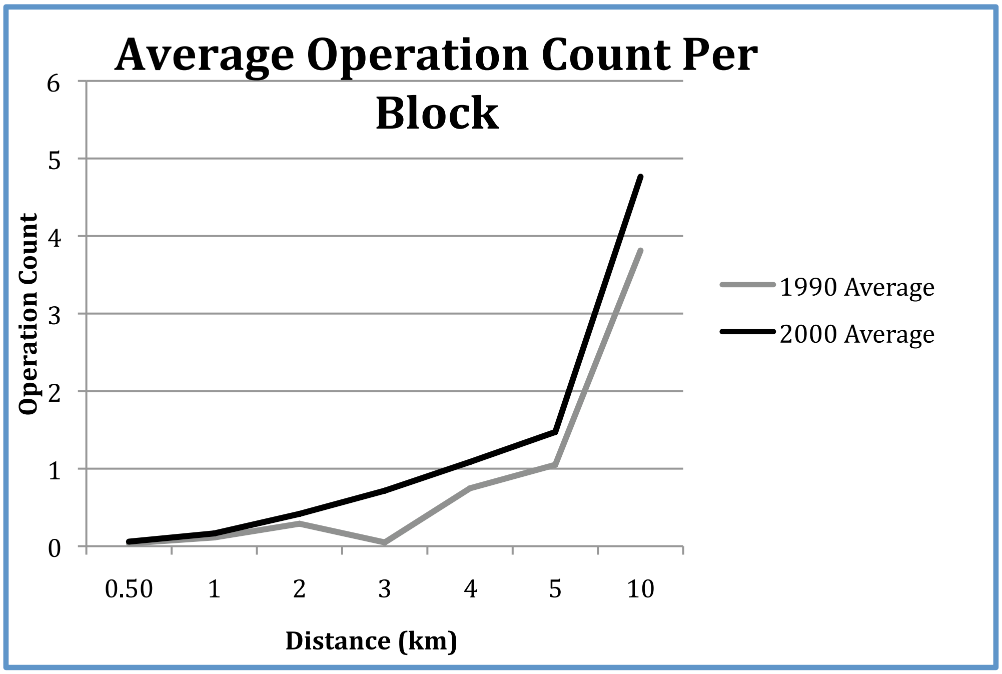
As the table above shows, from 1990 to 2000, the average census tract population grew 18%: from 4,801 to 5,644. The mean number of hog operations grew from 0.95 in 1990 to 1.6 in 2000. This is a 68.4% increase, suggesting a very high level of overall growth in the hog industry. I calculated the inflation rate across the decade as 31.8%, and reported all monetary variables in $2000. Real median household income increased from $28,166 to $38,274, which is consistent with the general increase in the rest of the country. Finally, real median housing value increased from $68,077 to $81,164. This is also expected, as the 1990s witnessed one of the greatest housing booms in the century. Most of the variables (number of bedrooms per house, percentage of the population with a Bachelor’s degree or higher, percentage of mobile homes, percentage of houses that are owner-occupied, percentage below the poverty line) remained very similar over the decade, due to the homogeneous nature of eastern North Carolina. Overall racial demographics changed very little. See Table 3 in the Appendix for tract means broken out by high-growth and log-growth hog counties.

Census blocks are "the smallest geographic area for which the Bureau of the Census collects and tabulates decennial census data" (Census Bureau). These data contain information on a much smaller subdivision of the tracts (on the order of around 250-550 housing units). The nature of the blocks allows me to calculate changes in housing value on a much smaller and more precise level than is possible using tracts.

These datasets are very appropriate for studying the effects of operations on housing values in eastern North Carolina because hog operations started to grow most significantly during the 1990s. Even though many of the operations started before 1990, residents in the area would have been less aware of associated externalities due to the operations' smaller presence. By analyzing data *before* the appearance of large, concentrated hog farms and comparing it to data a decade later, there should be clear, observable effects on housing values situated near those operations.

