Consolidation in the Meat Sector

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Slaughter industries are consolidating, as the number of firms falls and plant sizes grow. Related changes are occurring in upstream livestock production sectors: large cattle feedlots and hog farms account for sharply growing shares of livestock sales. As in poultry, new contractual relationships have begun to replace spot market cash transactions for cattle and for hogs. Those sharp structural changes have raised concerns about market power, pollution control, and the reliability of traditional price reporting sources. This is a research conference, aimed at encouraging evaluation and discussion of research methods, data sources, and results.

Topics covered at the conference include the following:

* The existence, extent, and effects of market power in livestock and meat industries; Causal factors in consolidation, such as scale and scope economies, mergers, changes in product mix, innovation, and changes in contractual relations;

* Vertical coordination, as compared to spot markets for transferring livestock, including summaries of recent developments and implications for location, for product characteristics, and for price discovery;

* Externalities associated with consolidation, including the effects of larger animal production facilities on pollution and the effects of local control regulations on consolidation.

Analysis of Swine Industry Expansion in the US: The Effect of Environmental Regulation*

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Abstract

Along with the industrialization process in the U.S. swine industry, environmental degradation has become a concern. As a result, new laws and regulations have been created to address animal waste problems in the swine industry and other livestock sectors. This research investigated the relationship between the stringency of state environmental rules and recent change in the swine industry. Specifically, it examined the hypothesis that the stringency of environmental rules influences the growth rate of hog inventories across states. Thirteen states were included in the analysis covering the 1988/89-1994/95 period. Four categories of independent variables, including a state's natural endowment, economic factors, business climate and regulations, were used to explain the growth or decline in hog inventories. A variance component model was used.

From an overall standpoint, the analytical results did not strongly support the hypothesis that the stringency of environmental regulations impacted hog sector growth. Five variables measuring the stringency of environmental regulations and their enforcement were used to test this hypothesis. These included two established general environmental regulation indices; three new variables specific to animal waste regulations were obtained through surveys. An interesting result is that the existence of the capability of local governments within a state to regulate livestock operations through their zoning powers appears to have impacted hog industry growth. States with local governments actively involved in regulating hog farming have made their regulatory environments less uniform and perhaps unstable, possibly discouraging operators' investment in the hog business.

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Charles W. Abdalla and Yin Mo[1]

Introduction

The hog industry is a major value-added sector in the US agricultural economy. The industrialization process in the livestock industry have been noted and discussed since the early 1960's (Breimyer, 1962). These processes have had major implications for swine production and marketing, including a dramatic decline in hog farm numbers and increases in farm size, over the past two decades. As pork production is concentrating in the hands of fewer, larger producers and processors, hog farmers and pork marketers are developing closer ties, forming a more integrated industry from the farm to the supermarket. Factors driving these changes include: new technologies (e.g., improved genetics and Multiple-Site Rearing), demand of more discriminating consumers, improved information flow between consumers, and producers via market structure change (Hurt, 1994; Barkema and Cook, 1993).

Along with the technological and institutional change, the swine industry has become less tied to natural resources than in the past. Agriculture was classified as a material-oriented industry, in that it was believed to be bound to the location of the basic natural resources upon which it depended, such as land or feed. An industry can be classified as truly material-oriented only when its savings in transfer costs outweigh the possible cost advantages of other sites (Barlowe, 1978). This helps explain why animal rearing has been closely linked to feed crop production. Since the transportation cost of feed from a feed crop growing area was high, it limited the development of the livestock industry in those areas where cheap sources of feed were not available.

Technological and institutional innovation in the livestock industry have changed this view of agriculture as material-dependent. Improvements in genetics and better management practices have aided the hog industry in reducing feed conversion ratios and death losses. The decrease of feed conversion ratios reduced the feed cost of finishing per hog. In addition, declining transportation costs as well as improvements in transportation service enabled the hog industry move away from the vicinity of relatively cheap sources of feed. Thus the importance of transportation cost of feed in the total cost became less important. The cost of transporting finished products to final markets

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increased in its role as a component of total costs. The emerging patterns of hog production in Utah led Bailey et al. (1993: 10) to conclude that " the decision as to where to locate new pork and poultry complexes in the future likely will be driven more by final market location and environmental issues than by location of available feed sources."

Economies of scale obtained by technological and organizational innovation in the swine industry have contributed to the per-unit production cost reduction. Such achievements can offset the disadvantage of a location which lacks natural resources, and thus the swine industry has become less tied to natural resources than in the past. Changes in the hog-pork sector brought to the Midwest a decline in their traditional comparative advantage in hog production. As Hurt (1994:12) notes, "The Midwest can no longer rely on its natural resource base... for industry location. Integrated firms are large enough now to provide all of their own support and can take their systems where they will be allowed to operate." As a result, new issues, such as where to expand or locate their operations, have become important to the future of the modern swine industry.

