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DISSERTATION

**NATIONAL, STATE AND LOCAL ECONOMIC INFLUENCES OF U.S.
ENVIRONMENTAL POLICY AND ANIMAL AGRICULTURE**

Submitted by

Dooho Park

Department of Agricultural and Resource Economics

In Partial Fulfillment of the Requirements for the

Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Fall 2002

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY DOOHO PARK ENTITLED NATIONAL, STATE AND LOCAL ECONOMIC INFLUENCES OF U.S. ENVIRONMENTAL POLICY AND ANIMAL AGRICULTURE BE ACCEPTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.


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DISSERTATION ABSTRACT

NATIONAL, STATE AND LOCAL ECONOMIC INFLUENCES OF U.S. ENVIRONMENTAL POLICY AND ANIMAL AGRICULTURE

My dissertation attempts to test the relationship between the US livestock industry and environmental policy in two distinct areas: In Part 1, the potential influence of difference in state level environmental policy on the location and inventory decisions across four principal livestock sub-industries is evaluated; beef cattle, dairies, poultry and hogs. In Part 2, I use a spatial hedonic approach to estimate the influence of livestock operations on residential housing prices in a fast growing, but traditionally agricultural area of Northern Colorado.

Results from Part 1 indicate that, in general, traditional economic factors are still important to farm level inventory decision making, but their influence varies across operation size. There are distinct effects of written stringency and evidence of the willingness to enforce environmental policy. Policy enforcement activity was shown to influence stocking decisions, and the impact was more sensitive on larger than smaller operations. Further, environmental policy's influence differs by livestock species. The hog industry, with rapid structural change, is more sensitive than the beef industry, with less structural change, to changes in the policy milieu.

Results from Part 2 indicate that the number of beef and dairy operations positively influence real estate values, potentially signaling a positive rural lifestyle effect. However, the number of hog and sheep operations has the opposite effect. In addition, the influence of the livestock sector on housing prices differs by house value. The cheaper the house, the more negative is the impact of an additional livestock operation. On the other hand, the higher the housing value, the more negative is the impact of more animals, or size of operation rather than number of operations. As expected, impacts decrease with increasing distance from the housing unit to the livestock operation.

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DEDICATION

This dissertation is dedicated to the four people who made degree possible: my parents, my wife and Dr. Andrew F. Seidl.

My parents have shown me the spirit of life to overcome difficult obstacles my entire life. My wife, Kyounggran Seoung, always encourages me whenever I am in hard times. Andrew F. Seidl has given me seemingly endless encouragement, guidance and patience. I could not have asked for a better advisor or mentor.

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INTRODUCTION AND OVERVIEW OF THE DISSERTATION

A free market economy is one of the institutional arrangements to allocate resources and might achieve an efficient allocation of resources. However, to achieve an efficient allocation of resource in the free market, certain conditions should be met. Among them are unattenuated private property rights and the absence of external effects or social and private benefits and costs are equal (Perman et al., 1996). If these conditions are satisfied the market efficiently allocates resources and economic analysis proceeds in what is termed a “first best” world. There is no economic justification for government policy. If these conditions are not satisfied the market will fail to allocate resources efficiently, the situation is termed “second best,” and there may be economic justification for government policy intervention to improve the efficiency and equity of the resource allocations observed.

An externality is said to occur when the production or consumption decisions of one agent affects the utility of another agent in an unintended way, and when no compensation is made by the producer of the external effect to the affected party (Perman et al., 1996). Among the most common external effects of economic activities is environmental damage. Environmental effects are commonly external to decision-making because, by their nature, they are difficult to capture within the market institution and private property rights are difficult to establish. Environmental quality is a public good, which is a good that, if made available to one person, automatically becomes available to others (Field, 1997). This situation will often call for public intervention, public

environmental policy, either to override the markets directly or to rearrange things so that they will work more effectively (Field, 1997).

An environmental policy in the operation of market economies offers the possibility of realizing substantial efficiency gain¹, by eliminating or mitigating situation of market failure, so thus improve social welfare, which is the primary objective of policy. However, due to the potential costs of establishing, monitoring and enforcing economic policy “the solution can be worse than the disease” and government failure results. Government failure can be either intermittent or chronic. It means that it can not simply be assumed that each and every attempt at public government policy will make the situation better and also refers to systematic tendencies and incentives within legislatures and regulating agencies that work against the attainment of efficient and equitable public policy (Field, 1997). The problem of government failure is that the impact of the failure is broad and long-term and sometimes irreversible.

To weigh the efficacy of market solutions versus the portfolio of potential economic policy tools to bring private and social costs and benefits together, the performance of economic policy needs to be evaluated. Without evaluating the effectiveness of policy we cannot be sure if the policy fixes the market failure or results in further distortion of the allocation of scarce financial and natural resources from a societal perspective.

In this dissertation, the U.S. livestock industry provides an excellent example of important economic activity sullied by environmental damage and the economic policy efforts to mitigate the negative effects without unduly influencing the positive effects of

the industry. The livestock industry produces food and creates jobs but is also major source of water and air pollution in the United States. The U.S. Environmental Protection Agency (EPA), states and localities have regulated the livestock industry for at least thirty years, but the effectiveness of these policies is not clear.

The American livestock industry has undergone substantial structural change in recent decades. Generally speaking, the US livestock industry is characterized by substantially greater concentration of animals on fewer and fewer operations than was observed in the 1970s and 1980s. However, operation size has changed inconsistently across livestock species and changes in livestock inventories have not been uniform across the United States. The livestock sector is clearly an important source of jobs, income and revenue to rural areas as well as to urban centers linked to the processing and distribution of livestock products. As a result, livestock may be an important or even dominant feature in the economic development portfolio of some parts of rural America and changes in the industry may strongly affect the vitality of rural communities and their residents.

Transitions in the US livestock industry have been accompanied by significant evolution in the public perception of the relationship between human “progress” and our natural environment and concomitant change in federal environmental policy. Rachel Carson’s 1968 best-seller Silent Spring and the 1972 Clean Water Act potentially epitomize this era of nascent environmental awareness. Public attention to environmental quality and parallel apprehension about the future of idyllic rural lifestyles and

¹ But it is also true that policy makers may have other objectives besides economic efficiency such as equity consideration, intergenerational effects, the sustainability of resource systems or social risk aversion (Freeman III, 1999)

“traditional family” farms have increasingly and steadily focused the pitch of federal, state and local environmental policy upon the livestock industry as a source of concern.

Livestock operations, particularly large and undiversified businesses, are increasingly viewed as akin to heavy industries like steel refineries and strip mines, generating valuable jobs, products and income, but also generating unwanted and unnecessary water and air pollution impeding the full use and enjoyment of our nation’s abundant natural resources. In economic terms, livestock operations were generating significant negative productive externalities, and regulations were to be put in place to reflect the differences in private and social costs of livestock production due to these unaccounted for externalities.

Substantial research effort has been expended in attempting to evaluate the efficacy of the various environmental policy efforts to address the external effects of industrial pollution. The important research questions surround whether environmental regulations actually result in less environmental damage or whether they have merely resulted in a transfer of the damage from one town or state or country to another with less stringent regulations or less willingness or ability to enforce them. The industrial sector has been the topic for most of these research efforts. However, there is a growing literature in the potential effects of environmental policy on the livestock sector.

In contributing to the growing store of information on this topic my dissertation attempts to test the relationship between the US livestock industry and environmental policy in two distinct areas:

1. In Part 1, the potential influence of difference in state level environmental policy on the location and inventory decisions across four principal livestock sub-

industries is evaluated; beef cattle, dairies, poultry and hogs. This analysis is undertaken across 48 states, employing primary and secondary data, and the models are estimated incorporating information over the three decades since the passage of the Clean Water Act. These analyses contribute to the literature by extending the number of species addressed, the length of the time series and the number of states included in the analysis, as well as through the employ of econometric techniques that have not been previously used in this area of inquiry.

2. In Part 2, I move to the other end of the jurisdictional scale and attempt to estimate the influence of livestock operations on residential housing prices in a fast growing, but traditionally agricultural area of Northern Colorado. Livestock operations pay taxes, employ people, purchase productive inputs, and pay wages, and, therefore, may have a positive influence on local public finance through their role in economic development. On the other hand, odor or other results of agricultural practices may negatively influence real estate values, reducing the amount of tax revenue gleaned from affected residential properties. A spatial hedonic approach is used to attempt to isolate the potential influence of the proximity of livestock operations of various sizes and species on residential sales. Development or odor mitigation technology scenarios may be simulated using these results in order to better inform local decision-making and understand the implications of public policy. The livestock industry has been the subject of only two hedonic analyses in the past, never a spatially explicit hedonic and never including more than one species of livestock nor differentiating size of operation from livestock inventory in the analysis. These are the contributions of this

dissertation to the literature on the relationship between environmental policy and livestock operations.

PART 1
RELATING U.S. ENVIRONMENTAL POLICY TO ANIMAL AGRICULTURE

CHAPTER 1

ANIMAL AGRICULTURE AND ENVIRONMENTAL POLICY

1.1 Problem Statement

The animal agriculture industry, broadly defined, is a leader within the agricultural sector in terms of gross sales. As a result, production relationships within the animal agriculture industry have been the subject of substantial agricultural economic research. Traditionally, firm scale input-output approaches provide the basis for understanding bulky and perishable agricultural products including animal products. However, the US animal agriculture industry has undergone recent and significant structural adjustment. Technological innovations and lower transportation costs have enabled livestock firm location decisions to be less tied to traditional location factors and theory. The resultant integration and concentration of the industry have altered the spatial distribution of the US livestock industry. Industry change has, in turn, generated changes in locality specific benefits and costs of the industry and the potential for local action to guide the industry through policy.

Recent structural change in the livestock industry has raised many questions among researchers, the public and public officials charged with guiding the industry. The geographical concentration and increasing size of livestock operations has brought environmental concerns, particularly concerning surface, ground water and air quality. Twenty-two states reported on impacts of specific types of agriculture on rivers and streams, attributing 20 percent of agricultural pollution to intensive animal feeding operations (USEPA, 1998), and the public perception of the potential environmental risks of the animal industry has heightened.

Collective actions, in the form of local and state level industrial and environmental policies, have evolved in response to the real or perceived challenges posed by these changes in the livestock industry. For example, some 23 states introduced legislation meant to guide aspects of the livestock industry in 1998 (Edelman et al., 1998). Local policy changes should influence stocking rates and management decisions for existing operations in the short term and location decisions in long term. However, the effectiveness and the real impact of these policies are unclear due to at least three potential challenges. First, policy is only one of many factors potentially affecting the location, management and inventory decisions within the livestock industry. Secondly, to the extent that the local policy environment drives location decisions, shifts in geographical industry concentration reflect a policy externality or spillover effect wherein the problem is not solved by policy, rather the problem and its impact are merely moved to where there is no policy, which may or may not imply diminished impact. Finally, secondary data quality and availability constrain the precision and accuracy of generalized approaches to the US livestock industry and environmental policy.

In Part 1, the relationship between the US animal agriculture industry and state level environmental policy is analyzed with attention to the location, size and species composition of the industry over time. In Part 2, the influence of livestock operations by size and species on rural residential property values is analyzed for an agriculturally important and fast growing region of Colorado.

1.2 The U.S. animal agriculture industry

Technological innovation and lower transportation costs have increased location alternatives and firm/industry structure decisions by weakening the geographic link between feed supplies and livestock. Structural change, including the dramatic trend toward fewer, larger, and more segmented and integrated operations, is evident across livestock species. For example, 17% of all broilers were processed by four firms (i.e., Tyson Food, Goldkist, Perdue and Conagra) in 1972. In 1994, these firms processed more than 40% of all broilers (Watts and Kennett, 1995). In 1988 the average hog operation was a 200 head farrow-to-finish operation. In 1997, the analogous statistic was a 550 AU farrow, nursery, or finish operation. Nationwide, the average size of beef cattle operations has increased 171%, from 35 to 95 head per operation, while poultry operations have grown 82%, from 2,327 to 4,224 birds per operation within the last decade (USDA-NASS, 1999c).

Current EPA regulations distinguish treatment of livestock operations on the basis of the number of animal units (AU) in an attempt to normalize regulations across livestock species. Using EPA standards, a “small” operation can be defined as containing 300 AU or fewer, a “medium” operation has 300-1000 AU, and a “large” operation has

1000 AU or greater. Considerable change in the structure of the US livestock industry can be observed using these three size categories. Since 1970, the size of livestock operations has increased substantially (Table 1-1). A concomitant and consistent downward trend in the number of livestock found on small operations is also observed. These trends were most pronounced in the mid 1980s, following a short period of growth in the small category. The number of livestock on medium operations generally increased during the early 1970s, but remained stable over the 30 yr period. The number of livestock found on large operations climbed steadily, except in the early 1980s, and accelerated from the mid 1980s through the 1990s (Table 1-1)

Table 1-1 Annual Percent Change of Operation Size (%)

Year	Small Operation	Medium Operation	Large Operation
1970	-2.07	5.43	3.35
1972	-2.16	4.90	3.30
1974	-2.26	4.46	3.10
1976	0.13	-1.19	5.96
1978	0.13	-1.22	5.33
1980	-0.85	1.76	-0.13
1982	-0.86	1.70	-0.13
1984	-3.22	-1.53	2.99
1986	-3.44	-1.58	2.82
1988	-2.00	1.77	4.15
1990	-2.08	1.71	3.83
1992	-2.17	1.65	3.56
1994	-2.36	-0.84	6.65
1996	-2.48	-0.85	5.87

Source: USDA-NASS, Census of Agriculture, 1997. Small Operation, ≤ 300 AU. Medium Operation, 300-1000 AU. Large Operation, ≥1000 AU.

Although fewer, larger and more geographically concentrated animal feeding operations is a national trend, variation by species is evident (Table 1-2 and 1-3). The beef cattle industry, typically requiring relatively more land per animal unit than other livestock industries, has a large but declining proportion of operations with relatively few

Table 1-2 State Rank of Beef Cattle Inventories

State	Rank			1997		
	1997	1985	1969	Inventory (1000 AU)	% of total inventory	Cumulative % of inventory
TX	1	1	1	14,533	14.71	14.71
NE	2	2	3	6,733	6.82	
KS	3	3	4	6,506	6.59	
OK	4	5	6	5,321	5.39	
CA	5	6	5	4,969	5.03	38.53
MO	6	8	7	4,313	4.37	
SD	7	9	8	3,723	3.77	
IA	8	4	2	3,629	3.67	
WI	9	7	9	3,440	3.48	53.83
CO	10	11	12	3,307	3.35	
MT	11	12	13	2,618	2.65	
KY	12	13	14	2,429	2.46	
MN	13	10	10	2,395	2.43	64.71
TN	14	14	17	2,145	2.17	
ID	15	18	19	1,908	1.93	
ND	16	17	15	1,839	1.86	
FL	17	16	16	1,809	1.83	72.51
AR	18	21	31	1,770	1.79	
WY	19	32	27	1,690	1.71	
NM	20	25	26	1,676	1.70	
PA	21	19	22	1,672	1.69	79.40
VA	22	22	30	1,639	1.66	
OR	23	24	29	1,559	1.58	
AL	24	23	25	1,459	1.48	
NY	25	20	21	1,450	1.47	85.58
IL	26	15	11	1,438	1.46	
OH	27	26	18	1,283	1.30	
GA	28	27	23	1,244	1.26	
WA	29	29	34	1,204	1.22	
MS	30	30	24	1,127	1.14	91.96
MI	31	31	28	1,026	1.04	
IN	32	28	20	977	0.99	
NC	33	36	36	1	0.95	
UT	34	35	35	1	0.93	
LA	35	34	33	1	0.89	
AZ	36	33	32	1	0.83	97.59

Source: USDA-NASS, Census of Agriculture 1969, 1985 and 1997

animals. Some 56.7% of the cattle inventory was found on small operations in 1969, 51.4% in 1980, and 42.1% in 1997 and the ten leading beef states have 55% of total

inventory. In contrast, in 1969 almost 80% of the hog inventory was found on small farms and there were no large operations. In 1997, small farms were only 12.6% of total hog inventory, 61% were found on large operations, and the ten leading hog states held more than 80% of total inventory (USDA-NASS, 1999a, Census of Agriculture, 1997) (Tables 1-2 and 1-3).

Table 1-3 State Rank of Hog Inventories.

State	Rank			1997		
	1997	1985	1969	Inventory (1000 head)	% of inventory	Cumulative % of inventory
IA	1	1	1	14,652	23.95	23.95
NC	2	7	12	9,625	15.73	
MN	3	4	5	5,723	9.35	
IL	4	2	2	4,679	7.65	
IN	5	3	3	3,972	6.49	63.18
MO	6	6	4	3,550	5.80	
NE	7	5	6	3,452	5.64	
OH	8	8	7	1,701	2.78	
OK	9	25	22	1,690	2.76	80.17
KS	10	10	10	1,585	2.59	
SD	11	9	9	1,396	2.28	
PA	12	14	18	1,101	1.80	
MI	13	13	17	1,032	1.69	88.53
AR	14	18	24	859	1.40	
CO	15	22	23	787	1.29	
WI	16	11	8	738	1.21	
TX	17	17	15	579	0.95	93.37
KY	18	15	13	564	0.92	
GA	19	12	11	514	0.84	
VA	20	20	27	386	0.63	
TN	21	16	14	322	0.53	96.29
SC	22	21	19	305	0.50	
UT	23	29	29	292	0.48	
MS	24	26	20	216	0.35	
CA	25	27	26	212	0.35	97.97
ND	26	23	21	197	0.32	
AL	27	19	16	184	0.30	
MT	28	24	25	178	0.29	
AZ	29	28	28	140	0.23	99.11

Source: USDA-NASS, Census of Agriculture 1969, 1985 and 1997, 1999a

1.3 Local, state and federal environmental policy

Since the enactment of the 1972 Clean Water Act (CWA), industries potentially creating point sources of water pollution have been required to obtain National Pollutant Discharge Elimination System (NPDES) operating permits. With the revision of the CWA in the mid-1980s, livestock operations with greater than 1,000 Animal Units (AU), as well as smaller operations found in environmentally sensitive locations, were also subject to federal regulation. Currently, 43 states have been granted enforcement authority of NPDES permits by the EPA (USEPA, 1999).

State and local concerns surrounding the environmental management of livestock operations have created a mosaic of state level environmental policy. Environmental policies applied to livestock generally are directed toward larger, incorporated, or vertically integrated operations (Martin & Zering, 1997; Hubbell, 1998; Metcalfe, 2000). These policies tend to address ground and surface water concerns and, increasingly, air quality issues.

Federal, state and local environmental regulations of the livestock industry all tend to discriminate by operation size. It is often argued that larger operations are targeted due to the increased risk of pollution resulting from a higher concentration of pollutants. However, watershed level enforcement of such policies on small operations would be commensurate with such an objective, but is rarely if ever employed. It is also argued that large operations can afford to adopt the most environmentally friendly technologies, whereas smaller operations may not be able to do so. Evidence is scarce to support or refute these arguments. Alternatively, policy efficiency is a motivating factor of the regulator. More water quality can be monitored with fewer dollars by targeting

relatively few, but large, operations. Moreover, political expediency may be at the root of size discriminating environmental policy. “Family” farms (thought to be “small”) are politically preferable to “factory” or “corporate” operations; it is generally more acceptable to the public to impose costly regulations on “greedy” corporations than on “hard working” families.

For a livestock operation, location and inventory decisions largely are determined by access to input and output markets, the management technology employed and environmental attributes of the land. Economic theory tells us that productive and consumptive externalities provide the impetus for public policy; so policy is reactive. However, experience tells us that policy can be put in place in anticipation of social costs; policy can be proactive. We also know that once policies are in place, firms will incorporate the costs of compliance (adjusted for the probability and cost of noncompliance) into their production function; industry reacts to positive and negative financial incentives.