Because my data give the year that each operation started, it is possible to determine the exact tract that a hog operation lies in by entering in its latitude and longitude in ArcMap software. Using this method, I counted the number of operations contained entirely within each tract in 1990 and 2000. See Table1 in the Appendix for operation percentiles. The median number of operations per tract was 0.95 in 1990 and 1.64 in 2000. I then counted the number of operations contained within varying radii of each block centroid for 1990 and 2000. See Figure 2 below for the average of these counts for selected distances.

FIGURE 2: Average Operation Count Per Block



As expected, the number of operations increased as the included distance around each block centroid increased. The average number of operations in 2000 was greater than the average number in 1990 at all distances.

IV. Theoretical Framework and Empirical Specification

To conduct this research, I follow methods of previous research on localized externalities by applying the fundamentals of house price hedonic analysis. Hedonics have become the gold standard for measuring the effects of specific characteristics on housing values. Housing is a heterogeneous good: a "product whose characteristics vary in such a way that there are distinct product varieties even though the commodity is sold in one market" (Champ, Boyle, Brown, 2003). These goods have a common price structure because their attributes comprise similar, but not identical, parts. The value of a house is generally written as a function of various attributes:

Value = $V(x_1, x_2, \ldots, x_n)$ where $x = (x_1, x_2, \ldots, x_n)$ is a vector of housing attributes.

Implicitly included in the value of a house are environmental variables that cannot be measured directly. Environmental amenities are generally thought of as non-marketable goods (clean air and water cannot be traded in a market). For this reason, economists use hedonic estimation by assuming that consumers implicitly buy an environmental good when they purchase a marketed good, such as a house (Boyle and Kiel, 2001). A house is made up of structural, neighborhood, and environmental characteristics, all of which are capitalized into the house's value. Examples of structural characteristics include: house age, median number of rooms, number of bedrooms, and heating method. Neighborhood and environmental characteristics may include: median household income, race, education levels attained, distance to work, and quality of environmental amenities. Because census data contain very limited amounts of information on structural housing characteristics, I will rely mainly on neighborhood characteristics for the tract analysis.

Regressing characteristics of a good on the value of that good (the house), we can extract the contribution of the environmental good to the value of the marketed good (Boyle and Kiel, 2001). This theoretical framework informs my empirical specification by suggesting likely explanatory variables and equational forms.

When using census tract data, I use only the concentration of hog operations in each tract as an independent variable to determine the impact of these negative externalities. When using census block data, however, I draw rings around each census block centroid and determine how many operations lie within certain radii of the centroid.

Hedonic models are generally estimated using ordinary least squares. I use both linear and logarithmic specifications. One basic cross-sectional equation with hog data to be estimated is as follows:

$$\begin{aligned} Ln(MedianValue)_{it} &= \alpha_0 + \beta_1 HogOperationCount_{it} + \beta_2 PctMobile_{it} + \beta_3 AfricanAmerican_{it} \\ &+ \beta_4 AmericanIndian_{it} + \beta_5 Electricity_{it} + \beta_6 Ln(MedHHInc_{it}) + \beta_7 Bedrooms_{it} + \varepsilon_{it} \end{aligned} \quad (1)$$

Willingness to pay (WTP) for a given characteristic can thus be valued by taking the partial derivative of the median house value with respect to a characteristic:

$$WTP_i = \partial MedianValue_i / \partial HogOperationCount_i \quad (2)$$

Each coefficient represents the marginal contribution of the attribute to the house value. My null hypothesis is that there is no significant association between median housing value and hog operation concentration (B_1=0). The alternative hypothesis is that the coefficient on hog operations will be negative and significantly different from 0.

Usually the price of a house (the dependent variable) is specified in semi-log form, which "allows for variation in characteristic prices across different price ranges within the sample" (Sirmans et al., 2007). This is relevant to my dataset because housing values range widely across the study area.