The changes in the swine industry have brought about not only benefits to society, such as low-cost pork products, but also new conflicts and concerns. The hog industry has been marked by some critics as a "dirty" industry since large confined hog facilities became the model for the industry in the 1990s. Citizens' concern over water quality and potential property value decline due to odors from hog facilities comes from the production process associated with the modern hog industry. Since a large number of hogs are raised in confinement operations, large volumes of manure are generated, stored in lagoons and spread on nearby farm fields. Over application of manure and spills from storage lagoons have degraded surface and groundwater and resulted in loss of fish and other ecological resources.

Environmental regulations have been enacted at the state and local level to reduce environmental damages from the rapid growth of livestock industries. Since there are differences in these regulatory programs, these differences may have influenced the growth of the hog industry across states, possibly leading over time to regional shifts in the location of the industry.

Industrial location issues are quite complicated. No factor can uniquely determine where hog farms locate. In addition to regulatory factors (e.g., environmental regulation), which possibly influenced where hog industry located, other factors are also important, or maybe critical in explaining where hog industry located. Such factors may be categorized into natural endowment, economic and business climate. The natural endowment factors attempt to capture states' differences in natural conditions that affect suitability for hog production. Economic factors, such as feed price and slaughtering capacity influence the profitability of doing business in a specific state. Business climate, which reflect whether hog industry is welcomed by the local communities, can affect hog farm's potential operating cost and strategy of expansion in the long run.

Although many factors may have influenced where hog industry located, major interest of this study is to investigate the impact of regulatory factors, especially, the environmental regulations on the location of hog industry. There is some anecdotal evidence supporting the hypothesis that the stringency of state environmental regulations influences firms' location choices. The evidence does indicate, at a minimum, that some large livestock producers or integrators have taken into account environmental regulations when making expansion or location decisions (Bacon 1993; Smith and Kuch, 1995)

Some academic researchers have concluded that differences in local and state institutions and policies for water quality and other relevant laws and local ordinances are exerting influence on the location of swine production. For instance, Hurt and Zering (1993) listed environmental and regulatory factors as one of the key factors explaining the boom in North Carolina's swine industry. However, the lack of systematic analysis has made it difficult for definitive conclusions about this relationship to be drawn. The intent of this study was to fill this gap in knowledge.

Who Should Regulate Animal Production Facilities?

This study's relevance lies not only in its potential to explain the role of environmental regulations on hog production growth patterns, but also in its possible implications for environmental policy design and implementation. There has been a long standing debate in the U.S. over the questions of whether federalism is an efficient way to achieve pollution abatement goals. The question of the appropriate division of responsibilities between national and local authorities has been a policy issue since the federal government placed much more emphasis upon pollution control in the early 1970s.

Agricultural pollution is regulated on two levels. Part of agriculture, such as large feedlots whose pollution is defined as point source pollution, is primarily regulated by the federal government. Most other agricultural operations are still within the scope of nonpoint sources and thus their pollution is primarily under control by the states (Malik, et al. 1992; Greenfield, 1985). Even for the first type of regulation, states generally have the authority to implement federal standards. As Greenfield (1985) pointed out, the actual administration of water quality standards for point sources has been left to the states, who are in turn free to impose stricter point source controls than those promulgated by U.S. Environmental Protection Agency (EPA). As it turned out, state governments have taken advantage of this flexibility and have much discretion in implementing federal environmental rules. Since only general guidelines exist on the federal level, each state interprets and implements these guidelines differently. In particular, it is not uncommon to find that state responses to federal regulatory guidelines are not dictated solely by environmental concerns (Smith and Kuch, 1995).

Economists and policy-makers who support a decentralized approach believe that such an approach could bring economic efficiency. They argue that decision makers at

lower levels are more likely to make policy choices consistent with the collective preferences of the affected group (Shortle, 1996). Therefore, decentralized policy making can allow local costs and benefits to be reflected in the decision process more accurately.

However, since policy makers at lower government levels have to take into account the collective preferences, it is not uncommon that environmental laws made at such levels serve purposes other than protecting the environment efficiently. For example, in the evaluation of the current decentralized approach of regulating the livestock industry, Smith and Kuch (1995) argued that only when the variation among states' implementation of federal guidelines is solely attributable to the unique environmental problems or needs of their own can the interstate patterns of livestock industry location reflect efficiently to environmental protection goals. Given that many factors[2] other than the states' environmental problems or needs affect how states translate federal guidelines and enforce the regulations, Smith and Kuch concluded that current patterns of interstate concentration in animal agriculture do not suggest economic efficiency in environmental protection.

Another important argument which is against a decentralized approach is the possibility of interjurisdictional competition through different environmental standards. The fear is that local officials would set less stringent environmental standards than necessary in order to attract business and jobs. For example, Cumberland (1979, 1981) argued that national minimum standards for environmental quality are needed to avert 'destructive interregional competition,' since state or local authorities are likely to compete with one another in terms of reducing standards for environmental quality so as to reduce the costs for prospective business enterprises. The underlying argument is that decentralized jurisdictions, if left to their own, will fail to select the optimal standards (Oates, 1990).