The literature on this subject commonly poses this classical “chicken and egg” problem; the stringency of environmental regulations either (a) is driven by or (b) is the catalyst for change in livestock industry inventory and location decisions (Mo and Abdalla, 1998; Martin & Norris, 1998). Alternatively, the willingness and ability to enforce these regulations, rather than their written stringency, may affect location and inventory decisions. State and local policy may affect, or be driven by, operation size, legal structure or livestock species, or it may reflect a cumulative effect of all livestock operations or stock of animals combined. Although policy debates over the

environmental management of the livestock industry are prominent in public discourse, little empirical evidence testing these hypothesized relationships is found in the literature.

Economies of scale may have shifted the industry toward fewer and larger operations, but researchers also have raised the possibility that different degrees of state regulatory stringency may affect industry change. Furthermore, we expect the impact of regulation should differ by size and species in the industry due to different structural transformations. However no existing research has combined an analysis of both the size and the species in the livestock industry.

1.4 Objectives and hypotheses

The main research objective of this study is to better understand the relationship between environmental policy and structural change within the livestock industry (both livestock inventory and location decisions). Toward a response to the question, the state level (48 states) effects of environmental policy across livestock and poultry species by total livestock inventory (i.e., hogs, beef cattle, dairy, and chickens) over the three decades since the passage of the CWA are examined. The similarities and distinctions of the influence of state level environmental policies on livestock inventory and location decisions by operation size and species are explored, reflecting the pervasive regulatory approach. The letter of the law and indicators of the willingness to enforce it are differentiated. Changes in stocking rates and operation profiles are expected to mirror the imposition of new environmental policies. The stringency of environmental regulation coupled with the greatest willingness to enforce is expected to most strongly guide the evolution of the livestock industry when location factors are most open.

Policy can lead or follow industry. It can be incentive based or disincentive based. The goal of policy is to achieve its objective at minimum cost. With regard to environmental policy and livestock operations it can be unclear whether the policy is to address air or water pollution concerns, animal ethics concerns, industry structure concerns or some combination of the aforementioned. Due to the challenges in identifying the objectives and outcomes of federal, state and local environmental policy, little empirical research has addressed their impacts and direction with regard to the livestock industry.

Therefore, the general objective of this study is to analyze the impacts and direction of environmental policy on the livestock industry by categories of interest. We expect different impacts by the size and species of the operation, so the specific objectives are to:

- 1) Test whether state level environmental policies influence livestock industry location decisions.
- 2) Examine whether state level environmental policies influence different size operations in a distinct manner.
- 3) Examine whether state level environmental policies influence livestock sub-industries (i.e. species) differently.

The stringency of state environmental regulations may lead to a shift in animal inventories across state lines, *ceteris paribus*, in reaction to increases in production costs created by regulatory compliance. Due to technical and structural change and genetic innovation, some segments of the livestock industry are more able to respond to a wider array of location attributes than they were traditionally. As a result, it can be expected

that this flexibility will result in greater responsiveness to natural and anthropogenic incentives and disincentives to livestock production, including environmental policies. It can be expected that:

1. Differences in state regulatory stringency and structure will influence the location of livestock inventories;
2. These influences may differ by the size of the operation, due to the tendency to impose size triggers within environmental policies affecting livestock operations;
3. These influences may differ by the livestock species being produced, due to overt distinctions in the legislation itself or due to differences in the industry structure, technical and management features of a typical operation, and flexibility across livestock species.

CHAPTER 2

LITERATURE REVIEW

Although a substantial body of research relates location decisions of manufacturing firms to environmental policy, the literature specifically relating environmental policy to the livestock industry is limited. Persistent challenges in compiling appropriate data and attendant analytical difficulties have contributed to the lack of published research-based information. Rather than enter the debate over whether large confined animal feeding operations are “farms” or “factories,” we draw insights from the broader literature base.

2.1 Environmental Policy and the Size and Location Decisions of Manufactures

The manufacturing sector literature conveniently divides into two categories: surveys of manufacturers regarding factors they consider in plant location; and secondary analyses of characteristics theoretically presumed to affect firm location (Mo and Abdalla, 1998). Industries studied include: plants of Fortune 500 manufacturers (Bartik, 1988); automotive plants (McConnell & Schwab, 1990); all industries falling under ozone regulations (Henderson, 1996); and the pulp and paper industry (Gomez et al., 1998). Analytical techniques include: microeconomic conditional logit specifications (McFadden, 1974; Bartik, 1988; McConnell & Schwab, 1990; Levinson, 1996; Gray,

1997); a microeconomic fixed effects model of panel data (Henderson); and a macroeconomic stationary Markov chain model (Gomez et al., 1998).

Most results suggest that geographic environmental policy variation has little effect on plant location (Bartik, 1988; McConnell & Schwab, 1990; Levinson, 1996), potentially due to low expected compliance costs. However, evidence of negative correlation between the stringency of environmental policy and plant location decisions has been shown in some cases (Henderson, 1996; Gray, 1997), and one study (Gomez et al., 1998) shows that the policy environment influences plant capacity decisions.

2.2 Environmental Policy and the Size and Location Decisions of the Livestock Industry

Unlike analyses of the manufacturing sector, most research on livestock is industry (species) specific. Compared to the manufacturing sector, only a handful of statistical analyses have tested the impact of environmental policy on the livestock industry. Taken as a body of research, the results are inconclusive. Thurow and Holt (1997) found that the timing and sequence of policy signals influence compliance behavior and options for Texan and Floridian dairies; thus, policy influences firm decision-making. Mo and Abdalla (1998) were unable to find a significant relationship between hog farm location and inventory decisions, and environmental policy stringency in the 13 leading hog producing states. Martin and Norris (1998) summarized previous work on environmental policy and livestock industry structure and concluded that it is more likely that industry drives policy rather than the converse.

Metcalfe (1999) extended Mo and Abdalla (1998) to include four policy stringency indices, expanded the number of states (to include the 27 most important hog producing states), and increased the length of the time series (1984-1998) in his treatment of the issue. The potential endogeneity of environmental regulations and hog production decisions was incorporated, addressing Martin and Norris' (1998) observation. However, Metcalfe fails to establish the link between policy stringency and firm location decisions and concludes that environmental regulation has no measurable influence on hog production decisions. However, traditional factors including corn price, transportation costs and agricultural infrastructure were significant predictors of hog production and location decisions (Metcalfe, 1999). Matthey and Royer (1999) and Gow and Langemeier (2000) examined the impact of (anti-)corporate farming laws on Nebraska and Kansas hog operations. The results of both studies indicated that regulations reduced the regional hog inventory. Potentially counter to theoretical expectations, these results suggest that policy leads industry. More recently, Metcalfe (2000) found a significant increase in the general level of state level control of the animal agriculture industry. He also suggests that, instead of additional federal legislation, state or local regulations may be more efficient (Metcalfe, 2000).

CHAPTER 3

EMPIRICAL MODELS AND DATA

The empirical model of state level environmental policy analysis is tested through the use of either a ‘fixed effects’ or ‘random effects’ model based upon the results of a model specification test. The analyses explore the impacts of environmental policy on location decisions across all livestock (AUs), by operation size and by species (beef cattle and hog industry).

3.1 Model Specification

3.1.1 Fixed versus Random Effects Models

Panel datasets provide rich sources of information about the economy that cannot be provided by either cross-sectional or time-series data sets (Green, 2000). Specifically, it is possible to identify and control for individual-specific effects in the analysis (Hausman and Taylor, 1981). The most common approach for dealing with panel data is the error components model, which is specified as:

$$Y_{it} = X_{it}\beta + Z_i\gamma + \alpha_i + \eta_{it} \quad (i = 1, \dots, N; t = 1, \dots, T), \quad (3.1)$$

where the vectors X_{it} and Z_i are time-varying and time-invariant variables, respectively.

The α_i represents the unobservable individual effect believed to exist across units, while the η_{it} is the usual stochastic error term. The observations are across T time periods and N units. The main problem of this model is the potential correlation of α_i with the columns

of X and Z , which results in biased and inconsistent estimation using OLS (Ordinary Least Squares) and GLS (Generalized Least Squares) techniques. Although we can eliminate the individual effects by transforming the data into deviations from the individual means, all time-invariant variables are eliminated by this transformation (Hausman and Taylor, 1981). In this research, the coefficients on the time-invariant variables, Z_i , are of central importance, which creates several estimation challenges.

Depending on model specification, either a fixed or random effects model can be applied to derive estimates of α_i . Hsiao (1999) suggested that if an experiment involves individuals who are considered a random sample from a larger population, random effects are more appropriate. However, if the situation is one of analyzing just a few individuals and the sole interest lies in just these individuals, then individual effects would more appropriately be fixed, not random. Mundlak (1978) suggested that the α_i should generally be considered in the random effects model. Other factors can enter into the decision to choose among feasible random or fixed effects specifications. For example, the estimates of β become similar between random and fixed effects when there exists a long time series in the panel.

For this research, the choice of a fixed effects model leads to a problematic complication. When the coefficients for time-varying variables are estimated using OLS, after the WITHIN transformation, $\hat{B}_w = (X'Q_v X)^{-1} X'Q_v Y$. $Q_v = I_N \otimes i(i'i)^{-1} i'$ is a projection operator that takes deviations from the unit mean of each variable in the X or Y matrices. Thus, $(Q_v X)_{it} = (X_{it} - \bar{X}_i)$ and $(Q_v Z)_i = (Z_i - \bar{Z}_i)$. As Hausman and Taylor (1981) noted, the Q_v transformation of Z_i leaves a vector of zeros because $Z_i = \bar{Z}_i$. Thus,

all time-invariant variables are eliminated by the WITHIN transformation, and γ , the environmental variables of interest here, cannot be estimated. As such, alternatives are needed. A random effects model can be used, or, building on Hausman and Taylor (1981), a two-stage method by Alvarez and Gonzlez (1999) can be used for estimating $\bar{\gamma}_i$ when a fixed effects model is preferred. The remainder of this section addresses that choice and the techniques used when estimating a random or fixed effects model.

The determination of whether to use a random or fixed effects model is based on the variances of α_i and η_{it} , and a derived value, θ . Let

$$\sigma_{\eta}^2 = \text{plim}_{N \rightarrow \infty} \frac{1}{N(T-1)} \eta_{it}' Q_v \eta_{it} \quad (3.2)$$

$$s^2 = (1/N)(Y_{it} - X_{it} \hat{\beta}_w - Z_{it} \hat{\gamma}_w)' (Y_{it} - X_{it} \hat{\beta}_w - Z_{it} \hat{\gamma}_w) \quad (3.3)$$

$$\sigma_{\alpha}^2 = s^2 - (1/T)\sigma_{\eta}^2 \quad (3.4)$$

$$\theta = [\sigma_{\eta}^2 / (\sigma_{\eta}^2 + T\sigma_{\alpha}^2)]^{1/2} \quad (3.5)$$

where σ_{η}^2 is the variance of the time varying error term estimated from the residuals of the fixed effects regression on just the X_{it} (because the Z_{it} are swept out from this specification). s^2 is the overall variance of the composed error calculated from the BETWEEN regression, and is used to create the σ_{α}^2 in the third equation. The $\hat{\beta}_w$ and the $\hat{\gamma}_w$ are the WITHIN estimates for the time varying and time invariant coefficients respectively (the latter to be discussed below). The $Y_{it} = (1/T)\sum Y_{it}$ and the $X_{it} = (1/T)\sum X_{it}$ are the unit means, averaged across all time periods for the dependent and independent variables. These variances are used to calculate a weighting variable, θ

which helps determine whether to use the fixed or random effects model. Moreover, θ becomes the weight for the random effects model (Greene, 2000; Hausman and Taylor, 1981).² For a given observation, the θ is used to create the weighting matrix $\Omega^{-1/2}$ used in the GLS transformation.

$$\begin{aligned}\Omega^{-1/2} &= \theta P_v + Q_v = I_{TN} - (1-\theta)P_v \\ \Omega^{-1/2} &= \Omega^{-1/2} X_{it} \beta + \Omega^{-1/2} Z_i \gamma + \Omega^{-1/2} \alpha_i + \Omega^{-1/2} \eta_{it} \text{ or} \\ Y_{it} - (1-\theta)Y_{i\cdot} &= [X_{it} - (1-\theta)X_{i\cdot}] \beta + \theta Z_i \gamma + \theta \alpha_i + [\eta_{it} - (1-\theta)\eta_{i\cdot}] \\ *P_v \text{ makes vector of group mean, so } P_v Y_{it} &= (1/T) \sum Y_{it} = Y_{i\cdot}.\end{aligned}\tag{3.6}$$

The above equations show that the random effects estimator differences the data, after a fashion, depending on the value of θ . From equation 3-5, if σ_α^2 were zero, then θ goes to 1, and GLS becomes ordinary least squares, as the $Y_{i\cdot}$ and $X_{i\cdot}$ terms drop out. If θ equals zero, then σ_η^2 is zero, and all variation across units would be due to the α_i and Equation 6 above reduces to the dummy variable, or fixed effects estimator. It is also clear from the equation above that the Z_i variables are affected, as they enter OLS in their original form when θ is 1 and drop out of the equation when $\theta = 0$.

The final issue related to the methods here is when the σ_η^2 goes to zero, we can use fixed effects setting. However, from Equation 3-6, it is seen that all time-invariant variables are eliminated in the fixed effects setting. Therefore, a two-step estimator, developed by Alvarez and Gonzalez (1999), is used. The first step is to estimate a fixed effects panel data model with all time-varying variables. The model is

$$Y_{it} = \alpha + X_{it} \beta + \eta_{it} - v_i \quad (\alpha_i = \alpha - v_i),\tag{3.7}$$

² Our presentation is based on Hausman and Taylor's (1981) definition of θ , which is equivalent to Greene's λ . Greene also used a θ , where $\lambda = 1 - \theta$ in his terminology. This is just another indication that industry standards have not totally reached the econometrics literature.

where α_i is the fixed effects of each cross-section unit.

In the second step, the $\hat{\alpha}_i$ are regressed against the set of cross-sectional characteristics, which are the time-invariant variables expressed as Z_i . The equation is a cross-sectional OLS estimation of $\alpha_i = Z_i\gamma + u_i$, where α_i is the residual from the WITHIN estimation, the expression for $\hat{\alpha}_i$ shows that the within residuals.

$$\begin{aligned}\hat{\alpha}_i &= Y_i - X_i' \hat{\beta}_w = [P_v - X_i \cdot (X_{ii}' Q_v X_{ii})^{-1} X_i' Q_v \\ &= \alpha + Z_i' \gamma + v_i + [P_v - X_i \cdot (X_{ii}' Q_v X_{ii})^{-1} X_i' Q_v] \varepsilon_{ii}.\end{aligned}\tag{3.8}$$

3.1.2 Equation Specification

Equation 3-1 defines the general model for panel data. The empirical model for policy analysis is applied to the general model as follows:

Animal Inventory = f (Natural Endowment, Economic Factors, Business Climate and Environmental Policy)

The dependent variables (Y_{it}) are specified as animal inventory in a state in a given year. The first dependent variable is the total livestock inventory measured as the sum of all animal units of four prominent livestock species (beef cattle, hog, dairy and broilers). The second dependent variable is also livestock inventory, but the variable is stratified by the livestock inventory located on three size categories of operations (small, medium and large), roughly coinciding with pervasive size standards in environmental policy. The last dependent variable separates livestock inventories by species and size and focuses on the beef cattle and hog industry. These three specifications facilitate the

revelation of the influence of environmental policy on different characteristics of the livestock industry.

The matrix of independent state characteristic variables (X_{it}) consists of the following principal categories: Natural endowments (1 variable), Economic factors (3), and Business climate (4). The matrix (Z_i) specifies the stringency of state environmental policies (5 variables), which are time invariant (following Mo and Abdalla, 1998). Both the breadth (48 states and 4 livestock species) and depth (30 yrs) of previously published work are extended in the first two analyses. For the third analysis, the 36 states with the greatest livestock inventory for beef cattle and 29 states for hogs are used over the same thirty-year period.

Table 3-1 Estimated " θ " for Each Group

	Total	Small	Medium	Large
Total Livestock Inventory	0.1719	0.1069	0.1453	0.1661
Beef Inventory	0.0001	0.0002	0.0001	0.0021
Hog Inventory	0.047	0.040	0.034	0.052

The model specification relies on Equation 5 and the values of θ calculated for each equation in this paper, corresponding to different sizes of livestock operations (Table 3-1). Estimations of θ is likely not zero for the Total Livestock Inventory estimation. As a result, the appropriate choice of estimation method is the random effect model. On the other hand, the θ s of the beef and hog industry inventories are nearly zero, which means σ_{η}^2 might be zero and we can use the fixed effects setting with the two step estimator for the third model specification and estimation.

3.2 Data Compilation

3.2.1 Environmental Policy and the Livestock Industry

The data required for analysis of livestock *location* regardless of size and by *size* category of operation include animal inventory and number of operations by size, livestock species and state, all over time. To fulfill these needs, agricultural census data (USDA-NASS, 1999a) were compiled and manipulated from 48 states (excluding Alaska and Hawaii) for dairy, swine, beef cattle and broiler industries over almost three decades (1969 to 1997). Annual state total animal inventory was calculated using animal unit equivalents for the *location* and *size* analyses. U.S. Environmental Protection Agency (EPA) standards were used and dry systems were assumed for poultry operations. For the *species* analysis, agricultural census data (USDA-NASS, 1999a) were compiled and manipulated from 38 states for beef cattle and 29 states for hogs over the same time period. For the *size* and *species* analyses, inventory per operation was segmented into three size categories, broadly based upon federal policy norms to the extent that data allowed. Unfortunately, the census categories for all livestock species do not directly map into the EPA's size thresholds for livestock operations. Values for non-census years were assigned based upon a linear extrapolation of intra-census trends.

The environmental regulation factors were based upon the "1998 National Survey of Animal Confinement Policies" database containing information from 48 states (Louisiana and West Virginia chose not to respond) (Edelman et al., 1998). NASS "Historical Data" provided the source for the rest of the variables (USDA-NASS, 1999b). Data sources, units and variables are summarized in Tables 3-2 and 3-3.

Table 3-2 Description of Variables in the Location and Size Analysis

Variable	Units	Abbreviation	Mean Value
Total Livestock Inventory	AU	Anitot	2,889,344
		AnitotG1	1,495,492
		AnitotG2	811,711
		AnitotG3	582,140
Beef-Corn price ratio	\$	Bratio(B/C)	170.63
Hog-Corn price ratio	\$	Hratio(H/C)	27.25
Slaughter capacity	Millions of Lbs	Slaughter	373.51
Land value	\$/acre	Landval	994.93
Unemployment Rate	%	Unemp	6.24
Population density	Ppn/1000 private acres	Popden	308.45
Average annual precipitation	Inches	Precipt	36.63
Property tax	\$/acre	Protax	7.05
Regulatory stringency index	(0, 1, ..., 19)	Regula	13.47
Fines imposed	(0,1)	Levfine	0.58
Staffing level	(FTEs)	Staff	2.57
Anti-corporate farm law	(0,1)	Corp	0.15
Local agricultural zoning	(0,1)	Zoning	0.17

Notes: Anitot G1, G2 and G3 are small (<300AU), medium (300-1000AU) and large (>1000AU) operations, respectively. Slaughter = (Beef Slaughter Capacity + Hog Slaughter Capacity) / Total Animal Inventory.

Sources: NASS, USDA; Anitot(G1-G3), Bratio, Hratio, Slaughter, Landval, Unemp, Precipt and Protax.

Census Bureau; Popden.

Task Force Survey; Regula, Levfine, Staff, Corp and Zoning.

As a representation of the relative profitability of the industry across location and time, state level beef-corn and hog-corn price ratios were included. Available labor may attract more animal operations and livestock to the state, so state unemployment rates were compiled and included as a relatively loose labor market might be expected to encourage industry expansion. As an indicator of industry transportation costs, combined annual beef and hog slaughtering capacity by state were included. Due to the potential covariance between inventories and slaughtering capacity, state total slaughtering capacity is divided by total state level animal inventory. All of these variables are expected to correlate positively with total state livestock inventory.