In a second specification, I perform a time-series analysis and control for the presence of other locally undesirable land uses that could also impact housing values by using county, tract, and block fixed effects. Fixed effects coefficients "soak up" all the across-group variation (Dranove, 2009). These control for time-invariant neighborhood characteristics by focusing on housing value changes over time, using a difference-in-difference approach (Davis). I assume that any macroeconomic exogenous changes affected all areas of eastern North Carolina equally. My fixed-effects specification is:

$$\begin{aligned} \Delta LogMedValue_i &= \alpha_0 + \beta_1 \Delta Operations_i + \beta_2 \Delta AfricanAmerican_i + \beta_3 \Delta Bedroom_i \\ &+ \beta_4 \Delta LogMedHHInc_i + \beta_5 \Delta Electricity_i + V_i + \varepsilon_i \end{aligned} \tag{3}$$

Problems may arise if unobservable characteristics *do* change over time.

When using block data, I utilized similar independent variables, but instead of including an independent variable for number of operations within each block, I count the number of operations within a specified distance of each block centroid. This overcomes the problem of having features of surrounding blocks being important property value predictors for a nearby block. Using Matlab, is it possible to draw circles around each block centroid and count the number of operations within various chosen radii. The most appropriate method of performing these calculations is done using the Great Circle

Distance formula, which takes two pairs of latitudes and longitudes (one from block centroids and one from hog operations) and draws a circle of a specified radius around a block centroid. The formula is:

$$D = \arccos(\sin(lat_1) \times \sin(lat_2) + \cos(lat_1) \times \cos(lat_2) \times \cos(long_2 - long_1)) \times R \qquad (4)$$

Equation 4 takes into account the spherical nature of the earth's surface and is thus very precise in measuring distances. Using operation counts around each centroid, I run cross-sectional and time-series regressions similar to the tract analysis.

V. Results

a. Census Tracts

The hog industry has changed from an abundance of small family farms to a concentration of gigantic swine operations. Abeles-Allison and Connor find that "one thousand hogs result in a drop of $430 in property value on a single property" for a five-mile radius around the house (Abeles-Allison and Connor, 1990). They also find that "larger hog operations have a greater impact than do smaller ones" (Abeles-Allison and Connor, 1990). Palmquist et al. suggest that "proximity caused a statistically significant reduction in house prices of up to 9% depending on the number of hogs and the distance from the house" (Palmquist et al., 1997). I compare my results at the tract level to these two studies. The results of the 2000 cross-sectional and fixed-effects regressions using census tracts is below:

TABLE 2: Tract-Level Analysis, and Fixed Effects

Variable	(1) 2000 Cross-Section	(2) 1990 Cross-Section	(3) Fixed Effects
Intercept	5.81**	3.16**	-0.028
	(0.66)	(0.59)	(0.0278)
Ops00	0.00075	-0.0041	.0091
	(0.0037)	(0.005)	(0.008)
Percent Built Last 5 Years	0.676**		
	(0.183)		
Percent Mobile	-0.404**	-0.323**	0.721**
	(0.122)	(0.114)	(0.224)
Percent African-American	-0.318**	0.089	-0.264
	(0.058)	(0.079)	(0.224)
Percent American Indian	-0.256**	-0.02	1.72*
	(0.095)	(0.12)	(0.922)
Percent with 0-2 Bedrooms	-0.358**	0.365*	-0.778**
	(0.108)	(0.15)	(0.217)
Log Median Household Income	1.23**	1.73**	1.176**
	(0.137)	(0.12)	(0.109)
Percent with Electricity	0.147*	0.40**	0.152
	(0.068)	(0.091)	(0.159)
Number of Observations	249	249	248
Adjusted R^2	.67	0.62	0.36

Note: Dependent variable is the logarithm of median property value for the tract. Standard errors are in parenthesis. An * indicates significance at the 5% level, a ** indicates significance at the 1% level.