However, interjurisdictional competition may result in the goal of efficiency in environmental protection not being met. If firms react to differences in environmental laws in such a way that they shift to areas where less stringent rules exist rather than modifying their operations within the jurisdiction, even greater net environmental damages may result from the change. This may happen since the locations into which firms move may have less appropriate physical conditions or greater nutrient surpluses than locations from which firms move (Abdalla et al., 1995). Given the mobility of current livestock facilities, the decentralized approach may cause a regional shift resulting in net environmental damages.

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[2] Other factors which result in the states' discretion in environmental laws regulating livestock industry include how people value the severity of their pollution problems, the financial capability of a state to enforce the laws, the administrative and legislative structures of state governments and partisanship in a state. In addition, a state's environmental regulatory response to livestock industry can be affected by issues of agricultural industrialization and rural development. The advocates of the traditional family farm structure may use environmental regulation to protect agriculture from industrialization (Smith and Kuch, 1995).

It is not sufficient to evaluate the decentralized regulatory process and its alternatives only via casual observation or theoretical deduction. Systematic empirical studies are needed. If researchers and policy analysts better understood the relation between the location of animal agriculture and the stringency of environmental regulations, they could more definitively assess the performance of the current decentralized regulatory system and determine if changes in the current institutional arrangements are needed.

Previous Research

Many studies have explored whether the stringency of environmental regulations affects firms' location decisions. However, almost all research has limited its focus to the manufacturing sector. None of the existing studies that focus on environmental regulations address the agricultural production sector. Relatively later previous research has been conducted on the topic for agribusiness or animal agriculture.

Empirical results from manufacturing studies do not suggest strong negative effects of environmental regulation on industry growth and local economic development. These studies take two basic forms: surveys of manufacturing executives regarding the type of factors they consider in plant location (Schmenner, 1982; Epping, 1986 and Stafford, 1985), and statistical analyses of state characteristics presumed to affect firm location (Leitner 1974; Healy 1979; Bartik 1988,1989; Duffy-Deno 1992; Crandall 1993; McConnell and Schwab1990; Levinson 1996a and Gray 1995).

Despite the theoretical intuition and the "conventional wisdom" supporting a linkage between state environmental policies and firm location decisions, most empirical studies to date, including both survey and analysis of secondary data, have found only weak and insignificant effects for manufacturing as a whole (Levinson, 1996a). In some studies (Leitner 1974; Bartik 1988 and Gray 1995), significant results were found in certain high-pollution industries but the magnitude of this relationship was small. Only one study (Gray, 1995) found a strong significant effect of the stringency of environmental regulation. Definitive conclusions about the effects of environmental regulations on the manufacturing sector await the completion of further research.

Research on the potential effect of environmental policies upon growth and location of farming and related businesses has been limited. Lopez and Henderson (1989) used telephone interviews with food processing executives in five Northeast states to identify factors affecting locational choices for their plants. Vesecky and Lins (1995) surveyed Illinois agribusiness decision-makers about factors affecting expansion and contraction. Findings from both studies suggest that state environmental policies and their enforcement appear to influence decisions of agribusiness to grow or contract and to locate their operations.

In a recent survey of U.S. large hog producers (Grimes and Rhodes, 1995), it was found that 44% of the large hog producers in the U.S. considered meeting environmental

rules and local opposition (which are often connected with environmental issues) as the limitations on their expansion. The concerns were found to differ by region. However, whether this difference was related to the stringency of environmental regulation was not analyzed.

Survey results and most empirical analyses of secondary data in manufacturing do not indicate a strong negative effects of environmental regulation on industry growth and local economic development. However, the empirical studies conducted thus far are too dissimilar to provide for a consensus among researchers about this relationship. It also has to be kept in mind that survey results may be not reliable since what people say can be different from what they actually do (Levinson, 1996b). In addition, since a few recent studies did find the presumed effect of environmental regulation, it encourages further studies in this area. Also, since little empirical work has been conducted thus far to investigate the effect of environmental regulation in agriculture, additional analysis of the agricultural production sector is warranted.

Data Collection and Analysis

To investigate the relationship between the stringency of the state's environmental regulations and hog industry's location or expansion decisions, an aggregate analysis[3] was conducted. Specifically, the dependent variable was the growth rate of hog inventory over the 1988/89-1994/95 period. A total of 16 independent variables were included in the analysis. Most were obtained from secondary data sources. A mail survey was used to obtain the data measuring the stringency of states' environmental regulations. A variance component regression model was used to investigate the proposed relationship.