Table 3-3 List of Variables in the Species Analysis

Variable	Units	Abbreviation	Mean Value	
			Beef	Hog
Inventory: Beef; Total	Head	Binven	2696765	
Small			1335738	
Medium			801402	
Large			559624	
Inventory: Hog; Total	Head	Hinven		1835697
Small				835735
Medium				627390
Large				372571
Animal-Corn Price Ratio:				
Beef	\$	Bratio(B/C)	168.61	175.19
Hog		Hratio(H/C)	27.17	27.41
Slaughtering Capacity (Beef + Hog)	Millions of Lbs	Slaught	1877.55	2235.22
Land Value	\$/acre	Landval	733.11	855.69
Unemployment Rate	%	Unemp	6.19	5.97
Population Density	Population/ 1000 private acres	Popden	188.28	206.24
Animal density: Beef	Head/1000 acres	Bexist	6.51	7.47
: Chicken		Cexist	26.25	33.52
: Dairy		Dexist	0.73	0.82
: Hog		Hexist	4.37	5.55
Annual Average Precipitation	Inches	Precipt	34.64	38.04
Property Tax	\$/acre	Protax	5.12	5.58
Regulatory Stringency Index	(0, 1, ...,19)	Regula	12.42	13.62
Fines Imposed	(0,1)	Levfine	2.93	0.66
Staffing Level	(FTEs)	Staff	0.67	3.39
Anti-Corporate Farm Law	(0,1)	Corp	0.19	0.24
Local Agricultural Zoning	(0,1)	Zoning	0.17	0.24

Notes: Slaughter = (Beef Slaughter+Hog Slaughter)/Total Animal Inventory.

Sources: NASS; Inventory, Bratio, Hratio, Slaught, Landval, Unemp, Precipt and Protax. Census Bureau; Popden.

Task Force Survey; Regula, Levfine, Staff, Corp and Zoning.

Since greater livestock-human interaction is likely to result in more conflict and greater perceived negative externalities, a variable describing the likelihood of this interaction was constructed. Because both people and livestock spend most of their time on private land, the likelihood of their interaction increases as their populations increase and as private land decreases. Population data and the amount of private land by state

over five census periods were compiled (1960, 1970, 1980, 1990, and 2000) and a measure of population density on developable land by state and over time was calculated. Potentially, we expect that higher population density in the state will correlate with less animal inventory growth in that state.

Land prices are an indicator of an important production cost in the livestock industry, including population growth pressure, land use policies, resident wealth and income, and current and future land use. State property tax also should be considered as an indicator of the business climate of the state. The states' average annual precipitation was taken into account to represent the state level climatic variation and environmental vulnerability. All three variables are expected to correlate negatively with the state livestock inventory.

A proxy variable (Regula) was constructed to represent the general stringency of state regulations using recent survey information (Edelman et al., 1998). The index was constructed as an unweighted sum of affirmative responses to twenty-nine regulatory stringency-related survey questions. Nineteen affirmative responses was the maximum observed and zero affirmative responses provided the lower bound on the regulatory stringency index.

Neither active enforcement (fines imposed over time or evidence of compliance with policies) nor effectiveness (changes in water or air quality) measures are currently available in a form usable for this analysis. As imperfect substitutes for enforcement information, a dummy variable (Levfine) indicating whether fines had been levied was created and a categorical variable indicating the number of staff (Staff) dedicated to monitoring and enforcement were included.

CHAPTER 4

RESULTS

The general hypothesis is that the more stringent the regulation, the lower the livestock inventory in the state. Another expectation of the analysis is that policy impacts on inventory and location of industry might differ by the size and species of the operation. In this chapter results are presented first overall, then by size and finally by species to test these hypotheses.

4.1 Environmental Policy Impact on Industry Location

Increased relative stringency of state environmental regulations are expected to result in lower animal inventories than would otherwise be found due to increasing environmental compliance costs. Table 4-1 presents estimates of the influences of other characteristics and the state level environmental policies on livestock inventories using the random effects model. The dependent variable is the sum of the livestock inventories of four livestock sub-industries (i.e., Beef Cattle, Dairy, Hogs and Broilers). The estimated relationship explains 74% of the variation in state livestock inventory, which is relatively high for a panel data estimate.

As expected, the higher the local slaughter capacity (Slaughter), the greater the tendency to locate livestock within a region. State average precipitation (Precip), unemployment rate (Unemp) and land value (Landval) showed the predicted sign, but

were not statistically significant predictive factors. As expected, the tendency to locate livestock in a region is proportionally lowered by higher population density (Popden). Counter to expectations, property tax is positively correlated with inventories. The potential explanations for this finding would amount to conjecture at this juncture.

Table 4-1 Random Effects Model for Animal Total Analysis

Variables (expected sign)	Total Livestock Inventory	
	Coefficient	t-stat
C	2641826	6.52*
Unemployment rate (+)	28730	1.22
Property tax (-)	43730	3.55*
Precipitation (-)	-4408	-0.99
Land value (-)	-31	-0.37
Population density (-)	-1249	-5.37*
Beef/corn price ratio (+)	-1725	-2.29*
Hog/corn price ratio (+)	4001	0.72
Slaughtering capacity (+)	1466	9.29*
Regulation index (-)	508	1.11
Full time staff (-)	32220	2.08*
Levied fine (-)	-1319773	-9.13*
Anti- corporate law (-)	4121937	17.69*
Agricultural zoning (+)	319054	1.77**
R ²	0.7444	
Adj R ²	0.7420	

Note: * and ** denote significance at 5% and 10% level,

Potentially contrary to expectations, the ratio between beef prices and feed costs (Bratio), a rough indicator of profitability, was negatively correlated with state livestock inventories. Among all livestock industries included in the total inventory figure, the beef cattle industry should be the most responsive to beef prices. However, that industry has shown the least variation over time and place, as states seeing the largest changes in livestock inventories are not traditional beef-producing states. Therefore, it could be argued that strong increases in poultry and hog production in non-beef cattle states drive the major changes in the dependent variable, rather than reactions within the beef cattle

industry. In addition, the hog/corn price ratio had an insignificant impact on total livestock inventories. Therefore, this effect may be an artifact of the data used for the analysis rather than a directly interpretable relationship between beef cattle and hog inventories and profitability.

Although the written stringency of regulations (Regula) was not a significant predictor of livestock inventories, the tendency to fine operations for noncompliance with regulations (Levfine) was significantly negatively correlated with livestock inventories, and protective agricultural zoning (Zoning) was positively correlated with livestock inventories, supporting the “policy drives industry” hypothesis. However, the unexpected positive sign on the dedicated staff variable (Staff) seems to support the “industry drives policy” hypothesis. Most of the leading livestock states (Illinois, Iowa, Kansas and North Carolina) have relatively higher numbers of full time staff to deal with the livestock industry, which may drive this relationship.

Counter to Krause (1983) and Matthey and Royer (1999), the dummy variable indicating the presence of legislation restricting corporate ownership of livestock operations (Corp) shows a positive relationship with livestock inventories. From an economic theory perspective, this result is somewhat unexpected because large operations are typically associated with a significant corporate presence, and it can be expected that anti-corporate legislation would, therefore, reduce the number of large operations and, probably, the overall size of the industry (Table 4-2). However, states with anti-corporate legislation also tend to have an important traditional agricultural sector relative to the total economy (e.g., South Dakota, Kansas). It may be that large operations have either been ‘grandfathered in’ or have found legal loopholes to the

corporate label, such as limited partnerships and family corporations, rendering the anti-corporate legislation largely ineffective in guiding industry behavior. Again, this supports the hypothesis that industry drives policy.

Table 4-2 Regulatory Stringency Index of Leading Livestock States, by Species

Production Rank	Beef	Chicken	Dairy	Hog
1	Texas (16)	Ohio (14)	Wisconsin (12)	Iowa (18)
2	Nebraska (17)	California (11)	California (11)	North Carolina (16)
3	Kansas (15)	Georgia (14)	New York (4)	Minnesota (12)
4	Oklahoma (19)	Indiana (11)	Pennsylvania (12)	Illinois (18)
5	California (11)	Pennsylvania (12)	Minnesota (12)	Indiana (11)

Notes: Parentheses indicate the relative regulatory stringency. Least stringent = 0 and most stringent = 19.

Data source: Animal Confinement Policy National Task Force, 1998.

4.2 Environmental Policy Impacts on Livestock Operation and Industry Sizes

Since many environmental policies, including the CWA³, explicitly differentiate larger from smaller operations for mandatory compliance, it is appropriate for our analysis to reflect this differentiation. Instead of total industry impact, size categories (i.e. livestock inventories found on small, medium and large operations) become the dependent variables in this analysis.

Each of the three estimated relationships is statistically robust, describing 75% of the variation found in the livestock inventory found on small farms, 78% of that found in medium operations, and 61% of that variation in large farms (Table 4-3). Eleven of the thirteen predictive variables were statistically significant in the small farm estimations, and 9 were significant in the medium and large operation models.

³ Federal regulations define a Concentrated Animal Feeding Operation (CAFO) as an animal feeding operation that: confines more than 1,000 animal units (AU); or confines between 301 to 1,000 AU and discharges pollutants into waters of the United States through a man-made ditch, flushing system, or similar man-made device; or directly into waters of the United States that originate outside of and pass over, across,

For small farm inventories, only the number of staff dedicated to regulatory compliance and the state unemployment rate were statistically uncorrelated with the size of the livestock inventory. In contrast, on medium sized operations, both of these variables were significant predictors of livestock inventories, but the hog and beef to corn price ratios, the regulatory stringency index and the presence of agricultural zoning were not found to be significant. On large farms, the hog to corn price ratio, agricultural zoning and regulatory stringency remained insignificant paralleling findings for medium sized operations. Like small operations, the beef-corn price ratio became significantly predictive and unemployment became insignificant in estimations involving large operations (Table 4-3).

Table 4-3 Random Effects Model for Size Analysis

Variables (expected sign)	Small Operation		Medium Operation		Large Operation	
	Coeffs	t-stats	Coeffs	t-stats	Coeffs	t-stats
C	1110307	4.98*	912809	7.62*	631159	4.24*
Unemp (+)	7780	0.61	14032	2.06*	6450	0.68
Protax (-)	-13918	-2.07*	29412	8.23*	27473	5.52*
Precipt (-)	12093	4.99*	-6778	-5.25*	-9953	-5.55*
Landval (-)	102	2.26*	-67	-2.80*	-62	-1.84**
Popden (-)	-316	-2.50*	-526	-7.80*	-404	-4.31*
Bratio (+)	-3244	-7.92*	-120	-0.55	1621	5.32*
Hratio (+)	6620	2.19*	-279	-0.17	-2308	-1.02
Slaughter (+)	603	7.02*	392	8.56*	470	7.38*
Regula (+)	424	1.69**	37	0.28	45	0.24
Staff (-)	-10568	-1.25	15057	3.35*	27992	4.53*
Levfine (-)	-381654	-4.85*	-453201	-	-475853	-8.21*
Corp (-)	2334464	18.39*	1218886	18.03*	550214	5.88*
Zoning (+)	232986	2.38*	62961	1.21	19499	0.27
R ²	0.7531		0.7748		0.6057	
Adj R ²	0.7508		0.7727		0.6020	

Note: * and ** denote significance at 5% and 10% level, respectively.

or through the facility or otherwise come into direct contact with the animals confined in the operation (EPA, 1998).

More often and more importantly, where predictive variables were significant, the magnitude and direction of impact varied substantially across farm size categories, as hypothesized. Interesting information is found within the highlighted treatments. The effect of the state unemployment rate (Unemp) was insignificant in small and large farm estimates and significantly positive for the medium farm estimate. Several explanations are possible. Most obviously, families, who do not need extra labor, usually operate small farms. Many large concentrated operations, which have the skilled labor already, also may not need to absorb excess labor in the state. The high technology-based new large farms seems to be less connected to excessive (often low skill) state labor (DeLind, 1998).

As a representation of the profitability of livestock operations, beef/corn and hog/corn price ratios (Bratio and Hratio) have distinct impacts on the state livestock inventory. The beef/corn price ratio was negative for small operations, insignificant for medium and positive for large operations. This implies that large sized farms are most abundant where it is most profitable to operate. It may be that more beef inventory is found on large operations relative to other livestock species, thus making these categories more sensitive to the beef/corn price ratio. Alternatively, small farms may depend less on purchased inputs, or on the livestock portion of their production portfolio. Another possible reason may be due to less structural change within the beef industry (Table 1-2).

On the other hand, the hog/corn price ratio was positive for small farm estimates, but not significant for the medium and large farm estimations. This result probably reflects the specialization of the hog industry on larger operations. Farrow and nursery operations have a far lower portion of their production costs dictated by feed prices than finish operations. As a result, although corn prices may create a significant driver for the

location of hog finishing operations, other input cost advantages tend to drive the location of farrow and nursery operations. Since smaller operations remain farrow-to-finish, they are more likely to be concentrated where corn prices are lower than are other portions of the industry.

Edelman et al. (1998) found that hogs are the most controversial species in most states, potentially creating a relatively restrictive livestock regulatory environment in large hog industry states. As a result, other livestock sub-industries (beef, poultry and dairy) may try to avoid states with large hog operations, creating downward pressure on the total state livestock inventory, particularly emanating from large operations. For example, Texas, California and Nebraska have the greatest total livestock inventory found on large operations in the United States, but are minor players in the hog industry.

The total of beef and hog slaughter capacity (Slaught) was significant in estimation of all sizes of operations. This implies that greater slaughter capacity, and, presumably, lower transportation costs to slaughter, were found where a high number of livestock are found. This result may be indicative of the traditionally dominant role of transportation costs in the industry or of the relatively higher fixed costs of establishing a slaughter plant relative to a livestock production operation. Furthermore, vertical coordination of the hog and the poultry industry drives higher inventories and more slaughtering plants in the same places.

Unlike the total industry analysis, stratification by size generated statistically significant results for both land value and property tax, bundled components of input costs. Land value (Landval) was positively correlated with livestock inventories in small operations, but, as expected, is negatively related to the medium and large operation

category. Property tax follows the opposite pattern. Several explanations may be posed to address this result. Small operations are more likely to have off-farm income as a component of total family income. As a result, location nearer to urban areas, and higher land prices, may become a reasonable choice. On the other hand, it may be that only small operations remain near urban and suburban areas. Higher property taxes diminish the incentive to speculate on small, high priced, properties for alternative development uses. The combination of low land prices and higher property taxes favor larger operations, which are less likely to convert their land out of agricultural uses and are more likely to lease at least a portion of their productive lands. Moreover, population density was negatively related to all size categories, indicative of the pressure to convert land to residential or commercial uses.

Regulatory stringency had no significant impacts on inventory and location decisions on medium and large operations, despite the fact that such regulations often target larger operations. In our estimates, the number of staff dedicated to monitoring and enforcement activities (Staff) and evidence of actual enforcement of the regulations (Lev_{fine}) had distinct influences on the inventory and location of the livestock industry. The states with larger numbers of livestock found on medium and large operations have more dedicated staff and more stringent regulations, but less evidence of enforcement, following the industry-drives-policy hypothesis. The results show that fines levied had a significant negative impact across all sizes of the industry, indicating that the state's willingness to enforce regulations, rather than their written stringency, is the cost factor entering into producer decisions.

Contrary to expectations, the presence of legislation restricting corporate ownership (Corp) showed a strong positive relationship across all sizes of the operations. Although corporateness and largeness may be related, it also may be that states with anti-corporate legislation tend to have a relatively important traditional agriculture sector (populated by small and middle-sized full time farmers) relative to the total economy. Therefore, state anti-corporate laws may encourage more small and medium farms. As indicated earlier, large operations may have found legal loopholes or have been “grandfathered in” to recently impose anti-corporate regulations. On a related issue, agricultural zoning regulations were expected to positively influence livestock inventories. Our results indicate that small farms are protected or encouraged by such zoning, but that it had no discernible effect on larger operations. It may be that larger operations are of sufficient size to insulate themselves from the typical challenges facing smaller operations (e.g., threats of nuisance suits, difficulty moving machinery across discontinuous holdings), or that they are not covered by such legislation since they are often defined as commercial or industrial operations beyond a certain size.

4.3 Environmental Policy Impacts on Livestock Species

Results are reported for beef cattle and hog operations by inventory on the three size categories defined above (Tables 4-4 & 4-5). Though least descriptive of large operations, all estimates are statistically robust, in particular for panel data. In general, our estimations show distinct effects across species and operation size, according to our hypothesized expectations.

The state's natural environmental factors and business climate have the expected impact on small farms in both the beef and hog sub-sectors. The unemployment rate is positively correlated with the number of hogs found on small and medium operations and with the number of cattle found on small beef operations. State unemployment rate is negatively correlated with the beef and hog inventory on large operations and on medium beef operations.

Table 4-4 Fixed Effects Analysis of Environmental Policy and the Beef Industry

Variables	Total		Small		Medium		Large	
	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat
Unemployment	8330	9.27*	11463	15.53*	-1814	-4.63*	-2232	-3.92*
Property tax	-4142	-5.92*	-13206	-11.81*	4842	15.77*	6460	10.42*
Precipitation	239	0.70	-1081	-3.39*	361	2.31*	392	4.42*
Land value	108	13.41*	7	0.72	55	16.46*	-8	-1.38
Pop density	572	4.11*	404	3.29*	-610	-16.59*	1147	6.93*
Beef density	166836	22.23*	90714	16.71*	71562	28.93*	9341	8.63*
Chicken density	917	5.13*	-324	-1.90*	592	6.33*	418	6.70*
Dairy density	213186	10.18*	350276	13.26*	-220137	-25.65*	45450	5.62*
Hog density	1837	1.14	16261	9.88*	3678	5.68*	-3190	-2.00*
Beef/corn price	499	11.62*	-68	-2.19*	214	11.06	165	6.46*
Hog/corn price	-739	-3.74*	-20	-0.12	-6	-0.06	-339	-3.79*
Slaughter	14	2.08*	-47	-5.78*	-19	-7.86*	44	6.77*
R-squared	0.990		0.974		0.982		0.954	
Adj R-squared	0.990		0.973		0.981		0.952	
F-statistic	9060.5		3371.3		4966.6		1897.9	
<i>Two-step regression of time invariant regulation variables</i>								
	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat
C	997094	0.72	-431251	-0.58	810837	2.31*	848949	0.67
Regulation index	-3627	-0.05	66031	1.97*	-16588	-0.96	-72150	-1.13
Staff number	105287	4.19*	16205	1.61**	9650	1.71**	91097	3.47*
Levied fine	-1362302	-1.50	-417718	-1.27	-466415	-2.04*	-538425	-0.91
Anti-corporation	2424652	2.05*	629994	2.74*	873347	3.17*	1008477	1.06
Ag zoning	-1719122	-2.37*	-12729	-0.06	-313944	-1.89*	-1592666	-2.43*
R-squared	0.97		0.98		0.98		0.91	
Adj R-squared	0.97		0.98		0.98		0.89	
F-statistic	276.2		521.4		384.3		58.2	

Note: * and ** denote significance at 5% and 10% level, respectively.

Property tax and precipitation had a significant negative impact on small beef and hog operation inventories. Unexpectedly, property tax and precipitation were positively related to large and medium beef operation inventories. Property tax on medium hog

operations and the precipitation in large hog operations also had a positive relationship with inventories. Land value, a high value of which would be indicative of conversion pressure and/or land scarcity, was expected to have a negative sign, but only small hog operations carried the expected effect. Large hog and medium beef and hog operation inventories were positively related to land value, which was insignificantly related to other categories.