In both 1990 and 2000, the coefficient on hog operations was not significant. Other explanatory variables, such as the percentage of houses with electricity, the logarithm of median household income, and the percentage of mobile homes all significantly affected housing value in the expected direction in the cross-sectional models. The adjusted R^2 was 0.67 and 0.62 for 1990 and 2000, respectively, indicating that a majority of the variance in housing value was explained by the model. In the panel regression, fewer explanatory variables were significant. Most importantly, the coefficient on change in hog operations is insignificant.

These results comprise the first segment of my research using tract data. In neither the cross-sectional regressions nor the panel regression did hog operations influence housing values significantly. Using a linear regression model and a semi-log model with different independent variables did not change the outcome: hog operations do not appear to be significantly related to housing prices at the tract level. I hypothesize that this does not mean that hog operations do not impact housing value, but rather that hog operations produce such a localized externality that tracts are too large a geographic unit at which to identify their impact. My results fit with what Ann Ulmer and Ray Massey describe in their summary of CAFO impacts on housing values, that " the impact of AFOs [animal feeding operations] on property value [is] localized or limited to properties near the AFO" (Ulmer and Massey, 2008). The effect of a hog operation is likely to affect only a very small percentage of the tract area, making it very difficult to determine the effect on median housing values in a miles-wide tract. Using block data overcomes this problem and yields much more accurate results.

b. Census Blocks

I hypothesize that hog facilities closest to census block centroids would negatively impact block median housing values. I expect the coefficients on kilometer radii to enter the regression negatively, and become less negative at greater distances as the externality dissipates. Having data on median housing value changes in areas with no operations serves as a baseline comparison. If values either increase or decrease significantly in blocks near many facilities, I can assume the value change is due to operation presence, as little else in the economy is likely to have changed over this period.

First, I run cross-sectional regressions using 1990 and 2000 census block data merged with hog operations counts using radii from 0.5 kilometers up to 5 kilometers around the centroid of each block. Included in these regressions are more explanatory variables than I included in the tract regressions, such as the median number of bedrooms, housing unit density, and the share of houses with incomplete plumbing. Secondly, I run panel regressions that control for unobserved variables that may differ across blocks but stay constant over time. See Table 3 for a comparison of the coefficients. This table shows a comparison for ½ kilometer only, because each of the 3 models at varying distances remained almost identical.