The null hypothesis is that the stringency of state environmental regulations does not influence the growth rate of hog inventory across states. Accordingly, the alternative hypothesis is that the stringency of state environmental regulations influences the growth rate of hog inventory across states. If the null hypothesis can be rejected and the alternative hypothesis can be accepted, it is expected that the more stringent the state environmental regulations are, the lower will be the rate of growth in a state's hog inventory. The analysis covers the period 1988-1994 and 13 major hog producing states[4] (Table 1).

Four categories of independent variables were included in the analysis: Natural Endowment, Economic Factors, Business Climate and Regulation Factors. The natural endowment factors are intended to capture the difference of natural conditions across states. The general economic factors take into account the profitability of doing business

[3] Aggregate analyses are those that investigate general economic activity such as employment growth to detect the effects of stringency of environmental regulations.

[4] Sixteen major hog producing states were initially slated for inclusion in the analysis. However, due to difficulties in acquiring data from three states, 13 states were included in the final analysis.

in a specific state. The business climate factors investigate attempt to determine whether hog producers are welcomed by people from potential locations. The last category, regulatory, is the main interest of this research. Four types of regulations are included. These are general taxation policy, general environmental regulations, states' environmental laws that regulate animal wastes and their enforcement, and other state laws or local ordinances that may impact livestock operation. (See Table 2 for a list of variables.)

Data for the last two categories (Business Climate and Regulations) were more difficult to obtain than the other categories. This is particular true for the regulatory factors. No existing source of systematic and quantitative data describing variation in environmental laws that regulate livestock operations in the 1988-1994 period was found. Therefore, primary data were collected to represent the effect of this variable. Multicollinearity checks were completed before variables were included in the final model. Several variables were excluded from the analysis based on high correlations.

Precipitation (*Precipt*) was included as a measure of differences in a state's climate and as a proxy for environmental vulnerability[5]. It is expected that if a state receives more precipitation, its hog inventory growth will be lower due to added difficulties in manure management.

The category of "general economic factors" includes 7 variables, all of which are in real terms (consumer price index, 1982-84=100 is used as a deflator). The price of the commodity, major production costs and agglomeration effects[6] were taken into account. The percentage of hog farms with hog inventory over 1000 heads (*Hogper*) was included as a proxy for economies of scale. This variable is expected to have a positive effect on hog inventory growth. Hog and corn prices were combined in one variable -- hog/corn price ratio (*Hcratio*)--to estimate the price effect. It is expected to have a positive influence upon hog inventory growth. Land value (*Landval*) was included to represent the cost of acquiring or renting land for production or manure disposal. The expected sign of this variable is negative.

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[5] Environmental vulnerability, in general, refers to the vulnerability of the environment to degradation by hog production. It is defined here to represent the degree to which the problem of manure leaching into the ground and surface water in a state could be. Other efforts have been made to measure it but were not included in the final estimated model presented (Interesting readers can find more details in Mo, 1997).

[6] Both industrial location theory and business location studies suggest that firms take into account the developmental level of the industry in which they exist when searching for a location. Since a well-developed industry usually indicates better infrastructure and service on the industry level, the individual firms may benefit from locating closely with other firms.

Table 1 Descriptive Statistics of Hog Inventory Growth in 13 States

State	Hog inventory (1000 head)		Inventory Growth (%)		Inventory Growth from 1994-95 (%)
	Mean	Std Dev.	Mean	Std Dev.	
IL	5562	330	-1.79	4.56	-7.8
IN	4394	150	-0.41	4.76	-0.7
IA	14387	574	0.47	4.17	-8.4
KS	1404	91	-2.54	3.4	-4.6
KY	904	102	-4.17	5.52	2.6
MI	1245	45	-1.10	4.15	-8.0
MN	4736	200	1.16	4.77	4.1
NE	4313	171	-0.07	4.29	18.6
NC	4615	2137	18.00	12.41	-5.7
OH	1906	188	-2.33	6.73	2.8
PA	994	61	1.14	5.73	-4.6
SD	1759	127	-2.41	7.59	-13.8
WI	1144	109	-4.24	6.38	-10.6

The unemployment rate of the state (*Unemp*) is intended to measure the availability of labor. It is expected that the higher the unemployment rate, the easier it is for the hog business to find labor and, hence, the higher the growth rate of hog inventories. State slaughtering capacity is also believed to influence hog production. The number of commercial hogs slaughtered (*Slaught*) in each state was used to represent slaughtering capacity. It is expected that as the number of hogs slaughtered in a state increases, the demand for live hogs becomes greater, and thus the possibility for expansion in a state's production also increases[7]. The last economic variable is hog density, which is the hog inventory lagged one period divided by land area in each state (*Exist*). It is intended to measure "agglomeration effects" and is expected to have a positive effect on hog inventory growth. Data were obtained from the U.S. Department of Agriculture National Agricultural Statistics Service (USDA-NASS) for all variables except for the Unemployment Rate (*Unemp*), which was obtained from the U.S. Census Bureau.