Table 4-5 Fixed Effects Analysis for Environmental Policy and the Hog Industry Sub-Sector

Variables	Total		Small		Medium		Large	
	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat
Unemployment	-11620	-6.79*	21450	10.41*	5899	8.59*	-35339	-10.39*
Property tax	2389	1.72**	-4382	-1.93*	9266	13.98*	1730	0.50
Precipitation	-301	-0.87	-1465	-2.74*	-102	-0.49	1321	3.16*
Land value	227	13.33*	-161	-6.81*	77	8.56*	266	8.83*
Pop density	-1360	-9.93*	1252	4.91*	-1526	-16.10*	-973	-3.11*
Beef density	-4426	-0.69	118805	8.68*	-13238	-2.72*	-69840	-5.48*
Chicken density	21	0.05	256	0.58	845	5.22*	296	0.47
Dairy density	-68098	-1.23	775102	10.20*	-24905	-1.13	-537833	-4.63*
Hog density	240697	14.54*	32041	3.92*	5426	1.89**	134455	3.41*
Beef/corn price	-186	-2.68*	61	0.58	-85	-2.3*	91	0.73
Hog/corn price	3822	10.46*	518	1.31	885	4.82*	1084	1.72**
Slaughtering	22	3.40*	-94	-8.36*	-8	-2.23*	124	11.09*
R-squared	0.975		0.907		0.909		0.664	
Adj R-squared	0.974		0.902		0.905		0.647	
F-statistic	2885.8		706.3		728.7		143.8	
<i>Two-Step regression of Time Invariant Regulation Variables</i>								
	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat
C	-7983685	-5.57*	-11621247	-6.43*	-14577761	-5.23**	11635262	6.22*
Regulation index	490637	6.92*	607500	6.79*	879244.3	6.38*	-637785	-6.89*
Staff number	-85149	-5.34*	-113279	-5.63*	-143973	-4.64*	115357	5.54*
Levied fine	1145244	3.12*	1627985	3.51*	1506406	2.11*	-832710	-1.73**
Anti-corperation	1396403	3.71*	1958263	4.13*	1839081	2.51*	-2096658	-4.27*
Ag zoning	1502020	5.60*	1981560	5.86*	3158878	6.06*	-2461042	-7.03*
R-squared	0.960		0.927		0.933		0.928	
Adj R-squared	0.952		0.912		0.919		0.912	
F-statistic	111.6		58.8		64.2		58.9	

Note: * and ** denote significance at 5% and 10% level, respectively.

The livestock industry is subject to conflict with urban human populations.

However, the results differ by species and size of the industry. The beef industry does not show conflict with increases in population density, except for medium sized farms, which

are more likely to be found on the urban fringe. However, except for small hog operation inventories, the hog inventories are negatively correlated with human population densities. These results may be explained as follows. Although the cattle industry is particularly land intensive, there has been little change in the leading beef cattle states over time. Potentially, strong local traditions in the industry may create less conflict. On the other hand, the hog industry has concentrated very strongly in few places, several of which have little tradition in animal agriculture in general and hogs in particular. This may have contributed to the status of the hog industries as the most controversial livestock industry sector (Edelman et al., 1998), and the strongly negative impact of the state population density on hog inventories across larger operation sizes.

According to expectations, the larger the operation, the greater the tendency to locate in states with a higher output/input price ratio in both species. The state slaughtering capacity had a significant positive influence on the large operations of both species and was negatively related to small and medium operation inventories across both species. In terms of location, large operations were closely associated with packing plants, while smaller operations were not.

The environmental policy variables indicate that there is a strong correlation with industry structure. The results of the hog industry estimations indicated a strong relationship among all of the policy variables and hog inventories. The analogous relationships with the beef cattle industry were substantially weaker.

All policy variables were positively related to hog inventories on small and medium operations except the number of people dedicated to the enforcement of regulations; this result potentially supports the industry follows policy hypothesis. The

results were absolutely the opposite for large operations; only dedicated staff was positively related to inventories on large operations, in support of the industry leads policy hypothesis. Three of the five policy variables were significantly predictive of beef cattle inventories on small operations and all were positive; regulatory index, staff, and anti-corporate legislation. On medium operations four of five policy variables were significant. Regulatory index became insignificant, agricultural zoning had a negative sign and fines levied became significant and negative. Number of staff and the presence of anti-corporate legislation remained significant and positively related to beef inventories on medium sized operations. On large operations, only two policy variables were significant. Like small and medium operations, number of staff dedicated to the monitoring and enforcement of environmental policy was positively related to beef cattle inventories. Like medium operations, agricultural zoning showed a negative correlation with inventories on large beef operations.

4.4 Livestock Industry Responsiveness to Policy Variables

The key factor in the estimated relationships is the behavior of the different dependent variables in each analysis. By differentiating the dependent variables, it is possible to incorporate both magnitude and the relative responsiveness of livestock inventories to changes in environmental policy. These elasticities are reported and interpreted for the following permutations: total industry inventories by animal unit, total industry inventories by size and by industry sub-sector of operation, and, finally, an analysis focused on two evolutionarily distinct sub-sectors by size of operation.

4.4.1 Regulatory stringency index

A regulatory stringency index represents the intensity of regulation toward a state's livestock industry. Environmental economic theory leads us to an industry drives policy hypothesis. However, the body of published research tends to imply opposite directionality.

In the total industry analysis, the impact of regulations was statistically insignificant and can be ignored in magnitude. The 1% change in environmental policy stringency resulted in only 0.002% change in state's total animal inventory. Dependent variables are the sum of four livestock industries and normalized by animal units. The choice of normalization by animal unit may have muted the influence of the poultry industry or rapidly changing hog industry relative to the comparatively staid beef and somewhat more actively changing dairy industries.

Table 4-6 The Directions and Impacts of State Regulatory Index

Industry Size	Total Industry		Industry by size				Hog Industry	
	Coeffs	Elasts	Coeffs	Elasts	Beef cattle Coeffs	Beef cattle Elasts	Hog Coeffs	Hog Elasts
Total	508	0.0024			-3627	-0.0167	490637*	3.6403
Small			424**	0.0038	66031*	0.6140	607500*	9.9005
Medium			37	0.0006	-16588	-0.2571	879244*	19.0875
Large			45	0.0010	-72150	-1.6013	-637785*	-23.3154

Note: * and ** denote significance at 5% and 10% level, respectively. Coeffs and Elasts are coefficients and elasticities of variables, respectively.

Unlike the total industry analysis, there is strong evidence of interaction between regulations and industry inventories in the species analysis. The calculated elasticities show that the hog industry is more sensitive by at least an order of magnitude to changes in policy than is the beef industry. Less structural change within the beef industry seems to provide less opportunity to adapt to a changing environmental policy milieu. However, the industry drives policy hypothesis can be supported in analyzing change in the more

mobile hog industry. Large hog operations seemed to be more sensitive to policy than the rest of the industry. A 1% increase in environmental policy stringency corresponds to an enormous 23% decrease in large hog operation inventories, a 19% increase in medium and 10% increase in small hog operation inventories. This high degree of sensitivity can be explained by the discrete nature of the index and the relatively little variation among regulatory stringency indices among hog producing states. One point on the stringency scale is predicted to result in an approximate decrease of 637,000 hogs on large operations (Table 4-6).

4.4.2 Staff

Table 4-7 The Directions and Impacts of Number of State Regulatory Staff

Industry Size	Total Industry		Industry by Size		Beef cattle Industry		Hog Industry	
	Coeffs	Elasts	Coeffs	Elasts	Coeffs	Elasts	Coeffs	Elasts
Total	32220*	0.0065			105287*	0.0262	-85149*	-0.0306
Small			-10568	-0.0041	16205**	0.0081	-113279*	-0.0895
Medium			15057*	0.0108	9650**	0.0081	-143973*	-0.1515
Large			27992*	0.0279	91097*	0.1091	115357*	0.2044

Note: * and ** denote significance at 5% and 10% level, respectively. Coeffs and Elasts are coefficients and elasticities of variables respectively.

The states with large numbers of livestock found on large operations have more dedicated staff, enforcement, and more stringent regulations, following the industry-drives-policy hypothesis in the size and species analyses. Staff can potentially fulfill roles other than monitoring and enforcement. Through education, technical and other support, dedicated staff can improve the management of hog operations for little or no additional cost to the producer, thus mitigating the expectation of a negative relationship between inventories and dedicated staff.

All sizes of beef and large hog operations are correlated with more staff, supporting the industry-drives-policy hypothesis. Small and medium hog operation inventories are negatively correlated with staff numbers. Again hog inventories are shown to be more responsive to changes in staff than is the beef industry. A 1% increase in staff is correlated with a 0.20% (115,357 hogs) increase in large hog operation inventories, a decrease of 0.15% (113,297) in medium and 0.09% (143,973) in small hog operation inventories. These changes may actually be indicative of shifts among operation sizes rather than absolute changes in total inventories. In contrast, a 1% change of staff is predicted to increase beef inventories on small and medium operations by 0.008% and on large operations by 0.1% (Table 4-7).

4.4.3 Fines Levied

Table 4-8 The Directions and Impacts of Fines Levied for Non-Compliance

Industry Size	Industry Total		Industry by Size		Cattle Industry		Hog Industry	
	Coeffs	Elasts	Coeffs	Elasts	Coeffs	Elasts	Coeffs	Elasts
Total	-1319773*	-1.1739			-1362302	-1.4801	1145244*	2.1149
Small			-381654*	-0.6559	-417718	-0.9163	1627985*	6.6036
Medium			-453201*	-1.4349	-466415*	-1.7053	1506406*	8.1396
Large			-475853*	-2.1008	-538425	-2.8190	-832710**	-7.5768

Note: * and ** denote significance at 5% and 10% level, respectively. Coeffs and Elasts are coefficients and elasticities of variables respectively.

The relationship between actual enforcement, as measured by fines levied, and livestock inventories is opposite to dedicated staff and more sensitive in terms of their elasticities than staff. Most of the industry sectors generate elasticities greater than 1, implying that a 1% change of the level of levied fine will result in a more than 1% change in animal inventory found on that operation size or species category. The sign of coefficients indicates decreasing inventory with levied fine across all analyses, except

small and medium hog operations. The elasticities of the hog analysis imply highly flexible inventories. Results imply an increase of more than 150,000 hogs on small and medium operations due to a 1% increase in the actual imposition of fines on the livestock industry. Concurrently, more than 830,000 hogs on large operations are expected to shift away from these operations with such an increase in fines levied (Table 4-8), indicating where fines are most likely to fall. The hog industry is highly concentrated and coordinated. This concentrated market power can correlate with bargaining power and political power. This political power may influence both written regulatory stringency and actual enforcement, although probably not costlessly, and could actually attract still more industry. Here we find evidence that the industry drives the stringency of regulation, but actual enforcement of the regulations drives the industry.

4.4.4 Anti-Corporate Law

Table 4-9 The Directions and Impacts of Anti-Corporate Law

Industry Size	Industry Total		Industry by Size		Beef cattle Industry		Hog Industry	
	Coeffs	Elasts	Coeffs	Elasts	Coeffs	Elasts	Coeffs	Elasts
Total	4121937*	0.2140			2424652*	0.1708	1396403*	0.1826
Small			2334464*	0.2342	629994*	0.0896	1958263*	0.5624
Medium			1218886*	0.2252	873347*	0.2071	1839081*	0.7035
Large			550214*	0.1418	1008477	0.3424	-2096658*	-1.3506

Note: * and ** denote significance at 5% and 10% level, respectively. Coeffs and Elasts are coefficients and elasticities of variables respectively.

Corporate ownership of livestock commonly is thought to imply less connection to community, which may result in less interest in being a “good neighbor.” Indifference toward any particular location may reduce attention to regulated and unregulated environmental and other effects of interest to a community. In addition, corporate ownership, commonly thought to imply largeness, and vertical integration are thought to

negatively influence the viability of traditionally smaller and more diversified “family” farms. As a result, a number of states have sought restrictions on corporate activities in agriculture (Knoeber, 1997). Typically, state anti-corporate laws exclude non-family corporations and limit agricultural partnerships, which may induce structural change within the livestock industry.

Results show that anti-corporate laws did not reduce state inventories either in total industry or species analyses. A 1% increase in the incidence of this law increased animal inventories across sectors by less than 1%. However, large hog farm inventories show a high level of negative sensitivity to state anti-corporate laws. States with this legislation are expected to have 2,096,658 fewer hogs on large operations than states lacking anti-corporate legislation (Table 4-9).

4.4.5 Agricultural Zoning Regulation

Estimates on agricultural zoning provide uncomplicated results, but a rather complex interpretation. The total animal agriculture industry inventories increased 0.02% when there was 1% increase in the prevalence of agricultural zoning. The variable was highly significant in all species based estimations, except for small beef cattle operation inventories. Large operations, regardless of species, show statistically strong negative correlation, and the elasticity marks a large impact on their inventories. More than 1,590,000 beef cattle and 2,460,000 hogs are predicted to shift out of large operations with this regulation. However, agricultural zoning is correlated with large increases in hog inventories on small and medium operations (1,981,560 and 3,158,878, respectively) (Table 4-10).

Table 4-10 The Directions and Impact of Agricultural Zoning

Industry Size	Total Industry		Industry by Size		Beef cattle Industry		Hog Industry	
	Coeffs	Elasts	Coeffs	Elasts	Coeffs	Elasts	Coeffs	Elasts
Total	319054**	0.0188			-1719122*	-0.1084	1502020*	0.1964
Small			232986*	0.0265	-12729	-0.0016	1981560*	0.5690
Medium			62961	0.0132	-313944*	-0.0666	3158878*	1.2084
Large			19499	0.0057	-1592666*	-0.4838	-2461042*	-1.5853

Note: * and ** denote significance at 5% and 10% level, respectively. Coeffs and Elasts are coefficients and elasticities of variables respectively.

CHAPTER 5

CONCLUSIONS AND FUTURE DIRECTIONS

The economic advantages of scale economies in agriculture, increasing demands for environmental quality and an increasingly urbanized population create policy challenges for individuals, communities and the nation (Martin and Zering, 1997). U.S. livestock industries produce important economic benefits in their host communities. For example, the top ranking 4 states, Texas (beef cattle), Wisconsin (dairy), Iowa (hog) and Georgia (chickens) contributed \$4.3 billion, \$2.9 billion, \$2.8 billion and \$2.2 billion in sales revenues to their state's economy, respectively (USDA-NASS, 1999c). However, manure, an unavoidable joint product of production, may create environmental and economic costs mitigating the contribution of the industry to society. Regulators, researchers and communities have raised concerns about the potential impacts of manure concentration. Efficient policies are, therefore, justified to bring private and social benefit and cost conditions together toward a maximization of social welfare.

Unfortunately, little information connecting industry performance with policy is in evidence. Policy effectiveness (changes in water quality measures) and enforcement (number, amount and date of fines or operation closures) are not readily available across states. Without effectiveness and enforcement information it is difficult to infer whether a lack of correlation between environmental policy and inventory/location decisions is due to highly efficient policies (those which reach social water quality objectives without

increasing livestock production costs) or completely ineffectual policies (no enforcement).

I have addressed the impacts of state environmental regulations on the livestock industry. Dynamic conditions within the livestock industry provide challenges in isolating the real impact of state's environmental regulations. Three distinct but closely related analytical treatments (Total Inventory, Inventory by size or species of operation and Inventories by size of operation within a species sub-industry) provide insights into the correlation and causality between regulation and industry.

The total inventory analysis, generally speaking, indicates that traditional economic factors are still important to farm level inventory decision making, but their influence varies across operation size. Our results appear to imply that, although environmental policy (Regulatory stringency index) factors may increase production costs differentially across state lines and operation sizes, either sunk costs in infrastructure and marketing channel development or other advantages the livestock and poultry industries do not appear to have been outweighed by increased regulatory compliance costs in those states. However, results point to distinct effects of written stringency and evidence of the willingness to enforce environmental policy. Policy enforcement activity was shown to influence inventory decisions in general and larger operations were found to be more sensitive to willingness to enforce than smaller operations.

To see whether the impacts and directions are different by species, two sub-sectors of the livestock industry were specifically compared: beef cattle and hogs. The beef cattle industry has experienced a relatively slow structural evolution, changing

relatively little from its traditional locations, size and market structures. Therefore, the beef cattle industry may be somewhat less flexible in responding to production cost increases fomented by increases in regulatory requirements. On the other hand, the hog industry has changed rapidly in size, structure and the location. As a result, the hog industry should be more responsive to changes in the policy milieu. In addition, environmental policy usually targets larger operations, so small farms should be less sensitive to the policy mix. Our results were stratified by size of operation, since federal policy focuses upon size, location, since regulations and their enforcement may differ across states, and sub-sector, since species and industry structure may be important determinants of the willingness and ability to adapt to a changing environmental policy milieu.

We expected that the more stringent the regulation, the higher the environmental compliance costs. Therefore, the test hypothesis was that “stringent state-level regulation leads to a decline in animal inventories in the state.” Our panel data estimates tentatively show that the state regulation does have an impact on the livestock industry. Traditional factors are still important predictors of location and inventory decisions. Generally, regulations seem to be induced by the structural change of industry; when industry creates externalities, regulators try to address them with policy tools. Written regulatory stringency may not effect behavioral change, rather the state’s willingness to enforce regulations seems to have a measurable influence. However, in the presence of rapid structural change, industry location is affected by written regulatory stringency.

An attempt has been made to relate state level environmental policies to livestock inventories by total inventory, operation size and species for the entire United States,

providing greater depth, breadth and methodological sophistication than previous work in this area. A number of interesting results have resulted from this effort. As always, refinements could be made. In order to improve the information set in this realm we suggest future analyses attempt to incorporate entry and exit information (as manufacturing sector studies have done), compile and include more comprehensive and temporally specific enforcement and effectiveness information, and explicitly consider the potential endogeneity of environmental policy and the size of the livestock industry.

PART 2

LIVESTOCK INDUSTRY LOCATION AND RESIDENTIAL PROPERTY

VALUES IN WELD COUNTY, COLORADO:

A SPATIAL HEDONIC MODEL

CHAPTER 6

INTRODUCTION

The livestock industry is an important sector in many local and state economies. The industry creates employment and infrastructure within a region. Additional jobs create income and can be a potential source of economic growth in a community. However, animal agriculture can also generate negative impacts beyond the boundaries of the farm, ranch, or feedlot including flies, odor, water pollution, farm vehicle traffic, and noise, for example. Recent structural change within the livestock industry has heightened concerns about the industry's potential negative impacts and the pursuit of avenues to mitigate these influences while maximizing its positive economic contribution to rural communities.

In addition to the potential for water pollution from the livestock industry, significant public attention has been directed toward offensive odors released from livestock operations (Palmquist et al., 1997). Farber (1998) discussed several perspectives from which to assess such externalities including the real or perceived health and amenity risks and environmental justice or civil rights. Assessing these social costs is

complex and is sometimes subjective. The odor from livestock operations can affect the quality of life of neighbors, the effect of which is difficult to evaluate objectively. However, odor may also influence more easily quantifiable aspects of human welfare. Consumers may express their preferences for some negative environmental externalities from the livestock industry in the marketplace (Fisher et al., 1991). If livestock odor is strictly non-preferred, the presence, strength, duration, and type of odor should influence real estate values in the vicinity. Lower real estate values imply a lower residential tax base than would obtain in the absence of the odor externality. This implies that the failure to mitigate odor due to poor community planning or poor management practices results in fewer services or that a greater tax burden is imposed on the general populace by livestock producers. An alternative perspective is that by tolerating odor, residents are subsidizing livestock production by incurring a greater tax burden or fewer services than they would have in the absence of these odors.

Hedonic techniques can estimate part of the social cost of the livestock industry through the housing prices. Housing prices implicitly contain all the characteristics of a house, such as house size, lot size, number of bedrooms and bathrooms, as well as community, neighborhood and environmental qualities. Therefore, housing price, the traded value, reveals the consumers' willingness to pay for the bundle of housing attributes. A hedonic analysis allows the analyst to reveal the marginal contribution of each of the components of the housing bundle to the market value.

The development effect of livestock operations should increase the demand for local housing while the odor effect should have a mitigating effect on demand. The net effect may be positive or negative and will depend upon a number of demographic factors

and environmental factors as well as features of the housing market. Palmquist (1992) noted that when an environmental change is a “localized externality”, welfare measurement from the hedonic schedule is possible. Non-marginal environmental change (expansion of large operation within a region) may shift market equilibrium prices of houses, but the hedonic regression in this analysis shows a market equilibrium locus of price. Here I estimate what observable local economic impact of livestock operations have on surrounding residential property values.