TABLE 3: Block-Level Analysis, and Fixed Effects

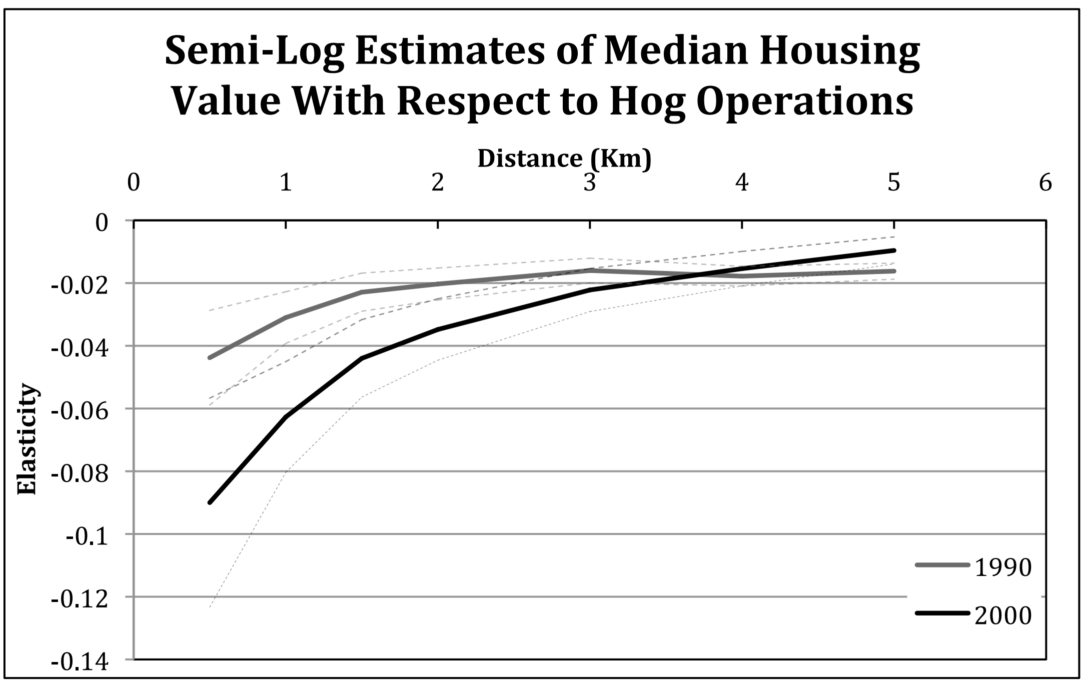
Variable	(1) 1990 ½ Km	(2) 2000 ½ Km	(3) Fixed Effects ½ Km
Intercept	9 (.046)	9.0 (.077)	.234 (.0078)
Distance (Km)	-.044** (.008)	-0.09** (.017)	-0.0071 (.015)
Percent Mobile	-1.2** (.012)	-0.834** (.012)	-0.77** (0.019)
Percent Plumbing	.12** (.024)	.182** (.059)	0.194** (.039)
Median Bedrooms	.077** (.0046)	.205** (.0065)	0.092** (.0062)
Percent African-American	.36** (.009)	-0.273** (.013)	-0.214)** (0.027)
Percent American Indian	-.38** (.02)	-.321** (.0283)	-0.06 (.095)
Percent BA+	.49** (.013)	.397** (.0173)	0.138** (.019)
Housing Density	0** (0)	-0.00** (0)	
Ln(Median Household Income)	0.10** (.004)	.151** (.0054)	$1.0e^{-06}$ $(1.02e^{-07})$
Observations	26,365	262,520	16,787
R^2	0.47	0.37	0.13

Note: A ** indicates significance at the 1% level. A * indicates significance at the 5% level. The dependent variable for models (1) and (2) was the logarithm of median housing value, and the dependent variable for model (3) was change in the logarithm of median housing values.

In both specification (1) and (2) – the cross sections - the coefficients on hog operation count at distances of up to at least 5 kilometers were all significant and negative. In 1990, the median house value was expected to be 4.4% lower for each additional operation within ½ kilometer. In 2000, the median house value was expected to be 9% lower. The magnitude of these coefficients decreased (become less negative) as the kilometer distances increase. As expected, at further distances operations impact housing values less. All other variables are significant and have the expected sign. For these two specifications, the semi-log model produced the best results. The results also fall within the range of what previous cross-sectional work has found.