As mentioned above, the business climate and regulation categories have fewer data sources than the other two categories. Several variables were initially selected to approximate business climate. These variables are proportion of rural population in the total population (*Rupop*), the population density in the nonmetropolitan area (*Rpopden*), and share of income from agriculture in a state's total income (*Ash*). Due to the problem of multicollinearity, only *Rupop* was included in the final analysis. Since rural people are familiar with farming practices, they are believed to be more tolerant of the unpleasant side effects of farming (e.g., odor from animal manure). Therefore, it is expected that the higher the percentage of rural population, the higher will be the growth rate of hog inventories. Data from the 1990 U.S. census were used for all 7 years since no annual data were available.

Substantial efforts have been devoted to measuring the effects of public policies upon business growth and industrial firm location. The stringency of taxation policy was measured by the property tax per acre of farm land (*Proptx*). It is expected to have a negative impact on hog inventory growth.

To measure the stringency of general environmental regulations, two established indices were initially used. These included: the Green index (*Green*) and Lester classification (*Lester*). Green index[8] is a comprehensive index which includes a ranking

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[7] One might argue that the slaughtering capacity within a state may not have a large influence over hog production if transportation costs are relatively low. Hog producers may slaughter their hogs in other states with surplus slaughtering capacity.

[8] The 1991-1992 Green index, which was built by Hall and Kerr (1991/92), used more than 200 indicators to rank the environmental conditions across different states. One important component of their index is "Green Policies", under which the status of 67 environmental regulations or policies in each state was evaluated, the spending for environmental programs was ranked and the leadership of pro-environment

Table 2 List of Variables

Variable	Unit	Abbreviation	Data Sources
Inventory Growth		Invengro	NASS, USDA
Percentage of hog inventory >1000		Hogper	NASS, USDA
Hog-Corn Price Ratio		Hcratio	NASS, USDA
Unemployment Rate		Unemp	Census Bureau
Slaughtering Capacity	lbs	Slaught	NASS,USDA
Land value	$/acre	Landval	NASS, USDA
Existing Hog Inventory/land area	head/ acre	Exist	NASS, USDA
Annual Average Precipitation		Precipt	NASS, USDA
Property Tax	$/acre	Proptx	NASS, USDA
Percentage of Rural Population		Rupop	Census Bureau
Population Density in Rural Area	people/ sqki	Rpopden	Census Bureau
Share of State Income From Agriculture		Ash	NASS, USDA
Stringency of Regulation		Regula	Survey
Average Amount of Fines Imposed	$	Levfine	Survey
Staffing Levels		Staff	Survey
Anti-corporate Farming Law		Corpo	Survey
Local Zoning Ordinances		Zoning	Survey

forces in U.S. Congress was counted. Therefore, 77 indicators were used to rank the stringency of general environmental regulation across states.

of the stringency of general environmental regulation across states. States with less stringent environmental regulations receive higher ranks in the Green index. Lester (1990) divided all of the 50 states into four categories after taking into account each state's commitment to environmental protection activities and its institutional capabilities. To utilize the indices, each state was ranked based on the category they were grouped in by the index. States with lower ranks had more stringent environmental regulations. Thus, both the Green index and the Lester index are expected to have positive signs.

Although the Green index and the Lester classification measure the stringency of a state's overall environmental regulations, they do not focus on regulations related to agriculture or specific to the livestock industry. Therefore, these indices do not accurately measure a state's regulatory environment for hog producers. Livestock operations, especially confined animal operations, are generally regulated through a state's animal waste management program.

In order to measure the stringency of each state program in terms of its impact on hog facilities' operation and cost, three mail surveys were conducted. The final analysis used two surveys[9]. One mail survey asked several highly recommended experts who have knowledge of multiple states' regulatory programs to evaluate the stringency of the 16 hog producing states' programs. Each of these experts was asked to give scores to the state programs in the 1987-1994 period[10], using a 0-10 scale. Seven questionnaires were sent out to two attorneys, one reporter for a leading swine industry trade publication, one environmental expert for a national swine industry trade association, two consulting agricultural engineers and one consulting veterinarian. Six of the experts responded to the survey. However, only one industry expert representing a national livestock trade association, one reporter for a trade journal, and one agricultural engineer were able to give the scores to most or all of the 16 states. The average scores of these states were calculated based on these three experts' opinion. These scores (*Regula*) were used to measure the stringency of states' animal waste programs. This variable is expected to have a negative sign, since the higher the score, the greater impact the program had on hog facilities and the lower growth rate the state had in the study period.

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[9] The third survey was sent to the agricultural engineers. The initial plan was to combine the survey results of agricultural engineers with those of the regulators. Weaknesses in the design of the survey to the ag engineers, including not allowing for a multi-period response, led to responses that could not be effectively combined with the results of the two surveys. Therefore, we did not use the results of the ag engineers' survey in the statistical analysis.