CHAPTER 7

OBJECTIVES AND HYPOTHESES

7.1 Objectives

The general objective of this study is to model and subsequently understand the influence of livestock operations on the rural residential real estate market. The housing market tends to exhibit significant neighborhood effects, or spatial correlation, but traditional hedonic model has typically ignored this important issue in the analysis. The lack of consideration of spatial correlation will lead to inefficient parameter estimates. We need to address this spatial issue to more precisely understand the interaction between the housing market and livestock odor by accounting for all other known effects, including neighborhood effects, as well as possible. It is useful to understand the monetary impact of livestock odor by its location and other characteristics of the operation relative to incompatible nearby uses such as residential development in order to guide development and local policy regarding agricultural and residential growth. The specific objectives of this study are as follows:

1. Test whether there is spatial correlation in the housing market.
2. Test whether the impacts differ by the size, number and species of the operation.
3. Examine the degree to which proximity to the operation affects housing prices.
4. Test whether these effects differ across price delimited sub-categories of the housing market

5. Forecast the likely economic impacts of new operations on current and future residential values

7.2 Hypotheses

It is expected that odor will constitute a negative externality on proximal residential property values. Specifically, the impact of livestock operations on residential property values will differ by the following:

1. Number and spatial concentration of operations;
2. Distance to the operation;
3. Species of the operation;
4. Characteristics of the housing market;
5. Neighborhood information;
6. Managerial and technological features of the livestock operation;
7. Topography; and
8. Climate;

Notwithstanding the importance of factors #6-8, available data facilitate the testing of only the first five proposed sources of influence at this time.

The spatial distance from the housing unit to the livestock operations can be measured through the use of geographical information system (GIS). “X” and “Y” coordinates of housing units give the distance of each housing in the GIS setting, which are exactly same approach by “latitude” and “longitude”, but more accurate. These kinds of spatial issues will be addressed in this study using a spatial hedonic model. I expect that the impact will be diminished by increasing distance from the operation. I also

expect that the larger the livestock inventory and the greater the number of operations, ceteris paribus, the greater will be the observed negative influence of livestock odors on residential real estate values. Finally, I expect that the higher end of the housing market will be more strongly affected in both proportion and magnitude than the cheaper end of the market because I expect that the development effect will be concentrated in the lower end of the market and that odor will be perceived as more offensive at the upper end of the market.

CHAPTER 8

LITERATURE REVIEW

8.1 Relevant Research Focusing on Commercial and Industrial Sectors

The hedonic pricing method (HPM) has received significant use since Lancaster (1966) and Ridker and Henning (1967). The method developed a theoretical framework and interpretation mainly to assess the value of environmental (dis)amenities (Griliches, 1971; Rosen, 1974; Nelson, 1978). There were many debates about using this method as a tool of evaluation for environmental goods in the early stages of its development. Harrison and Rubinfeld (1978) investigated the methodological problems of using housing data to estimate the willingness to pay for clean air, and Freeman (1979) reviewed the theoretical basis and assumptions, which are required in hedonic analyses. Freeman (1979) noted “there are many instances of successful models of housing prices in which the actual data diverge from the theoretical ideal, and in which the assumptions about the nature of the housing market and preferences are oversimplified.” In response, he recommended greater investigation into housing market segmentation and the identification problem in future studies.

The empirical studies of the effects of undesirable facilities and activities on surrounding property values have been limited to the analysis of residential property values (Farber, 1998). There are many reasons to utilize HPM in studies of different conditions of environmental qualities, such as air and water. In particular, property value

indicates the cost of environmental disamenities and also the willingness to pay for the potential amenities. Most of the studies have tested the impact of the location of undesirable land uses around residential areas such as hazardous materials manufacturing, electric or nuclear power plants and solid waste.

Nelson (1981) and Gamble and Downing and (1982) examined the impact of a nuclear site on the surrounding residential property values. Nelson tested the Three Mile Island (TMI) accident on March 28, 1979. Gamble and Downing examined the effects on the residential property values of four nuclear power plants in the Northeastern United States before and after the TMI accident with actual sales values for 540 single family properties in the vicinity. However, neither study found any significant impact on housing prices.

In the case of hazardous waste, the revealed impact is completely different from nuclear power plants. Most research (Gamble and Downing, 1982; Michaels and Smith, 1990; Kohlhasse, 1991; McClelland et al., 1990; Ketkar, 1992; Greenberg and Hughes, 1992 and 1993; Hite et al., 2001) has found significant negative impact on surrounding property values. A Pennsylvania study by Gamble and Downing. (1982) found no significant effect of landfills on the property values in 1977 and 1979, but the “distance to the landfill” was significant in 1978.

In order to avoid the single price function describing the equilibrium price within it, Michaels and Smith (1990) divided the housing market into three categories: premier, above average and average. The housing values around the hazardous waste site increased by 1.3% to 1.9% per mile, particularly after the announcement that those sites would be listed as NPL (National Priority List) sites. Kohlhasse (1991), conducting similar

research in Houston, found that the price of housing is higher when located further from a site; as much as \$3,310 per mile evaluated at the mean. Ketkar's (1992) hedonic study of New Jersey showed that the cleaning of one more site will increase the median price range of a property from \$1,300 to \$2,000 (US\$1980). He showed that the benefits of cleaning up these sites exceeded the cleanup costs. Greenberg and Hughes (1993) investigated different housing sale prices with and without Superfund sites in New Jersey. They found that the value of houses sold in communities with Superfund hazardous waste sites was lower than average. McClelland et al. (1990) also found a negative impact of hazardous waste landfills on housing values and that closing the sites would increase average value by \$5,000.

8.2 Relevant Research on the Livestock Industry

Unlike industrial research, there is very little empirical evidence related to the livestock industry. The structural changes of hog industry, especially geographical concentration of large operations has brought more research that is concentrated on hogs in major hog states. Abeles-Allison and Conner (1990) estimated the residential property value over 300 properties around 8 hog operations. They found that larger operations have more impact than smaller and one more hog decreased the housing value by \$0.43 within 5 miles. However, the sample hog farm on this analysis, received multiple odor complaints, thus it may have created biased estimation if it were not representative of the norm.

Research in North Carolina by Palmquist et al. (1997) is the only peer-reviewed study to date. They evaluated 237 rural residential properties in nine North Carolina

counties within two miles of swine feedlots. They created an index⁴ of hog manure production at different distances from the houses to estimate the differing impact on housing prices. They found a 4.75% (\$2,889) drop within one-half mile from a 2,400 head swine operation. However, the impact dropped to 0.57% and 0.56% for one-half mile to 1 mile and 1-2 miles, respectively.

In a working paper, Taff et al. (1996) expanded the North Carolina study by obtaining the exact location of properties and feedlots in Minnesota so that they could measure the direction and distance of each livestock operation to each house. They ran a regression of the house characteristics only and then added feedlot information to test for potential improvement of the model. The results showed that houses closer to feedlots appear to have sold for more than would have been expected based on knowledge of the characteristics of the house alone. It could be argued that the development effect outweighed any potential odor effect in this case, or that there was some omitted variable (i.e., the construction of a casino nearby) driving the unexpected changes. The authors do not recommend generalization of their results.

The regional or localized environmental impact of the livestock industry should differ by the spatial dependence and heterogeneity of the housing market. We expect that, if there are significant impacts, the housing values depend on not only the distance to livestock operations, but also the value of other housing units nearby. This spatial issue has been recognized in some research areas, especially in regional economics, but less in empirical studies and never in an assessment of livestock industry impacts. Evidence appears to support the contention of neighborhood effects: Nearby housing prices seem to

⁴ Manure index, which represents potential environmental damage, is based on the accumulated effect of hog operations by distance: $MAN = NMAN0 + \gamma_1 * NMAN1 + \gamma_2 * NMAN2$. Where $NMAN0$, $NMAN1$ and $NMAN2$

be dependent on one another. Given the observed homogeneity within modern subdivision developments, this is not a surprising result.

Quite recently, Rabotygov (2002) revisited North Carolina hog operations in his Master's thesis. The results show that hog production influences property values in both directions. Large scale hog operations, especially when they are spatially concentrated, generate more income and beneficially impact housing values. However, he also found that more hog inventory decreased housing value after a fashion.

Unfortunately, none of the previous hedonic studies on the livestock industry have addressed spatial issues in the model. Failure to address spatial issues is analogous to ignoring autocorrelation in time series analysis., leading to biased and inconsistent results and misrepresenting the real impact of the livestock industry on society. Here, spatial econometric methods are applied to correct for this potential problem.

are manure (tons) per year for each distance ring, and γ_1 and γ_2 are the estimated weights.

CHAPTER 9

STUDY AREA AND DATA

9.1 Study Area

Weld County is one of the fast growing counties in Colorado (Figure 1). Rooted in agricultural-industry and food processing, the economy has grown and diversified substantially over the past 25 years. In terms of sales, it is among the most important agricultural counties in the nation. It is also becoming more important as a milk-producing county with close to half of the state's dairy herd located in the county (EDAP⁵, Weld County). Meanwhile, total population has increased by more than 37% in the past 10 years, creating substantial growth in the new housing construction sector and in residential real estate sales in the area. As a traditional livestock county, some sources of livestock odors may not be considered disamenities. However, given the preponderance of newcomers from more urban backgrounds, livestock traditions may run less deep among the new residents of the county.

⁵ http://www.gwedap.org/demographic_profiles/agriculture.htm.

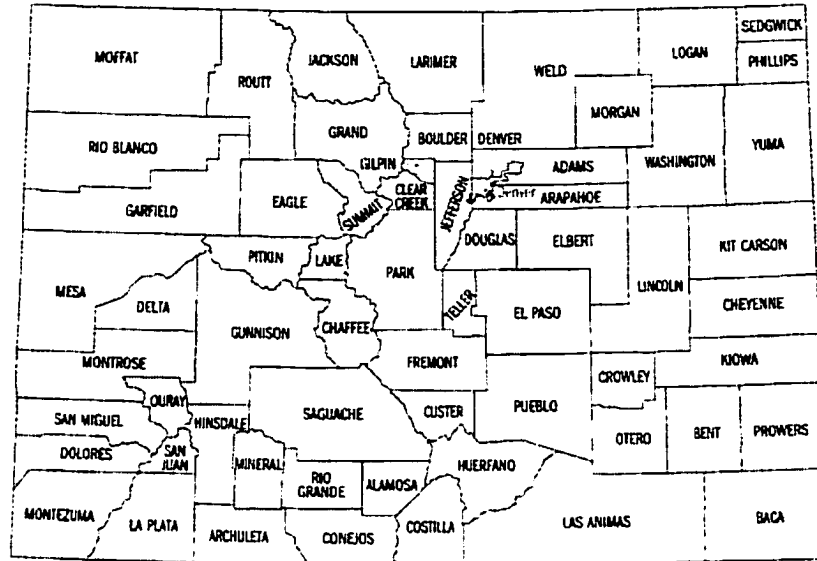


Figure 1 State of Colorado

The county office of Public Health & Environment has heard increasing complaints about odor and other problems surrounding livestock operations in recent years. Greeley is the county seat and the study area included 18 cities and towns including Greeley. The exact study area is not the entire county, but its Southeast section, which is the fastest growing portion of the county and is located closest to (within commuting distance of) the Boulder-Longmont and Denver metropolitan regions (Figure 2).

9.2 Data

A total of 3,354 residential housing sales data were collected over three years (1999-2001). Housing sales data were provided by Weld County Assessor's Office and processed using GIS to get spatial information. The characteristics of housing units, neighborhood and livestock operation information were collected. Age of house, number of bedrooms, number of bathrooms, square feet of heated area (building size), lot size and

house sales price were collected. The proximity to major highway, population density, school budget and student/teacher ratio represent neighborhood influences. However, since the spatial boundaries of this study lie within a single county, available secondary neighborhood information does not vary substantially within the study region. The resulting multicollinearity in the empirical analysis forced us to consider only proximity to major highway in the final regression.

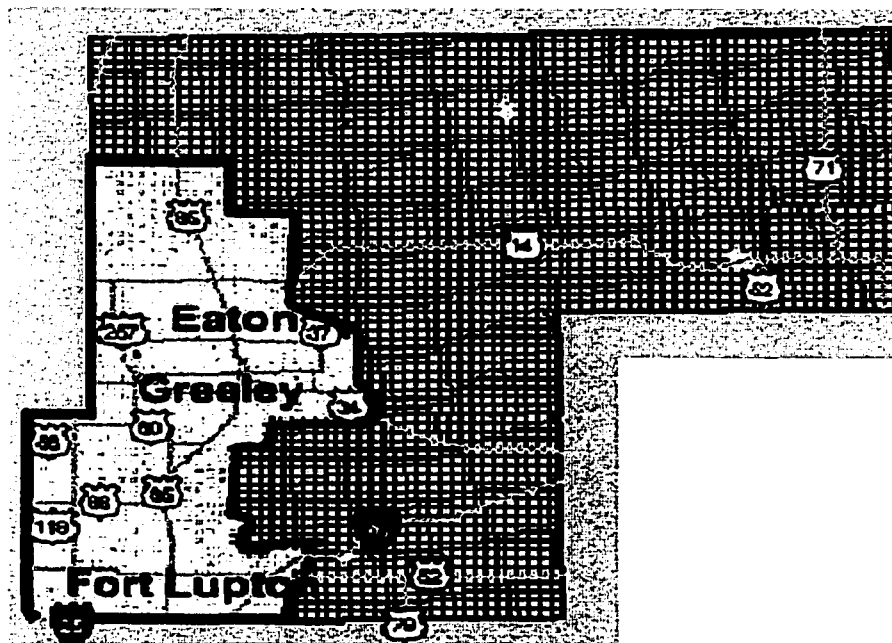


Figure 2 Study Area in Weld County

Finally, the livestock operations nearby each rural residential sale are collected to estimate a social cost of livestock sector. The County Clerk is supposed to maintain a record of all land use permits in the county. Feedlot and livestock operations require special land use permits if there are more than four animal units per acre, which means that almost every operation should have a permit. County office records can track around three decades of permits. However, some existing operations were without permits because they had been in business prior to the establishment of a permitting system.

Other sources of information include the Planning Department and the Public Health & Environment Department. I searched all three sources to find correct information of current livestock operations in the county. There were around 250 feedlots and livestock operations in the first pass, but some of them closed and/or canceled their permits before the study period (1999-2001) or were locating out of the final study area. Ultimately, 184 livestock operations were included in this analysis. Within the sample there were 72 dairy farms, 59 beef cattle operations including feedlots, 25 hog operations and 28 poultry and others species (20 chicken + turkey and 8 sheep). Most of these operations were located more than 3 miles from the main city, Greeley, and excluded in the final analysis.

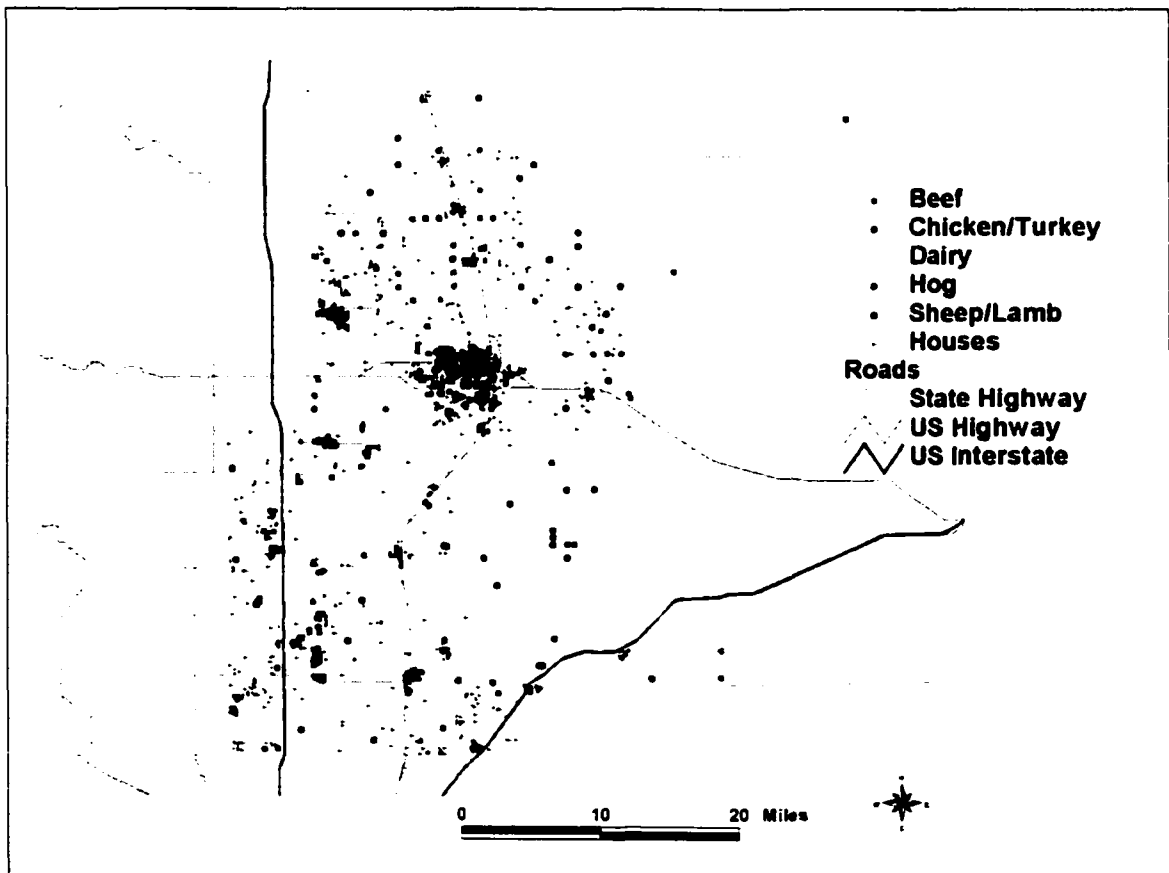


Figure 3 Spatial Distribution of Home Sales and Livestock Operations

An advantage of this study is that we can use Geographic Information System (GIS) of the county. All of the housing sales information is found in the “Shape File” of the county’s GIS & mapping office. We put the feedlot and livestock operation data into the GIS file to have spatial information (Figure 3). Every land use has a parcel number or other legal description and it is possible to measure the distance of each parcel to each livestock operation in a GIS environment. We drew three ring radiuses from each housing unit. The three radii were: 0 to 1 mile, 1 to 2 miles and 2 to 3 miles. Within each mile radius we collected the number, size and species of operations for every single housing unit. The number of animals was converted to an animal unit basis, which is based on the EPA’s norms⁶. This spatial information was incorporated into the Matlab Software to create the spatially weighted matrix and spatial regression. All the variables and descriptive statistics are reported in Table 9-1.

If air quality is a normal good, it can be presumed that the willingness to pay for different air quality increases with income. Unfortunately, county housing sales data do not include individual household income of the purchaser. From a policy perspective, it is important to verify whether the impacts of livestock operations differ by residence location. Housing markets are commonly clustered by its price and the impacts of livestock operations of the same size in the lower housing value area may not be the same as the high housing value area. Therefore, instead of using household income, I assert that higher household incomes should be strongly correlated with higher priced home purchases. Further, by dividing the dataset among low, medium and high priced houses, we have, in essence, proxied the effect of income on housing and, therefore, odor preferences. The mean value of housing prices in consideration of all three housing price

⁶ Beef cattle is 1AU, 1 Dairy is 1.4AU, Hog is 0.4AU, Chicken is 0.01 (Turkey 0.02), Sheep is 0.1 etc.

categories is approximately \$175,000. The low housing price group is less than \$150,000, the medium price is more than \$150,000 but less than \$200,000, and the high price group is over \$200,000. Therefore, this is an appropriate designation because mean housing value of the medium price group is also \$175,796. Tables 9-2, -3, and -4 present the dataset for each of these three groups.