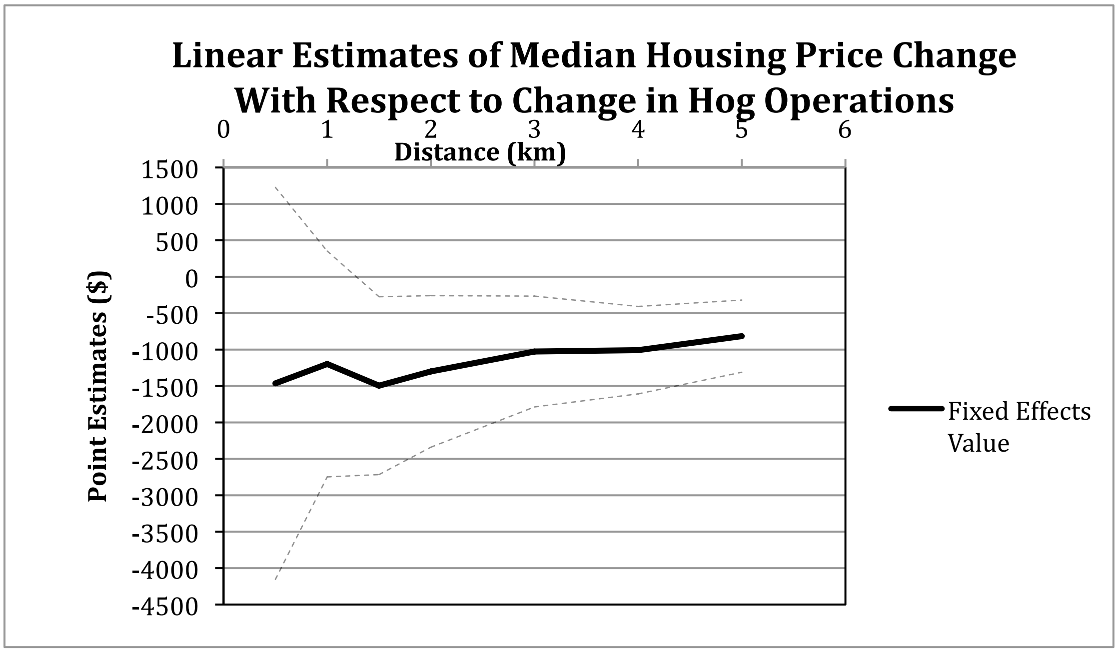
The figure below shows the point estimates for all kilometer distances up to 5 kilometers in 1990 and 2000. The dark line, representing 2000, lies above the 1990 estimates at all values until 4 kilometers. These coefficients imply that after the expansion and construction of hog operations throughout the decade, those who lived closest felt the negative externalities more acutely. If there is an increasing marginal effect, then the increase in number of operations would also increase the effect across the decade.

FIGURE 3: Point Estimates of Hog Operation Distance Coefficients, Cross Sections



In terms of actual magnitudes, housing value decreases $6,968 at ½ kilometer radius in 2000. The figure for 1990 is $4,307 after adjusting for inflation. With a sample of 22,520 houses in 2000 this amounts to a total property value loss of at least $156, 919, 360. In reality this figure is much larger because the sample of 22,520 is much smaller than the total number of observed houses (over 50,000) in the twenty two counties I gathered data for. Even at a distance of four kilometers one operation can lower value by $1,039. One operation therefore may not have a significant effect in terms of magnitude, but as more operations locate in close proxmity to a house, the more severly a house's value will be affected. Figure 4 shows magnitudes for the panel dataset.

FIGURE 4: Point Estimates of Hog Operation Distance Coefficients, Panel



In Figure 4, all point estimates of housing value change were negative, but only some were significant. The ones that were significant had a much smaller magnitude than those in the cross-section. These estimates are conservative, but the results suggest that at 1.5, 2, 3,4, 5 kilometers, all coefficients were significant at the 1% level. For the cross-sectional models, the semi-log model produced the best results, however, running the panel regressions with actual median housing value change produced the best results. Even after controlling for unobserved variables in the panel regression, I still find a negative effect. The effect decreases in magnitude from the cross-sectional regressions, but it is still significant and suggests that hog operations affected value.

The results are not surprising. It seems that in 1990, the majority of farms in eastern North Carolina all raised a small number of hogs. By the end of the decade industry expansion had taken off, and the farms that chose to specialize in hogs increased their farm capacity by the thousands. Residents living in the area in 1990 would have been unlikely to be upset with small farms containing a small herd of hogs. Residents living in the area in 2000, however, would have been much more likely to notice the effects of gigantic facilities emitting odors and thousands of pounds of manure each day. Most likely, the increase in facility number and the increase in hog concentration caused the increase in the magnitude of the coefficient on operation counts over the decade.