[10] In the survey, each expert was asked to give scores to the 1987-88, 1989-90, 1991-92, 1993-94 periods. Therefore, it was assumed that the programs did not change within each of these two-year periods. This was done to simplify the ranking process for the respondent.

Not only the environmental regulations "on paper" affect hog facilities' operation and cost, how these regulations are enforced are also important. Therefore, another survey was sent to state regulators to obtain the enforcement information[11]. Two variables measuring enforcement capabilities and penalties were included. Specifically, annual staffing level (*Staff*, measured by "full-time employee equivalent") devoted to state animal waste control programs was used to represent the enforcement efforts. The "penalties" was measured by "average amount of fines imposed annually" (*Levfine*). These two measurements are both expected to have negative signs.

In addition to the animal waste management program, measures of two other types of state laws believed to influence hog facilities' expansion were also included. These are the anti-corporate farming laws (*Corpo*) and local zoning ordinances (*Zoning*). They are measured by two dummy variables separately. States enacting anti-corporate farming laws are given "1", otherwise are given "0". On the contrary, states without local government involvement in regulating swine industry (those states with laws that provide agriculture an exemption to local zoning) are given "1", otherwise are given "0". The first dummy variable (anti-corporate farming law) is expected to have a negative sign while the second dummy variable (local zoning ordinances) is expected to have a positive sign. States with anti-corporate farming laws discourage the growth of larger hog facilities, which are believed to have brought most of the expansion in the swine industry. States without local government involvement in regulating hog operations have a more uniform regulatory environment. Since fewer individual decisions are made about regulatory rules, it may be more stable as well. Such an environment would likely encourage investment in hog production.

Results

A linear model was used to estimate the relationship between the growth rate of hog inventory and all other relevant variables. Given the nature of the data (pooled time-series and cross-section analysis), a variance component (or error components) model was chosen (Dielman, 1989). This model is especially appropriate when more cross-sectional than time-series observations exist (Greene, 1990).

The Fuller-Battese method, which is available in the TSCSREG (SAS) procedure, was used to estimate the model. The general model is:

$$y_{it} = \sum_{k=1}^{p} x_{itk}\beta_k + u_{it} \qquad i=1,...,N;\ t=1,...,T$$

where N is the number of cross sections, T is the length of time series for each cross-section, and p is the number of independent variables.

[11] The survey was sent to the 16 state regulators and 15 of them responded. However, some of the returned questionnaires were not complete.

Fuller and Battese (1974) decomposed the random errors into three components:

$$u_{it} = v_{it} + e_{it} + \varepsilon_{it} \qquad i=1,2,...,N;\ t=1,2,...,T$$

where the first two terms are the individual and time-specific random effects of the error disturbances. All of the three error components are assumed to be independently distributed with zero means and positive variances. The variance components are estimated by the fitting-of-constants method, and the regression parameters are estimated with generalized least squares (GLS).

The results for eight models are presented Table 3-4. The basic model included all economic variables, a natural endowment variable, a business climate variable and the variable for taxation policy. The second model kept all variables in the basic model while adding the Green index (*Green*). Similarly, the third model replaced the Green index with the Lester classification (*Lester*). The fourth model replaced the Lester classification with a regulatory variable specific to the livestock industry (*Regula*). This variable represented the stringency of states' animal waste management programs. The last four models grouped the five measurements of laws or enforcement actions towards the livestock industry in different ways.

Since the units of the variables are different, it is difficult to compare the marginal effects of the independent variables on the dependent variable. In order to compare the numerical value of one regression coefficient with that of another, a standardized regression was estimated (Ramanathan, 1995). Following this method, the dependent variable as well as each independent variable was adjusted by its mean and standard error.

All models explained about 54 percent of the variation in the change of hog production. The magnitude of the variance components for the cross-section and time-series components in most of the models indicates that the individual effect and time period effect exist. Most variables performed consistently across models. Four variables (including *Hogper*, *Hcratio*, *Precipt* and *Rupop*) were significant at the .10 or lower level in all models.

Of the four categories of variables included in the analysis, the general economic factors were found to have the greatest influence on swine industry growth. The hog/corn ratio was significant at .10 level or lower in all models with a correct positive sign. The magnitude of the beta coefficients indicates that an increase of one standard deviation in hog/corn ratio led to an increase of the hog inventory growth rate by .3 standard deviation.