Table 9-1 Variables and Descriptive Statistics of Analysis for the General Model

Variables	Description	Units	Min	Max	Mean	Std Dev
Hp	housing sale prices	\$1,000	53.00	880.00	175.80	69.97
Yr	age of house	years	1.00	82.00	11.62	16.56
Bed	# of bedroom	#	0.58	6.00	2.97	0.58
Bath	# of bathroom	#	0.00	6.00	2.24	0.71
Pox	proximity to highway	mile	0.00	6.20	1.87	1.41
Bdsize	building size	sq ft	468	8336	1541.98	606.56
Lotsize	lot size	acres	0.03	14.65	0.42	1.25
beef1	# of operation(1 mile)	#	0.00	3.00	0.25	0.55
beef2	# of operation(2 mile)	#	0.00	9.00	0.91	1.18
beef3	# of operation(3 mile)	#	0.00	13.00	1.58	2.12
beefAU1	AUs per operation(1 mile)	1000AU	0.00	10.00	0.33	1.01
beefAU2	AUs per operation(2 mile)	1000AU	0.00	27.75	1.36	2.47
beefAU3	AUs per operation(3 mile)	1000AU	0.00	100.00	2.87	5.69
hog2	# of operation(2 mile)	#	0.00	2.00	0.19	0.40
hog3	# of operation(3 mile)	#	0.00	3.00	0.22	0.42
hogAU2	AUs per operation(2 mile)	1000AU	0.00	1.27	0.19	0.44
hogAU3	AUs per operation(3 mile)	1000AU	0.00	1.60	0.14	0.35
chicken2	# of operation(2 mile)	#	0.00	3.00	0.16	0.42
chicken3	# of operation(3 mile)	#	0.00	2.00	0.34	0.61
chickenAU2	AUs per operation(2 mile)	1000AU	0.00	24.10	0.43	2.39
chickenAU3	AUs per operation(3 mile)	1000AU	0.00	24.10	0.35	1.51
sheep2	# of operation(2 mile)	#	0.00	2.00	0.07	0.28
sheep3	# of operation(3 mile)	#	0.00	3.00	0.11	0.39
sheepAU2	AUs per operation(2 mile)	1000AU	0.00	7.00	0.14	0.66
sheepAU3	AUs per operation(3 mile)	1000AU	0.00	7.00	0.15	0.56

Table 9-2 Variables and Descriptive Statistics of Price Analysis (Low)
(HP = less than 150,000)

Variables	Description	Units	Min	Max	Mean	Std Dev
hp	housing sale prices	\$1,000	50	149.4	123.6	19.8
yr	age of house	years	1	82	18.5	20.3
bed	# of bedroom	#	1	5	2.8	0.5
bath	# of bathroom	#	1	4	1.8	0.6
pox	proximity to highway	mile	0	6.2	1.4	1.1
bdsz	building size	sq ft	468	3678	1192.4	303.7
lotsz	lot size	acres	0.03	4	0.2	0.2
beef1	# of operation(1 mile)	#	0	3	0.3	0.6
beef2	# of operation(2 mile)	#	0	9	0.9	1.2
beef3	# of operation(3 mile)	#	0	13	1.5	1.8
BeefAU1	AUs per operation(1 mile)	1000AU	0	10	0.4	1.2
BeefAU2	AUs per operation(2 mile)	1000AU	0	8.4	1.1	1.9
BeefAU3	AUs per operation(3 mile)	1000AU	0	100	3.3	7.5
hog2	# of operation(2 mile)	#	0	1	0.1	0.3
hog3	# of operation(3 mile)	#	0	3	0.2	0.4
HogAU2	AUs per operation(2 mile)	1000AU	0	1.264	0.1	0.2
HogAU3	AUs per operation(3 mile)	1000AU	0	1.6	0.1	0.3
Chicken2	# of operation(2 mile)	#	0	2	0.1	0.4
Chicken3	# of operation(3 mile)	#	0	2	0.4	0.7
chickenAU2	AUs per operation(2 mile)	1000AU	0	16.85	0.6	3.0
chickenAU3	AUs per operation(3 mile)	1000AU	0	10	0.3	1.1
sheep2	# of operation(2 mile)	#	0	1	0.1	0.3
sheep3	# of operation(3 mile)	#	0	3	0.1	0.3
sheepAU2	AUs per operation(2 mile)	1000AU	0	2	0.2	0.5
sheepAU3	AUs per operation(3 mile)	1000AU	0	5.333	0.1	0.5

The age of the house is significantly different for all three price categories (low mean =18.5, medium mean = 7.82 and high mean = 6; $t_{lm} = -15.3$, $t_{lh} = -17.8$ and $t_{mh} = -3.6$)⁷. The number of bedrooms is also shows statistically different by housing price (low mean = 2.8, medium mean = 3.01 and high mean = 3.22; $t_{lm} = 10.1$, $t_{lh} = 15.8$ and $t_{mh} =$

⁷ This is based on pairwise comparison of the calculated mean values in each of the three property value subcategories. t_{lm} , t_{lh} and t_{mh} indicate t-stats between low and medium, low and high and medium and high priced groups, respectively. $t = \frac{m_1 - m_2}{\sqrt{\frac{s_1}{n_1} + \frac{s_2}{n_2}}}$

7.9), and for the number of bathrooms (low mean = 1.8, medium mean = 2.35 and high mean = 2.76; $t_{lm} = 22.4$, $t_{lh} = 32.7$ and $t_{mh} = 14.2$).

Table 9-3 Variables and Descriptive Statistics of Price Analysis (Medium)
(HP = over 150,000, but less than 200,000)

Variables	Description	Units	Min	Max	Mean	Std Dev
hp	housing sale prices	\$1,000	149.5	199.4	170.83	14.24
yr	age of house	years	1	82	7.82	12.06
bed	# of bedroom	#	1	5	3.01	0.50
bath	# of bathroom	#	1	4	2.35	0.58
pox	proximity to highway	mile	0.1	6.2	2.19	1.55
bdsz	building size	sq ft	734	6630	1490.72	353.32
lotsz	lot size	acres	0.0439	9.34	0.30	1.52
beef1	# of operation(1 mile)	#	0	3	0.25	0.49
beef2	# of operation(2 mile)	#	0	8	0.87	1.16
beef3	# of operation(3 mile)	#	0	13	1.70	2.52
beefAU1	AUs per operation(1 mile)	1000AU	0	6	0.27	0.77
beefAU2	AUs per operation(2 mile)	1000AU	0	13.42	1.64	2.73
beefAU3	AUs per operation(3 mile)	1000AU	0	50.22	2.22	3.47
hog2	# of operation(2 mile)	#	0	1	0.23	0.42
hog3	# of operation(3 mile)	#	0	2	0.21	0.41
hogAU2	AUs per operation(2 mile)	1000AU	0	1.264	0.26	0.50
hogAU3	AUs per operation(3 mile)	1000AU	0	1.264	0.16	0.38
chicken2	# of operation(2 mile)	#	0	2	0.14	0.37
chicken3	# of operation(3 mile)	#	0	2	0.35	0.58
chickenAU2	AUs per operation(2 mile)	1000AU	0	16.85	0.22	1.42
chickenAU3	AUs per operation(3 mile)	1000AU	0	24.1	0.22	1.24
sheep2	# of operation(2 mile)	#	0	2	0.04	0.20
sheep3	# of operation(3 mile)	#	0	2	0.15	0.46
sheepAU2	AUs per operation(2 mile)	1000AU	0	7	0.07	0.40
sheepAU3	AUs per operation(3 mile)	1000AU	0	2	0.19	0.55

The proximity of medium price category homes to a major highway does not differ from the high price category (medium mean = 2.19, high mean = 2.2 and $t = 0.15$). However, the low price property category was significantly closer to the highway on average than and medium and high end homes (low mean = 1.4, $t_{lm} = 14.2$ and $t_{lh} = 13.2$). Building size (low mean = 1,192.4, medium mean = 1,490 and high mean = 2,183; $t_{lm} = 21.8$, $t_{lh} = 36.1$ and $t_{mh} = 24.8$) and lot size (low mean = 0.2, medium mean = 0.3 and high

mean = 0.94; $t_{lm} = 2.3$, $t_{lh} = 13.2$ and $t_{mh} = 9.0$) for the three groups were also statistically different, both increasing with increases in property value as expected.

Table 9-4 Variables and Descriptive Statistics of Price Analysis (High)
(HP = over 200,000)

Variables	Description	Units	Min	Max	Mean	Std Dev
hp	housing sale prices	\$1,000	199.5	880	267.70	78.16
yr	age of house	years	1	82	6.00	10.40
bed	# of bedroom	#	1	6	3.22	0.63
bath	# of bathroom	#	0	6	2.76	0.67
pox	proximity to highway	mile	0	6.2	2.20	1.43
bdsz	building size	sq ft	820	8336	2183.43	744.35
lotsz	lot size	acres	0.03	14.65	0.94	1.59
beef1	# of operation(1 mile)	#	0	3	0.25	0.51
beef2	# of operation(2 mile)	#	0	8	1.01	1.11
beef3	# of operation(3 mile)	#	0	13	1.57	1.99
beefAU1	AUs per operation(1 mile)	1000AU	0	10	0.34	0.92
beefAU2	AUs per operation(2 mile)	1000AU	0	27.75	1.43	2.79
beefAU3	AUs per operation(3 mile)	1000AU	0	53	3.11	4.72
hog2	# of operation(2 mile)	#	0	2	0.25	0.44
hog3	# of operation(3 mile)	#	0	2	0.21	0.42
hogAU2	AUs per operation(2 mile)	1000AU	0	1.266	0.29	0.53
hogAU3	AUs per operation(3 mile)	1000AU	0	1.6	0.11	0.29
chicken2	# of operation(2 mile)	#	0	3	0.24	0.48
chicken3	# of operation(3 mile)	#	0	2	0.18	0.46
chickenAU2	AUs per operation(2 mile)	1000AU	0	24.1	0.39	2.46
chickenAU3	AUs per operation(3 mile)	1000AU	0	16.85	0.56	2.26
sheep2	# of operation(2 mile)	#	0	2	0.08	0.34
sheep3	# of operation(3 mile)	#	0	2	0.09	0.39
sheepAU2	AUs per operation(2 mile)	1000AU	0	7	0.20	1.06
sheepAU3	AUs per operation(3 mile)	1000AU	0	7	0.14	0.68

CHAPTER 10

SPATIAL HEDONIC MODELS AND RESULTS

Local housing market transactions can be affected by livestock operations in several ways. People may seek employment near livestock operations. More operations should certainly imply more jobs and income and greater livestock inventories may imply more jobs *ceteris paribus*, depending upon the relative labor requirements of larger versus smaller operations per unit of output. More jobs and income in basic industries like livestock production imply greater local economic multiplier effects. These “development effects” should put upward pressure on local housing prices. It is likely that this effect would be greatest on the lower end of the housing market due to the relatively low salaries associated with such work.

On the other hand, livestock operations may also create localized negative externalities due to the odor of animal manure and potential health impacts through air and water pollution. Notwithstanding the oft-cited idiom “smells like money,” livestock odors should negatively influence proximal housing prices, *ceteris paribus*. In addition, livestock operations are primarily found in rural areas. Growth in Colorado is in part driven by people who have urban jobs (and incomes), but have the desire for rural lifestyles, viewscapes and other natural attributes of rural Colorado without necessarily living off of the land. Higher urban incomes and the lack of connection to agricultural land productivity should increase land the fee simple price of agricultural and non-

agricultural lands in high growth areas. It is likely that urbanites place less value on traditional agricultural practices in a rural region, are more likely to discount agricultural odors and practices in the purchase decisions, are less likely to seek out homes near livestock operations due to their employment potential, and are more likely to purchase expensive homes than those dependent upon agricultural production for their livelihoods.

10.1 Traditional hedonic model

The economic rationale for the traditional hedonic model provides a simplification of reality in the housing market. Essentially, the demand for housing units is a function of its structural characteristics and neighborhood conditions and is based on individual utility maximization. Each household maximizes utility as

$$U = u(X_i, HC_i, EQ_i), \quad (10.1)$$

subject to the budget constraint

$$Y_i = X_i + HP_i \quad (10.2)$$

where

X_i = Bundles of composite goods, such as all other household expenditures,

Y_i = Annual income of the i^{th} household,

HC_i = Housing characteristics,

HP_i = Hedonic housing price function.

Housing demand is also a function of environmental quality (EQ_i) such as air and water quality. The hedonic model allows us to isolate the net impact of environmental quality from other housing characteristics. Let's say HC_i , NB_i and EQ_i indicate the vectors of housing characteristics, neighborhood information and environmental quality

(related to livestock operations), then the price of each housing unit is a function of levels in each area:

$$HP_i = hp(HC_{il}, \dots, HC_{in}, NB_{il}, \dots, NB_{im}, EQ_{il}, \dots, EQ_{ip}) \quad (10.3)$$

This is the hedonic or implicit price function, which permits estimation of the implicit price of each characteristic. The main purpose of this function is to derive implicit prices for different levels of environmental quality, controlling for other effects. By adding or subtracting one more unit of the environmental amenity or disamenity, it is possible to derive the marginal impact of varying environmental quality by one unit. The first differential of equations (10.1) and (10.3) with respect to environmental quality obtains:

$$\frac{\partial U / \partial(AUs_j)}{\partial U / \partial X} = \frac{\partial HP_i}{\partial(AUs_j)} \quad (10.4)$$

where AUs is Animal Units and the ratio of animal unit per operation. It implies how much more (less) consumers are willing to pay for housing, when adding one more livestock operation (or animal unit) to a locality. It is expected to differ by income, which is also likely to be reflected in the house price category considered by the buyer. Therefore, the equilibrium point in the housing market should be the point where the marginal implicit price of the environmental disamenities is equal to the willingness to pay curve for each individual.

Traditional hedonic analysis has ignored the correlation among values of housing units in a neighborhood within a local housing market. Housing units tend to be clustered in areas with similar prices, so there exists a high correlation of housing prices within spatial proximity. Therefore, it is valuable to include an autocorrelation relationship of some kind to capture this effect in the housing demand function. However, many traditional hedonic models use OLS, which causes unbiased, but inefficient results under

conditions of autocorrelation. In addition, if the error term of the regression does not show serial correlation, the OLS estimator is consistent for both time series and cross sectional regression. This condition does not hold in the spatial model. Consider following basic spatial autoregressive model (Anselin 1988, LeSage 1998):

$$y = \rho W y + \varepsilon \quad (10.5)$$

Where W is a spatial contiguity matrix⁸, y is expressed in deviations from means form and is in effect a lagged dependent variable. The OLS estimation of ρ in the model is:

$$\hat{\rho} = (y' W' W y)^{-1} y' W' y \quad (10.6)$$

If $E(\hat{\rho}) = \rho$, then this estimation is unbiased with OLS. The substitution of y into equation (10.6) yields the following equation:

$$\begin{aligned} E(\hat{\rho}) &= (y' W' W y)^{-1} y' W' (\rho W y + \varepsilon) \\ &= \rho + (y' W' W y)^{-1} y' W' \varepsilon \end{aligned} \quad (10.7)$$

As LeSage noted if $E(\varepsilon) = 0$, then the second (biased) term will be equal to zero when the explanatory variables in the matrix X in OLS are fixed in repeated sampling. However, due to the spatial dependence, it is not possible to make the case that $W y$ is fixed in repeated sampling (LeSage, 1998). Anselin (1988) showed that the probability limit ($plim$) for the term $y' W' \varepsilon$ is not zero.

$$plim N^{-1} (y' W' \varepsilon) = plim N^{-1} \varepsilon' W (I - \rho W)^{-1} \varepsilon \quad (10.8)$$

This is equal to zero only if ρ equals zero, which means that there is no spatial correlation in the dependent variable in the model. However, OLS is biased and inconsistent for a

⁸ The rows of the matrix sum to one.

spatial regression when ρ is not zero, and the body of literature recommends (quasi) maximum likelihood estimation to correct for spatial autocorrelation.

10.2 Correction of Spatial Autocorrelation in the Spatial Hedonic Model

The autocorrelation problem has been considered for time series and panel data in traditional econometrics textbooks for many years. However, geographic proximity and spillover effects of environmental externalities are emphasized in the discussion of autocorrelation in cross-sectional data. According to an emerging body of spatial econometrics literature, spatially explicit model specifications need to incorporate the spatial dependence and heterogeneity that is found among observations proximate to each other in location (Anselin, 1988; Dubin, 1988; Moulton, 1990; Topa, 1996; LeSage, 1998; Kelejian and Prucha, 1999).

As noted earlier, housing price tends to interact spatially at a county level. A spatial econometrics model is appropriate to deal with the spatial dependency and heterogeneity of the housing market. Two types of models can be generated depending upon the specification: the spatial autoregressive model (SAR) and the spatial error model (SEM). The spatial autoregressive model is analogous to a first-order AR model with time series data. In this model, observations of nearby housing prices partially explain local housing prices. Therefore, this approach is appropriate to capture neighborhood spillover effects (Kim et al., 1998). The model is

$$\begin{aligned}
 P &= \rho WP + X\beta + u \\
 u &\sim N(0, \sigma^2 I_n)
 \end{aligned}
 \tag{10.9}$$

Where P contains an $n \times 1$ vector of observations on the dependent variable and X represents an $n \times k$ matrix of independent variables. W is a known $n \times n$ spatial weighted matrix and ρ is the scalar spatial lag coefficient. It reflects the spatial dependence inherent in the sample data, measuring the average influence of neighboring, or contiguous, observations in the vector y (LeSage, 1998). The maximum likelihood estimator for ρ chooses a value of ρ that maximizes the following likelihood function:

$$L(P \setminus \rho, \sigma^2) = \frac{1}{2\pi\sigma^{2(n/2)}} |I_n - \rho W| \exp\left\{-\frac{1}{2\sigma^2} (P - \rho WP)'(P - \rho WP)\right\} \quad (10.10)$$

Here, the housing price is a function of not only the X variables, but also the weighted price of all other housing prices;

$$(P_i = \rho(w_{11}P_1 + w_{12}P_2 + \dots + w_{1n}P_n) + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots + \beta_k X_{ik} + u_i) \quad (10.11)$$

This spatial model is eventually OLS, but it takes several steps (Anselin, 1988).

1. Running OLS for $P = W\beta_0 + u_0$ and $W_p = X\beta_L + u_L$.
2. Compute residuals $u_0 = P - X\hat{\beta}_0$ and $u_L = Wp - X\hat{\beta}_L$.
3. Given u_0 and u_L , to find ρ that maximizes the concentrated likelihood

$$\text{function: } L_C = C - (n/2) \ln(1/n)(u_0 - \rho u_L) + \ln|I - \rho W|.$$

4. Given $\hat{\rho}$ that maximize L_C , compute;

$$\hat{\beta} = (\hat{\beta}_0 - \rho \hat{\beta}_L) \quad \text{and} \quad \hat{\sigma}_u^2 = (1/n)(u_0 - \rho u_L)'(u_0 - \rho u_L).$$

Another approach is the Spatial Error Model (SEM) model, which is one of the most widely referenced models for addressing spatial autocorrelation.

$$\begin{aligned}
P &= X\beta + u \\
u &= \lambda W u + \varepsilon \\
\varepsilon &\sim N(0, \sigma^2 I_n)
\end{aligned}
\tag{10.12}$$

Here, λ is the coefficient of a spatially correlated error, which is the same term with the serial correlation problem in time series analysis. This model is usually estimated by the (quasi) maximum likelihood estimator. However, computational problems may exist for large samples (Kelejian and Prucha, 1999). They suggest substituting a generalized moments estimator that is computationally simple regardless of the sample size. The

specification in equation (10.12) implies that $u_i = \rho \sum_{j=1}^N m_{ij} u_j + \varepsilon_i, \quad i = 1, \dots, N$. For

example, if the cross-sectional units are geographic regions, one might take $m_{ij} \neq 0$ if the i th and j th regions are contiguous, and $m_{ij} = 0$ otherwise. Therefore, one distinguishing feature of a spatial model would be that the i th disturbance term is directly related to both “future” and “past” disturbances. In a spatial model, there is typically no natural order for arranging the sample (Kelejian and Prucha, 1999), so the choice of W , the contiguity matrix, is essential for determining this relationship.