VI. Conclusions

In my research, I draw and expand upon the conclusions reached by previous researchers by using a more up-to-date detailed dataset, incorporating GIS techniques, and extending analyses from different areas of the United States to an expansive area in North Carolina. I found inconclusive results when using data from the census tract level, and found conclusive results using census block data, as census blocks are much more precise geographic areas and have more homogenous demographic and housing characteristics. In both 1990 and 2000, hog operations negatively impact median housing values in blocks with higher numbers of hog operations in the vicinity.

This has important implications for the hog industry, policy makers and regulators, and researchers. Clearly, those individuals living in closest proximity to the facilities notice their environmental damages, and these damages can be quantified into monetary terms. Specifically, one operation located within one kilometer of a home caused a $5,057 decline in value in 2000. Controlling for unobserved variables over the decade, the decline in value was $1,495 at 1½ kilometers, significant at the 5% level. Having solid economic data to back up their complaints, homeowners will be able to protest expansion and construction of hog facilities. Using these results, policymakers may impose stricter regulations on operations, impose a tax per animal to generate revenue to compensate residents for living near hogs, or force operations to adopt cleaner waste management technologies.

My results are also important in terms of research methods. Studies conducted at large heterogeneous geographic areas, such as counties and tracts, may not accurately capture the benefits or drawbacks of specific types of land uses. Block-level data, though difficult to obtain, yield much more significant results. Census Bureau data in general, with large sample sizes across time, allow for a more comprehensive analysis than is possible using individual housing sales and selected hog operations.

My results support and confirm earlier findings on the loss of housing value due to hog operation proximity. Palmquist, Roka, and Vukina find that rural residential property values decrease 9% if an operation locates within ½ mile. Similarly, I found that at ½ kilometer, housing values decline by 9% as well, in 2000. Palmquist et al.'s article was published before the swine lagoon ban in 1997, yet my results show that the ban did not impact housing values in a positive manner.

In 2007, North Carolina was the first state to ban the construction and expansion of new lagoons and spray fields by passing the Swine Farm Environmental Performance Standards Act. In that year, policymakers made serious reforms regarding the waste problem. This act sets strict standards for any new waste management system (EDF). An interesting area for future research would involve using 2010 census block data to determine if this Act caused a significant decline in the amount of negative externalities produced by waste lagoons, leading to a corresponding rise in house values.

My research shows that using information from 250 census tracts and over 50,000 census blocks in an expansive area of North Carolina produces a picture of how localized externalities can impact the value of residential property. It would be interesting to extend this analysis to other forms of confined animal feeding operations to see if the results are as conclusive.

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APPENDIX

TABLE 1: Hog Operation Percentiles, 1990 and 2000

Year	25%	50%	75%	90%	100%
Tract 1990	0	0	1	3	13
Tract 2000	0	0	2	5	19
Block 5 km 1990	0	0	1	3	14
Block 5 km 2000	0	1	2	4	13
Tract Observations = 250, Mean 1990 = 0.95 Mean 2000 = 1.649					
Block Observations= 52,404 Mean 1990=1.05 Mean 2000=1.47					

Note: The mean number of hog operations per tract increased from 0.952 to 1.648.The mean number of operations within a five-kilometer radius around each block increased from 1.05 to 1.47, a 40% increase.