Table 3. Regression Results (1)

Independent Variables	Explanation of variables	No. of Obs.	Model 1	Model 2	Model 3	Model 4
Hogper	farms over 1000 head/total farms	91	.38** (2.01)	.42** (2.34)	.28* (1.86)	.40** (2.06)
Hcratio	hog/corn ratio	91	.33** (1.96)	.28* (1.73)	.54** (3.37)	.32* (1.84)
Landval	land value/acre	91	.68** (2.38)	.65** (2.59)	1.02** (5.48)	.68** (2.42)
Precipt	annual precipitation	91	-.29** (-2.04)	-.30** (-2.14)	-.35** (-2.69)	-.29** (-2.03)
Rupop	people in rural area/total population	91	.57** (2.72)	.66** (3.60)	.54** (5.33)	.57** (2.80)
Unemp	unemployment rate	91	.12 (.76)	.10 (.65)	.17 (1.36)	.11 (.69)
Slaught	slaughtering capacity	91	.08 (.41)	.00 (.06)	.19* (1.79)	.08 (.41)
Proptx	property tax/acre	91	-.06 (-.24)	-.24 (-1.02)	.18 (1.57)	-.05 (-.21)
Exist	hog inventory lag one/area	91	-.33 (-1.34)	-.42** (-1.95)	-.43** (-3.31)	-.35 (1.43)
Green	Green index	91		-.03* (-1.76)		
Lester	Lester classification	91			.60** (5.00)	
Regula	regulations towards livestock industry	91				-.00 (-.05)
Zoning	local zoning ordinances	91				
Corpo	anti-corporate farming law	91				
Staff	annual staffing level (FTE) devoted to the program	91				
Levfine	average amount of fines/violation	91				
Itslfine	Levfine × Staff	91				
R^2			.59	.59	.59	.59
R^2 adjusted			.55	.54	.54	.54
Variance (Cross Section)			.31	.18	.003	.28
Variance (Time Series)			.14	.14	.14	.16
Variance (Error)			.45	.45	.45	.46

* statistically significant at 10% level.
** statistically significant at 5% level.
T-values are included in the parentheses.

Continue Table.4. Regression Results (2)

Independent Variables	Explanation of variables	No. of Obs.	Model 5	Model 6	Model 7	Model 8
Hogper	farms over 1000 head/total farms	91	.41** (2.06)	.42** (2.20)	.34* (1.87)	.53** (2.90)
Hcratio	hog/corn ratio	91	.30* (1.67)	.30* (1.75)	.32* (1.91)	.31* (1.83)
Landval	land value/acre	91	.66* (1.68)	.53* (1.74)	.38 (1.36)	.23 (.81)
Precipt	annual precipitation	91	-.27* (-1.81)	-.29** (-2.04)	-.28** (-2.04)	-.32** (-2.33)
Rupop	people in rural area/total population	91	.64** (2.81)	.60** (2.99)	.62** (3.55)	.66** (4.11)
Unemp	unemployment rate	91	.16 (.89)	.10 (.61)	.13 (.85)	.11 (.74)
Slaught	slaughtering capacity	91	.00 (.00)	.35 (.18)	-.02 (-.14)	-.18 (-.98)
Proptx	property tax/acre	91	.05 (.17)	.04 (.17)	.10 (.48)	.34 (1.56)
Exist	hog inventory lag one/area	91	-.52* (-1.65)	-.46* (-1.80)	-.39* (-1.71)	-.58* (-2.73)
Green	Green index	91				
Lester	Lester classification	91				
Regula	regulations towards livestock industry	91	-.03 (-0.18)	-.01 (-.07)		
Zoning	local zoning ordinances	91	.59 (1.08)	.54 (1.10)	.89* (1.82)	.80** (2.05)
Corpo	anti-corporate farming law	91	.43 (.55)			
Staff	annual staffing level (FTE) devoted to the program	91			.28** (2.40)	
Levfine	average amount of fines/violation	91				-.40** (-2.17)
Itslfine	Levfine × Staff	91				.23** (2.13)
R^2			.60	.59	.62	.61
R^2 adjusted			.54	.53	.57	.55
Variance (Cross Section)			.32	.26	.18	.12
Variance (Time Series)			.16	.16	.16	.16
Variance (Error)			.46	.46	.45	.44

* statistically significant at 10% level.
** statistically significant at 5% level.
T-values are included in the parentheses.

The percentage of farms with a hog inventory over 1000 animals (*Hogper*) was found to have a positive sign and was significant in all 8 models, providing some evidence that economies of scale may have influenced hog industry expansion. The land value (*Landval*) variable was significant in most models[12] but had an unexpected positive sign. Land values do not appear to be acting as a cost factor. Instead, increases in land values were associated with increases in hog production, perhaps by serving as source of income for farmers or assisting in the acquisition of loans needed for expansion. The hog inventory density in the previous period (*Exist*) was significant in most models, but had an unexpected negative sign. Thus, the existence of agglomeration effects was not supported by the results.

The state slaughtering capacity (*Slaught*) was only significant at the .10 level in one model. The beta coefficients and signs varied in different models. The state unemployment rate (*Unemp*) was insignificant in all models, though the positive signs were as expected. This variable reflects the unemployment rate at the state level, including both rural and urban areas. Thus, it may not accurately measure labor availability in rural areas. The insignificance of *Slaught* and *Unemp* suggest that these variables do not affect hog expansion.