By combining two models, we can generate a general model for spatial autoregressive properties (LeSage, 1998);

$$\begin{aligned}
P &= \rho W_1 p + X\beta + u \\
u &= \lambda W_2 u + \varepsilon \\
\varepsilon &\sim N(0, \sigma^2 I_n)
\end{aligned}
\tag{10.13}$$

where $\rho W_1 p$ and $\lambda W_2 u$ are independent. To account for spatial relationships, all three specifications will be tested and compared using the spatial function in Matlab created by LeSage (1998).

A key issue in spatial econometrics is the creation of the spatial weighting matrix “W”, which requires the construction of a spatial contiguity matrix (LeSage, 1998). This task is carried out using Matlab’s spatial function “xy2cont”, which essentially uses triangles connecting the x-y coordinates derived from the GIS analysis to deduce contiguous entities. This function is based on the “*Delaunay Triangulation Method*” from computational geometry⁹. Given a set of data points, the Delaunay triangulation produces a set of lines connecting each point to its natural neighbors, which is each housing unit in this analysis. This is the method used in this research. It does not explicitly reflect a fixed distance nor does it relate more points than three (needed to create the triangles), so there is not really a determination of “nearness” based on either distance or numbers of other housing sales. (The distance between the centroids of all neighbors (contiguous regions) in the data set could be averaged to give an indication of the effective distance on which the analysis was based.)

It is also possible to create the “W” matrix based explicitly on distances or the closest number of neighbors in an ad hoc fashion. Given distances between points determined from the x and y coordinates, the two (or any chosen number) nearest neighbors could be calculated for each observation, and the remaining observations would be given zeros. Also, all neighbors with a certain distance of the sale could be considered, but this would lead to varying lags across observations, which would cause problems. The robustness of the results to these differing approaches is left for further research.

Finally, even though we can maximize “ ρ ” with the (quasi) maximum likelihood function, there is a remaining complexity in the empirical estimation. This is especially

⁹ The actual procedure of this method is given by Matlab and is reproduced in Appendix B.

true for large data sets. In the maximum likelihood function (equation 10.10), the term

$$\ln|I - \rho W| = \sum_{i=1}^N \ln(1 - \rho \lambda_i),$$

where λ_i denotes the i th eigenvalue of W , which needs to be

calculated (Kelejian and Prucha, 1999). Finding the eigenvalues of the $N \times N$ matrix of W is complex, because the matrices of this dataset are 3,354 by 3,354, so the sparse matrix function in Matlab is used to reduce the structure of the matrix in Figure 4.

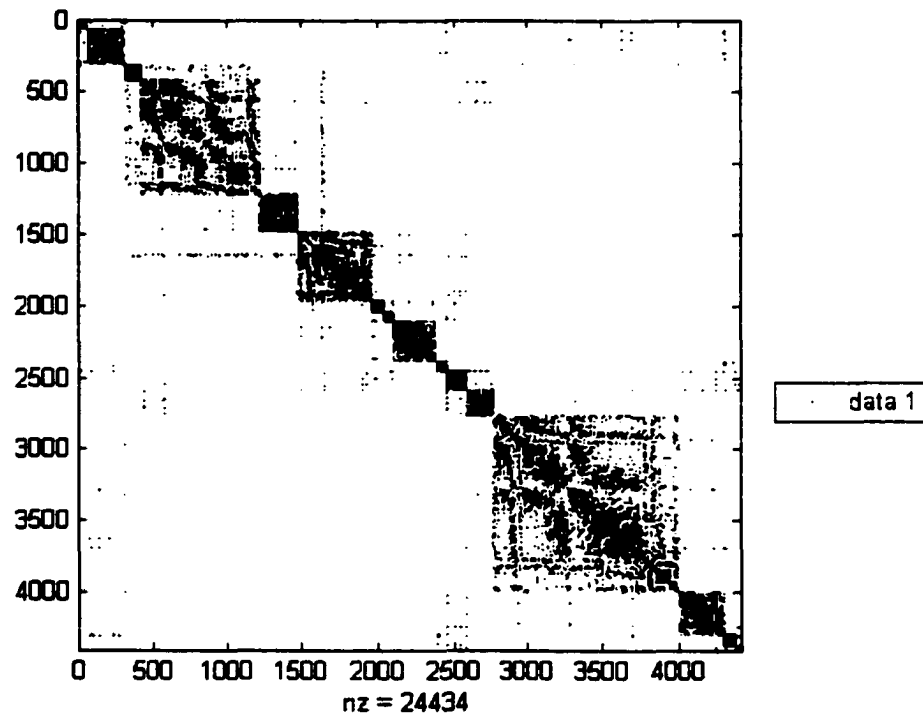


Figure 4 The Sparse Structure of the "W" Matrix

10.3 Empirical Model Specification

The empirical model in this analysis will be:

$$\log(\text{Home sale price}_i) = f(\text{HC}_i, \text{POX}_i, \text{AUs}_i, \text{Animal Operations}_i)$$

which will be

tested for all three model specifications. In this case, the variables are

HC = all housing characteristics,

POX = proximity to the highway from each house,

AU = animal units of each species within 1-3 miles,

Animal Operation = number of livestock operations, by species, within 1-3 miles.

In addition to the general model analysis, each variable was separated into three housing price categories using slope dummy variables to see if there would be different marginal impacts by housing price category. For this analysis, the dataset was divided into three subsets based on housing price (low price houses were less than \$150,000; medium was over \$150,000 but less than \$200,000; and, the high price group was over \$200,000). For example, from the general model:

$$\log(\text{Home sale price}) = \beta_1 + \beta_2 AUsD_1 + \beta_3 AUsD_2 + \beta_4 \text{ all other variables}$$

where

AUsD₁ = animal units within certain miles in the medium price group

AUsD₂ = animal units within certain miles in the high price group, and

β_1 = coefficient for the constant term.

This regression permits three different coefficients on animal units for all three housing price groups, and β_2^* and β_3^* , described below, use the estimated coefficients to reach the impacts of animal units by housing price category as any slope dummy variables do. Therefore, it is possible to investigate the income effect of willingness to pay for the same disamenity.

$$\beta_2^* = \beta_1 + \beta_2$$

$$\beta_3^* = \beta_1 + \beta_3$$

To represent better the housing market structure with related to the spatial issue, three common models, the linear, semi-log and log-linear were examined. Size and location data were collected for beef cattle, dairy, chicken, turkey and hog operations.

Preliminary analysis of the data revealed that there were sufficient rural residential sales observations within one mile of beef and dairy operations to run the models. However, there were insufficient rural residential real estate sales near chicken and turkey operations. As a result, chicken and turkey farms were combined to form a category called “poultry” and the final models were run with less than 2 miles as the closest potential impact zone rather than our original intent to model influences from within a mile. In addition, no significant differences in housing prices were observed due to beef cattle versus dairy operations, providing preliminary evidence that species may matter more than operation type. As a result, beef cattle and dairy operations were combined into one category representing cattle.

10.4 General Model Results by Spatial Specification

Among the potential functional forms available for estimating these relationships, the log-linear functional form provided the best fit, and those results are reported in Table 10-1. The significance of ρ in the SAR model indicates that there is spatial correlation between housing prices and proximity to livestock operations and due to the assumption of the particular W matrix used in this analysis. The t-stat of ρ is 13.5 and we would interpret this statistic in the typical regression fashion to indicate that the estimated ρ lies 13.5 standard deviations away from zero. Likewise, the significance of λ in the SEM model indicates that there is spatial autocorrelation in the error term. Therefore, it seems reasonable to use the general model (SAC), which has a spatial weighting matrix both as independent variables and in the error term. In the results of the SAC model, the rho (ρ) and lambda (λ) are statistically significant. Based on the SAC model, the traditional

hedonic variables (Housing Characteristics) show the expected signs and significance, except the proximity of each housing unit to the highway.

Table 10-1 Results of Three Spatial Model for Species Analysis

Variable	SAR Model		SEM Model		SAC Model	
	Coeffs	t-stat	Coeffs	t-stat	Coeffs	t-stat
Const	4.243	188.7	4.471	204.8	4.345	182.8
yr	-0.004	-15.7*	-0.003	-12.6*	-0.004	-15.2*
bed	0.018	2.9*	0.025	5.2*	0.018	3.3*
bat	0.090	15.6*	0.061	13.1*	0.077	14.3*
pox	0.005	1.4	0.028	5.1*	0.009	2.0*
bdsiz	0.0002	81.0*	0.0002	176.1*	0.0002	54.4*
lotsiz	0.029	9.3*	0.020	7.5*	0.024	8.2*
beef1	0.058	4.3*	0.058	3.1*	0.054	3.6*
beef2	0.047	9.5*	0.052	7.1*	0.054	9.3*
beef3	0.034	9.2*	0.033	6.3*	0.036	8.3*
BeefAU1	-0.019	-2.8*	-0.014	-1.7**	-0.014	-1.8**
BeefAU2	0.000	0.0	0.001	0.3	-0.001	-0.4
BeefAU3	-0.002	-2.5*	-0.002	-1.7**	-0.002	-2.0*
hog2	-0.237	-8.9*	-0.219	-5.3*	-0.267	-8.4*
hog3	-0.019	-1.1	0.051	2.0*	-0.006	-0.3
HogAU2	0.249	8.8*	0.225	5.1*	0.281	8.4*
HogAU3	0.036	1.4	-0.041	-1.2	0.019	0.7
Chicken2	0.059	3.0*	0.028	0.9	0.064	2.8*
Chicken3	-0.019	-2.3*	-0.023	-1.6	-0.028	-2.7*
ChickenAU2	-0.015	-5.2*	-0.007	-1.4	-0.016	-4.5*
ChickenAU3	0.016	5.7*	0.002	0.6	0.016	4.9*
sheep2	-0.334	-8.6*	-0.400	-6.3*	-0.388	-8.5*
sheep3	-0.216	-6.3*	-0.307	-6.6*	-0.241	-5.9*
SheepAU2	0.116	8.3*	0.120	5.0*	0.132	7.9*
SheepAU3	0.094	5.3*	0.143	6.0*	0.109	5.2*
Rho	0.033	13.5*			0.029	12.4*
Lambda			0.721	81.1*	0.278	24.4*
R-squared	0.6492		0.7557		0.7083	
Adj_R-squared	0.6467		0.754		0.7062	

Note: * and ** denote significance at 5% and 10% level, respectively.
SAR(Spatial Autoregressive Model), SEM(Spatial Error Model)
and SAC(Spatial General Model)

These results can be illustratively depicted in terms of a one-unit change in each of the independent variables¹⁰. From the mean residential sale value of \$175,800, the housing value depreciates by \$703 with each year of age. By adding one more bedroom, it increases the housing price by \$3,164, and one more bathroom is worth \$13,536 on average. One hundred square feet of living space is worth \$380, and adding one acre of lot size increases housing value by \$4,219¹¹.

As expected, the signs and significance levels differ by species and distances to livestock operations. In general, the number of existing livestock operations, not the size of those operations, contributes negatively to surrounding housing units. However, the number of beef cattle and dairy operations indicates significant positive impacts. Traditionally, there are many beef and dairy operations in this region, which may create more jobs and create higher housing prices. Potentially, more and smaller operations may generate relatively less concentrated odor impact than fewer larger operations for the same level of total inventory. People may associate small livestock operations as a positive amenity of rural lifestyles. However, as the size of the operation increases, the positive impacts disappear. The coefficient on the animal units per operation (BeefAU1) within a mile of the house shows a significant negative effect on housing prices. If one more unit (1,000 AU) of beef and dairy locates within a mile, housing values decrease by 1.4% (\$2,461). Beef and dairy operations within two miles (BeefAU2) are negative, but not significant. The operations within three miles (BeefAU3) are significant and negative,

¹⁰ The average housing value is \$175,796, and the coefficient is a relative change (% change) given a one unit change for a given independent variable. Therefore, $\$175,796 \times \text{coefficient}$ gives the dollar value of the coefficients.

¹¹The North Carolina study (Palmquist et, al) showed \$29 for one more square foot, \$7,500 for one more bathroom and \$3,000 for lot size, and the mean house value was \$73,132.

but the real dollar impact per 1,000AUs was small (\$352). Chicken operations within two miles have a positive effect, but larger operations within two miles decrease housing prices by 1.6% for each additional 1,000 AUs of chicken processing or growing added to the area.

The number of hog operations has the expected negative sign, but the impact is not statistically significant beyond two miles. However, the impact of hog operations within two miles reduces the housing value by 23% for each additional operation. The degree of negative impact from adding a sheep operation within two miles is more than 38%, while it remains high, at 24%, within three miles.

While beef and dairy operations are almost evenly distributed throughout the entire study area, most of the hog and sheep operations are located in the North side of the county (Figure 3); therefore, these results may pick up some strictly localized negative externalities. Also, the average number of operations is around 0.2 for both species, thus the actual monetary impact of these species maybe smaller than its coefficient because of the unlikely event that enough operations would be added to raise the average from 0.2 to 1.2 (a full unit change). It is further likely that these effects could vary by housing prices, as housing dynamics could differ by income levels, something that is addressed in the next section.

10.5 Results by Housing Prices

In this section, housing price ranges are used to separate the original variables by price levels to test different willingness to pay by income (Tables 10-2, 10-3 and 10-4). A housing price is not exactly income, but can be an appropriate proxy in some sense.

Because housing is one of the major purchases a family makes, the distribution of home purchases reflects to a reasonable degree the distribution of income, which is fortunate as the disaggregation of the data by locality and time does not permit conventional household income to be used. In essence, the autoregressive structure of nearby housing prices partly accounts for income variations in the willingness to pay model reported in this section, which are shown in Table 10-2.

Unlike the general model in the previous section, the lambda (λ), which is the coefficient of spatially correlated error of the SEM, was not statistically significant. Thus, neither the general model (SAC) nor the SEM models, with autocorrelated error terms, are reported here. The regression results are based on only the Spatial Autoregressive Model (SAR) in this result.

Traditionally, older and cheaper houses have been found in rural areas, but expensive new homes have been developed in the countryside in recent years. The effective age of the house in all three groups has a negative impact, but it is not significant in the medium group. The number of bathrooms and bathrooms seems to increase housing value regardless of the price, but the number of bedrooms within the low price group indicates a negative relationship with housing prices. The building and lot sizes still indicate a significant positive impact, but lot size is not significant within the medium group.

When lower income people live in rural areas, and close to a livestock operation, there may be a net negative or positive impact due to the odors versus jobs created by the operation. However, a number of small livestock operations may not have much of a negative effect, as they are seen as a rural amenity, until large operations locating nearby

cause excessive odor. The regression results in Table 10-2 support this idea, generally, but sufficiently to understand the relationship between the local housing market and livestock location.

The impact of beef and dairy operations is not clear for low price groups. The coefficients are negative within one mile (beef1), but not significant, and there is a positive effect within two and three miles, but these are not significant at three miles.

Table 10-2 Coefficients and Elasticity of SAR(Spatial Autoregressive Model) Model by Housing Sale Prices

Housing sale Price	<150,000 (1,137 observations)		>150,000 and <200,000 (1,193 observations)		>200,000 (824 observations)	
Variable	Coeffs	Elasticity	Coeffs	Elasticity	Coeffs	Elasticity
Const	4.7440		4.7440		4.7440	
yr	-0.0039*	-0.07172	-0.0002	-0.00185	-0.0026*	-0.01556
bed	-0.0166*	-0.04609	0.0253*	0.07597	0.0281*	0.09031
bat	0.0207*	0.03751	0.0214*	0.05033	0.0917*	0.25293
pox	-0.0115*	-0.01576	0.0008	0.00174	0.0007	0.00160
bdsz	0.00004*	0.05247	0.0001*	0.14013	0.0001*	0.25983
lotsz	0.0677*	0.01310	0.0006	0.00018	0.0378*	0.03559
beef1	-0.0004	-0.0038	0.0380*	0.0208	0.0618*	0.063
beef2	0.0244*	0.0287	0.0069	0.0025	0.0353*	0.029
beef3	0.0047	0.0115	0.0058	0.0109	0.0169*	0.027
beefAU1	0.0026	0.0010	-0.0103	-0.0028	-0.0350*	-0.012
beefAU2	-0.0059**	-0.0063	0.0019	0.0031	0.0048*	0.007
beefAU3	-0.0020*	-0.0068	-0.0008	-0.0018	-0.0003	-0.001
hog2	-0.0961*	-0.0918	0.0134	-0.0159	0.1628*	0.302
hog3	-0.0986*	-0.1154	0.0095	0.0137	0.2328*	0.158
hogAU2	0.1391*	0.0096	0.0174	0.0045	-0.2266*	-0.066
hogAU3	0.1489*	0.0217	-0.0157	-0.0025	-0.2176*	-0.023
chicken2	-0.0421	0.0018	0.0409***	0.0142	0.1188*	-0.034
chicken3	-0.0167*	0.0196	0.0089	-0.0024	0.0878*	0.024
chickenAU2	0.0015	0.0010	-0.0062	-0.0014	-0.0198*	-0.008
chickenAU3	0.0027	0.0009	-0.0002	0.00004	-0.0153*	-0.009
sheep2	0.0162	-0.0013	-0.0474	0.0569	-0.4783*	-0.454
sheep3	0.1253**	0.1071	-0.0238	-0.0234	-0.2518*	-0.146
sheepAU2	0.0021	0.0003	-0.0341	-0.0024	0.1551*	0.031
sheepAU3	-0.0626	-0.0074	0.0158	0.0030	0.0811*	0.011
Rho	0.0194	11.3587	0.0194	11.3587	0.0194	11.3587

Thus, beef and dairy appears to have little, or slightly positive, impacts on low priced homes. On the other hand, the coefficients for higher price groups indicate significant and positive effects at all distances, which may imply that small beef and dairy operations could create rural lifestyle amenities rather than odor disamenities. However, livestock operations are not an amenity as their size grows. For low income groups, an additional 1,000 AUs head of beef and dairy per operation within two miles causes a 0.59%, or a \$729 reduction, in mean housing value, while within three miles there is a 0.2% (or \$247 reduction), which shows the significant negative impact that decreases with distance.

Unexpectedly the effect was not significant within one mile¹². The impact was negative (within one mile and three miles) for medium price groups, but not significant. For the high price group, large operations within one mile have a significant negative impact. With an additional 1,000 AUs of beef or dairy per operation, housing price depreciates by 3.5% on average, which is a \$9,369 reduction from the mean housing value of \$267,700 for the high price group.

Hogs and chickens show similar patterns across all ranges of housing prices. Both species have a negative impact by the number of operations, but positive impacts by size of operation for the low price group. However, it is opposite in the high price group. For hogs, the number of operations within two and three miles has a negative impact in the low price group. Adding one more hog operation decreases housing values by 9.6% (\$11,877) within two miles and 9.8% (\$12,112) within three miles. One more additional chicken operation decreases housing value by 4.21% (\$5,203) within two miles, and

¹²The impact may be offset between the negative disamenity and employment impact within the one mile radius.

1.67% (\$2,064) within three miles in this housing price category. On the other hand, large hog and chicken operations have significant negative impact for the high price group, and especially for large hog operations. There is a 23% (\$58,894) decrease within two miles and 21% (\$56,217) within three miles as another 1,000 AUs of hogs are added per operation. The impact of an additional 1,000 AUs per chicken operation is relatively smaller than for hogs. Within two miles there is 1.98% (\$5,300) decrease in sale price and a 1.53% (\$4,095) decrease within three miles for the high price group. The positive impact of larger hog operations for the low price group may be driven by the employment effect. The impact of sheep operations is not consistent with other species. Generally, the impacts are not significant for the low price group, except the positive impact of the number of sheep operations within three miles. The number of sheep operations contributes negatively to high priced housing at both two miles and three miles. Only eight sheep operations were used in the analysis, so the results may not be reliable due to the lack of information.