Figures 1-3: Dun and Bradstreet Hog Data

Figure 1: Total Employees

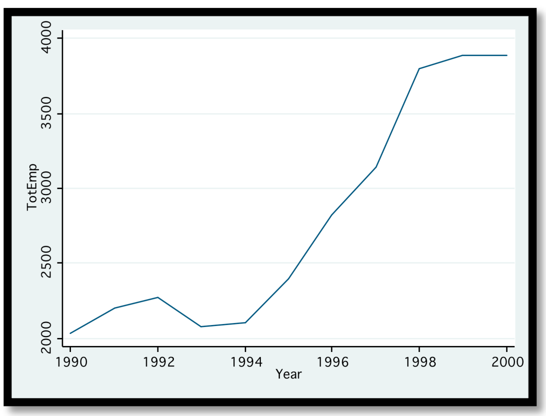

Figure 2: Total Firms

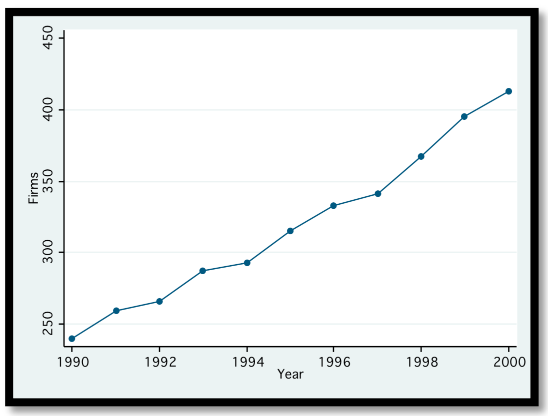

Figure 3: Average Sales

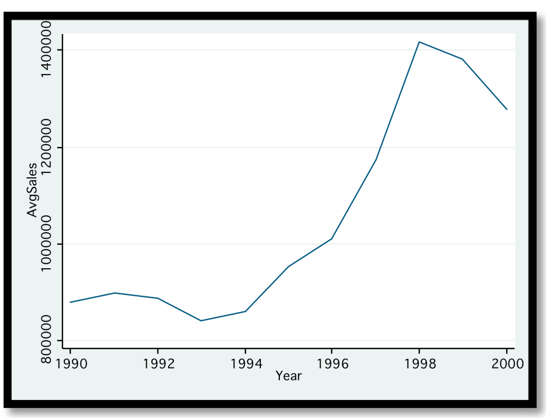

TABLE 2: Hog Operation Employee Growth Per County, 1990 to 2000

County	Percentage change in Operation Count (1990-2000)	Employees in 1990	Employees in 2000	Percent Change in Absolute Number
Beaufort	-0.10	61	42	-0.31
*Bladen	0.66	23	93	3.043
*Columbus	0.70	2	43	20.5
*Craven	0.60	64	105	0.64
*Duplin	0.40	473	1523	2.22
*Edgecombe	0	26	40	0.54
Greene	0.285	112	42	-0.63
Halifax	-0.30	56	56	0
Harnett	0	47	25	-0.47
*Johnston	0.12	50	170	2.4
*Jones	0.375	18	41	1.28
Lenoir	0.2	93	86	-0.078
Nash	-0.25	17	11	-0.35
Northampton	-0.27	37	14	-0.62
*Onslow	0.555	42	100	1.38
*Pender	0.72	16	92	4.75
*Pitt	0.393	148	337	1.28
Robeson	0.346	87	90	0.034
*Sampson	0.417	364	589	0.62
Warren	-0.5	18	4	-0.78
Wayne	0.43	272	381	0.40

Note: An * denotes those counties with high hog operation growth, using percentage increase in absolute number of operations as well as percentage increase in number of employees.

TABLE 3: Means of High Hog Growth v. Low Hog Growth Counties, 1990 and 2000

	High Hog Growth Counties		Log Hog Growth Counties	
	1990	2000	1990	2000
Hog Operations (Tract Level)	1.133	2.417	0.764	0.854
Median Household Income	$27,968.53	$38,277.26	$28,369.87	$38,272.41
Median Property Value	$71,300.46	$83,263	$64,748.9	$78,996.75
Percentage of Population with at least a Bachelor's Degree	0.124	0.148	0.103	0.126
Average HH Income	$35,663.64	$40,634.12	$36,133.67	$40,914.01
Tract Population	$4,892.22	$5,737.22	$4,708.545	$5,546.84
Percentage White	0.647	0.613	0.588	0.543
Percentage African-American	0.328	0.336	0.348	0.372
Percentage of Mobile Homes	0.187	0.215	0.184	0.224
Percentage with Electricity	0.455	0.571	0.341	0.443