While some of these amounts seem very large, it may be unrealistic to increase the average value by one more unit of operation. For example, if mean value is 0.1 (average number of hog operations within two miles), a 100% increase in mean value is only 0.2 operations. Therefore, a one unit increase may not be a realistic assumption, as it implies a 1,000 percent increase in the number of hog operations locating near houses in Weld County. Alternatively, elasticities provide a proportionate change based on the mean values in the dataset. The species density per operation is a ratio, which is AUs/Operation. Therefore, the calculation of the elasticities of the number of operations and animals per operation are the following:

The hedonic model is:

$$\ln(HP) = \beta_1 + \beta_2 HC + \beta_3 * Operation + \beta_4 (AUs / Operation) \quad (10.14)$$

Taking the derivatives of both sides of (10.14) and solving for the slope of the relation between the housing price (*HP*) and number of operations (*Operation*) yields

$$\begin{aligned} \frac{1}{HP} * \frac{\partial(HP)}{\partial(Operation)} &= \beta_3 - \beta_4 * \frac{(AUs)}{(Operation)^2}, \text{ so} \\ \frac{\partial(HP)}{\partial(Operation)} &= \beta_3 * (HP) - \beta_4 * \frac{(AUs * HP)}{(Operation)^2}. \end{aligned} \quad (10.15)$$

The elasticity of the number of operations thus becomes:

$$\begin{aligned} \frac{\partial(HP)}{\partial(Operation)} * \frac{(Operation)}{(HP)} &= [(\beta_3 * (HP) - \beta_4 \frac{(AUs * HP)}{(Operation)})] * \frac{(Operation)}{(HP)} \\ &= \beta_3 (Operation) - \beta_4 \frac{AUs}{Operation} \end{aligned} \quad (10.16)$$

Likewise, for the average size of operations (*AUs/Operation*), the steps are

$$\begin{aligned} \frac{\partial(\ln HP)}{\partial(AUs)} &= \frac{1}{HP} * \frac{\partial(HP)}{\partial(AUs)} = \beta_4 \frac{1}{Operation} \\ \frac{\partial(HP)}{\partial(AUs)} * \frac{(AUs)}{(HP)} &= (\beta_4 \frac{1}{Operation}) * \frac{(AUs)}{(HP)} \\ &= \beta_4 * \frac{(AUs)}{(Operation)} \end{aligned} \quad (10.17)$$

All the calculated elasticities are based on the mean values of Aus. The number of operations are reported in Table 10-2 and the negative dollar impact of the elasticities of significant variables are presented in Table 10-3. Table 10-2 indicates that the value of the medium price group is relatively uncorrelated with the surrounding livestock operations, thus the dollar impact is calculated only on the low and high price groups' housing values.

As we notice from the Table 10-2, the low price housing group has less negative impact from livestock operation odors than the high price housing group. The animal units of beef and dairy and the number of hog operations within two and three miles have a negative impact on low housing prices. For 1% increases in beef and dairy animal units per operation from mean values, there is a decrease in the low price housing value by 0.0063% (\$7.79) within two miles and 0.0068% (\$8.40) within three miles on average. The impact of the number of hog operations is much bigger than for beef and dairy operations.

Table 10-3 Housing Price Damages of the Low and High Income Group, Elasticities

Variables	less than \$150,000 Mean HP = \$123,585			over \$200,000 Mean HP = \$267,704		
	elasticity	mean	\$impact	elasticity	mean	\$impact
BeefAU1	-	-	-	-0.012	0.3412	-32.12
BeefAU2	-0.0063	1.066	-7.79	-	-	-
BeefAU3	-0.0068	3.307	-8.40	-	-	-
hog2	-0.0918	0.119	-113.45	-	-	-
hog3	-0.1154	0.236	-142.62	-	-	-
HogAU2	-	-	-	-0.066	0.2895	-176.7
HogAU3	-	-	-	-0.023	0.1058	-61.6
Chicken2	-	-	-	-0.034	0.3919	-91.0
ChickenAU2	-	-	-	-0.008	0.0752	-21.42
ChickenAU3	-	-	-	-0.009	0.0934	-24.09
sheep2	-	-	-	-0.454	0.0752	-1,215.38
sheep3	-	-	-	-0.146	0.0934	-390.85

A 1% increase in hog operations from its mean¹³ decreases housing prices by 0.0918% (\$113.45) within two miles and 0.11% (\$142.62) within three miles. Contrary to expectations, the impacts by distance to the operation do not decrease for the low price group.

The negative impact by distance on the high price group is clearer than for the low price group. Each housing unit has 341 AUs per beef and dairy operation within one mile on average. The 1% increase from its mean reduces the high price group's housing value by 0.012% (\$32.12). It also means that there is \$26,466¹⁴ total reduction of housing value to society due to the 1% increment. The impact of beef and dairy operations outside of one mile away was not significant. The larger the size of hog operations within two miles, the higher the impact, and it is more than five times greater than beef and dairy. With a 1% increment of AUs per operation from its mean, high end rural residential real estate values decrease by 0.066% (\$176.7). A detectible impact remains at two miles, decreasing values by 0.023% (\$61.6).

The number of chicken operations within two miles decreases housing values by 0.034% with a 1% increase from the mean, but again there is no significant impact after two miles. The impact of chicken AUs per operation does not show a decreasing trend over three miles. Rather, the effect is quite similar over the measured distance, measuring 0.008% (\$21.42) and 0.009% (\$24.09) within the two and three miles distance,

¹³ The total number of low price housing units is 1,337 and mean hog operations within two miles is 0.119 per housing unit. Thus, there are approximately 135 houses that have a hog operation within two miles. Unfortunately, it is not possible to infer how many operations will be added with a 1% increase from the mean. If an operation is going to locate in a high density residential area, the mean of number of operations within a certain distance will be higher than that of low density housing area.

¹⁴ \$32.12 reduction for each house of high price group and the total number of houses is 824.

respectively. The number of sheep operations within two miles has the highest negative impact, 0.45% (\$1,215.38), decreasing to 0.14% (\$390) within three miles.

CHAPTER 11

CONCLUDING REMARKS AND FUTURE DIRECTIONS

As one of the fastest growing regions in Colorado, Weld County residents can expect new housing development and new people in their communities and rural areas. The livestock industry is one of the major sectors in the county economy, but odor associated disamenities may reduce the positive economic impact of the industry by reducing the value of the real estate sector or damaging the quality of life in the county. This externality is a social cost of regional development, and the level of cost will go up with more population density. As Palmquist et al. (1997) noted, future growth and development of the livestock industry depends on the successful resolution of these competing concerns. Hedonic technique allows us to quantify the monetary impacts of livestock industry on surrounding property values. I quantified the property price impact of 199 livestock operations for 3,355 housing sales from 1999 to 2001 in Weld County. All the spatial information was formulated using Geographical Information System facilitating spatial analytical techniques as well as eventual simulations and policy analyses using the results of this analysis.

The distinguishing methodology of this analysis is using spatial econometric model supported by GIS mapping. By GIS mapping it was possible to capture all livestock operation and exact distances from every single housing unit and distance between the housing units. The housing market is locationally correlated and

incorporating spatial information can give us more reliable and unbiased results in the analysis. The results of the spatial model showed that housing prices have significant spatial correlation with nearby residences. Therefore, spatial models need to be considered when we deal with local housing markets.

From the results of the general model, the numbers of operations of beef and dairy, which are the traditional agricultural sector, seem to create a positive rural lifestyle amenity effect. People are willing to pay to locate in the countryside with small livestock operations. However, the net impact of livestock operations on rural residential sales turns to negative if the operation is over a certain size, especially within one mile. As Rabotyagov (2002) noted there is a threshold at which “enough is enough,” so people seem willing to pay less for the residential property because of the odor and other potential disamenities of beef and dairy operations. More hog and sheep operations contribute negatively to property values. The national debate and controversy about hog operations is well known and has now been documented in two published works from North Carolina. The chicken industry shows mixed impacts with the number of operation and size of the industry.

The regression results, based on the housing prices (as a proxy for income), gives slightly different housing demand patterns. Generally speaking, the cheaper the house, the more negative the impact of another operation, and the higher the housing value, the more negative the impact of greater animal inventories. There is decreasing impact by increasing distance from the housing units to the operations. However, the number of livestock operations shows significant positive impacts to the high price group’s housing value. The dollar impact of large hog operations was highest, except for sheep.

It is not easy to detect the interaction and relationship between the housing market and the location of the livestock industry. The results were not fully consistent with the hypotheses, even though several of interesting features have found. In spite of increasing public concern about the potential externalities by the livestock industry, Weld County is not a hot spot as much as North Carolina, and the accuracy of available data is a concern. For example, the number and size of the livestock operations in Weld County published in the National Agricultural Census, the state office of the EPA and the County Assessor's office do not match. Furthermore, it is not certain whether operation are currently in existence and how many and what kind of species are there. Improved results may be found with more accurate livestock sector information.

From a policy perspective, it is important to know the marginal impact a new operation might have. It would be worthwhile to estimate the marginal impact of additional animal units of a particular species in a specific area. Clearly, it would be of use to explore the fiscal impacts of odor mitigation technologies or of different residential development options as well. Although it is not currently possible to simulate these potential effects, future analysis should be conducted with such goals in mind.

In sum, I could not derive perfect information on the impact of animal odor on residential property values due to a number of limitations. However, the results provide enough information to understand the potential social cost of the livestock sector in the region. Policy makers may incorporate this social cost in the regional planning to minimize the social and maximize the development effect. Due to the accumulated effects of the animal manure odor, the higher the population density, the higher the social cost of the animal operation and possible this impact differs by species. Moreover, the

efficacy of odor mitigating technologies and local policies could be evaluated relative to anticipated tax revenue collection increases from their adoption. Therefore, local officials and private individuals should carefully consider the location and characteristics of new residential properties and animal operations alike.

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- Weld County GIS and Mapping's Office. <http://www.co.weld.co.us/departments/gis.html>**

APPENDIX A

Matlab Function of SAR, SEM and SAC Model

```
% Dooho Park July.19.2002
% using x,y cordinance

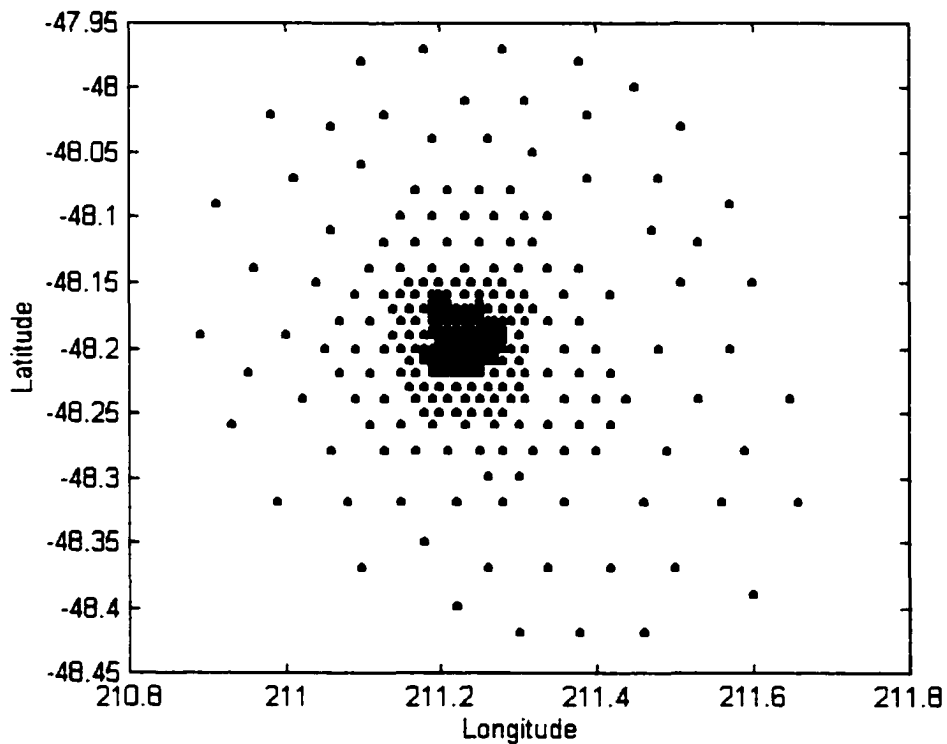
y = log(data(:,3));
x1 = data(:,4);
x2 = data(:,5);
x3 = data(:,6);
x4 = data(:,7);
x5 = data(:,8);
x6 = data(:,9);
x7 = data(:,10);
x8 = data(:,11);
x9 = data(:,12);
•
•
•
latt = data(:,1);
long = data(:,2);
n = length(y); x = [ones(n,1) x1 x2 x3 x4 x5 x6 x7 x8 x9 x10 x11 x12 x13 x14 x15 x16
    x17 x18 x19 x20 x21 x22 x23 x24 x25 x26 x27 x28 x29 x30 x31 x32 x33 x34 x35
    x36 x37 x38 x39 x40 x41 x42 x43 x44 x45 x46 x47 x48 x49 x50 x51 x52 x53 x54
    x55 x56 x57 x58 x59 x60 x61 x62 x63 x64 x65 x66 x67 x68 x69 x70 x71 x72];
clear x1; clear x2; clear x3; clear x4; clear x5; clear x6; clear x7; clear x8; •••••
clear data;
n = 3354;
[junk w junk] = xy2cont(latt,long);
w2 = make_nnw(latt,long,1);
vnames = strvcats
    ('hp','const','yr','bed','bat','pox','bdsizes','lotsizes','bf1','bf2','bf3','bpf1','bpf2','bpf3','hf
    2','hf3','hpf2','hpf3','cf2','cf3','cpf2','cpf3','sf2','sf3','spf2','spf3','bf1(<200)','bf1(>20
    0)','bf2(<200)','bf2(>200)','bf3(<200)','bf3(>200)','bpf1(<200)','bpf1(>200)','bpf2(
    <200)','bpf2(>200)','bpf3(<200)','bpf3(>200)','hf2(<200)','hf2(>200)','hf3(<200)',
    'hf3(>200)','hpf2(<200)','hpf2(>200)','hpf3(<200)','hpf3(>200)','cf2(<200)',
    'cf2(>200)','cf3(<200)','cf3(>200)','cpf2(<200)','cpf2(>200)','cpf3(<200)',
    'cpf3(>200)','sf2(<200)','sf2(>200)','sf3(<200)','sf3(>200)','spf2(<200)',
    'spf2(>200)','spf3(<200)','spf3(>200)');
info.lflag = 1;
```

```
% SAR (Spatial Autoregressive Model)  
res = sar(y,x,w, info)  
% SEM (Spatial Error Model)  
res = sem(y,x,w, info)  
% SAC (General Spatial Model)  
res = sac(y,x,w,w2,info);  
prt(res,vnames);
```

APPENDIX B

Construct “W” Matrix by Delaunay Triangulation Method in Matlab¹⁵

Phase 1



Given a set of data points, the Delaunay Triangulation produces a set of lines connecting each point to its natural neighbors.

In this example, we use data from an underwater mountain to create a 3-D image of the mountain in MATLAB and then estimate its volume and surface area.

¹⁵ <http://www.mathworks.com/products/demos/matlab/triang/tri1.html>.

Slide 1

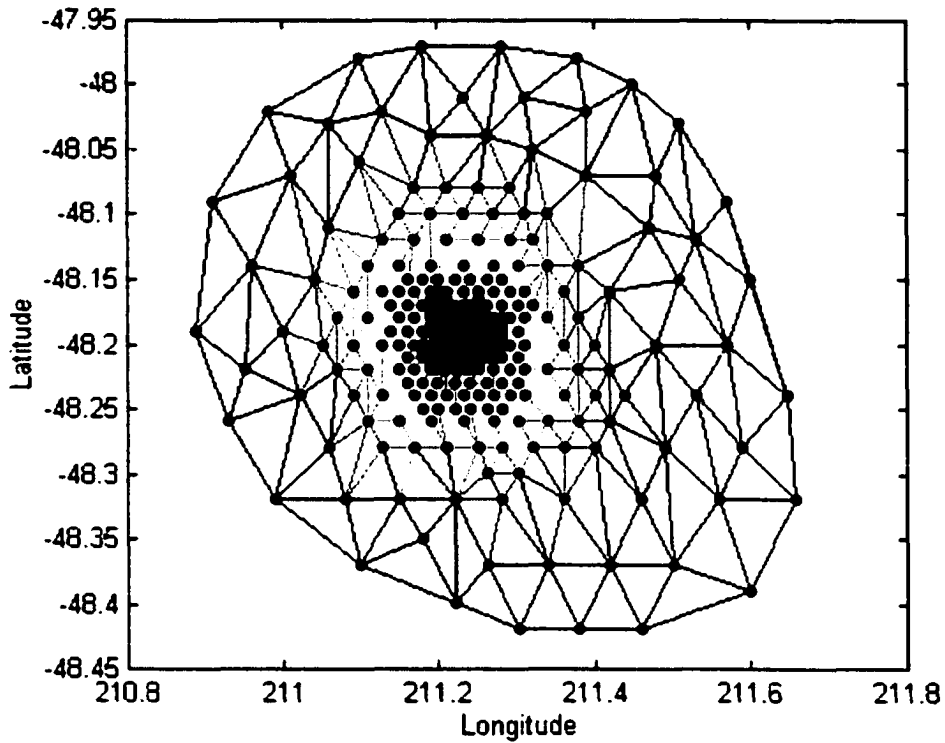
Next >>

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Reset

Exit

Phase 2



Here, the Delaunay and Trimesh functions create an image of the mountain viewed from the top.

```
tri = delaunay(x,y);  
trimesh(tri, x, y, z);  
view(0,90);
```

Slide 2

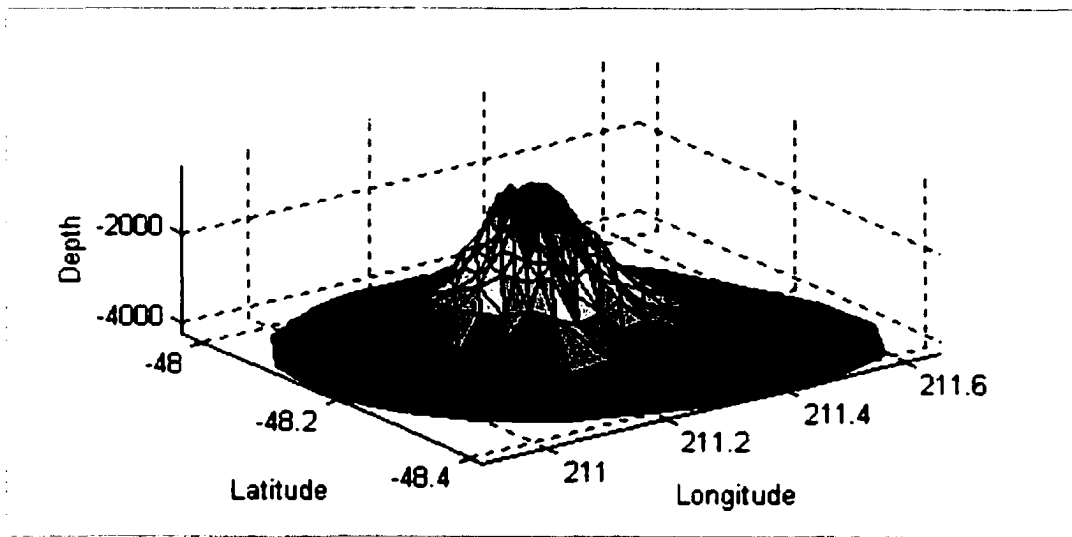
Next >>

Prev <<

Reset

Exit

Phase 3



To get a 3 dimensional view of the mountain, we use the trisurf function:
`trisurf(tri, x, y, z);`

Slide 3

Next >>

Prev <<

Reset

Exit