The variable reflecting a state's natural endowment, annual precipitation (*Precipt*), was significant at the .10 or lower level and had the expected negative signs in all models. The beta coefficients were consistent in all models, indicating an increase of one standard deviation in a state's annual precipitation led to a decrease in its hog growth rate by .3 standard deviation. Thus, states receiving less rainfall had greater swine industry growth. One explanation is that lower rainfall (and related climatic factors) made manure management easier and less costly favoring expansion in drier states. Also, the potential for serious water quality impairment is likely to be lower in states receiving less precipitation.

The proportion of a state's rural population in the total population (*Rupop*) was found to be significant at the .05 level in all models, with an expected positive sign. This suggests that states having more rural residents relative to urban residents produce a business climate that is more conducive to swine industry expansion. Specifically, an increase of one standard deviation in the percentage of rural population would result in an increase in the hog inventory growth rate by .6 standard deviation. This impact is larger than that of most of the economic variables.

The coefficient of the property tax per acre of farm land (*Proptx*) was insignificant in all models. Also, the changing magnitude and sign of the coefficient for this variable in different model specifications raises questions about its importance.

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[12] Land value was not significant in model 7 and model 8. Possibly it is correlated with *Zoning*. The Pearson Correlation Coefficient between these two variables is .56. Though it is lower than the threshold level (.60) used in the correlation check, it is relatively high compared to other coefficients.

The results for the three variables measuring the stringency of state environmental policies were mixed. The two indices measuring the stringency of general environmental policies--Green index and Lester classification--were both significant, but had opposite signs. The Green index, which is a comprehensive ranking of attributes of state environmental policies, had a negative sign. This result is counterintuitive, indicating that states with lower rankings had higher growth rates. This could have resulted from the fact that several states, such as Iowa and Minnesota, with high Green index rankings are also among the largest traditional hog production states.

The coefficient of the simpler and more subjective Lester classification had the expected positive sign. States with lower Lester classification rankings tended to have lower hog production growth rates. This finding supported the alternative hypothesis that differences in the stringency of states' environmental regulations have influenced swine industry expansion. One characteristic that distinguishes the Lester classification from the Green index is that it took into account each state's institutional capabilities to implement existing policies in addition to indicators of the stringency of environmental regulations that are "on the books". The sign of the Lester index implies that the states' enforcement capabilities possibly have influenced the change in the swine industry in the state studied.

The third variable (*Regula*) differs from Green index and Lester category in that it tends to measure the stringency of environmental laws regulating livestock industry specifically and varied in the study period. It is an average subjective score calculated from a survey of three industry experts for each state included in the sample. This variable was believed to be a more accurate measure than the first two general indices[13]. *Regula* was insignificant in all three models, though the negative signs were as expected. The t-values of the variable were very small (less than -0.1 in two models). The poor performance of this variable is probably due to the lack of variation.

The other two regulatory variables are anti-corporate laws (*Corpo*) and local zoning ordinances (*Zoning*). *Corpo* was included in model 5. The results indicated that "anti-corporate farming laws" (*Corpo*) was insignificant (t-value was .55 in model 5[14]) and thus it appears to have no relationship to hog growth or expansion. The findings do not support a strong effect of anti-corporate farming laws on the hog industry as suggested by others (e.g., Aiken, 1994).

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[13] This variable (*Regula*) attempts to measure the stringency of laws regulating livestock industry directly and varies over the study period. Thus, it is believed to be more precise in terms of testing the current hypothesis. However, it is less well developed and measured than the two other indices, especially the Green index. Additional efforts are needed to explore the potential of and refine such regulatory variables.

[14] Although only one model including *Corpo* was reported here, additional models were estimated. T-values of *Corpo* in these models were less than 1.0.

"Local zoning ordinances" (*Zoning*) was included in four models. In two models, the estimated coefficient was significant and had an expected positive sign. Therefore, the states with laws that provide an exemption to agriculture from local zoning had a greater growth or slower decline than the states without such laws. This result provides some evidence that the hog industry was more likely to expand in states with less local government involvement in policies affecting the livestock industry.

Personnel devoted to the states' animal waste management programs (*Staff*) and average amount of fines per violation states imposed on livestock facilities (*Levfine*) measure the states' enforcement capability and penalties respectively. *Staff* was included in model 7 while *Levfine* was included in model 8[15]. In addition, an interaction term between these two variables was also included in model 8; it is assumed that the marginal impact of states' enforcement efforts (measured by *Levfine*) upon hog expansion also depends on their enforcement capability (measured by *Staff*). It is expected that the more personnel involved in enforcement, the higher the probability that fines were imposed. Therefore, the impact of enforcement efforts on hog expansion will be greater when more staffing exists.

The results indicated that the coefficient of *Staff* was significant but with an unexpected positive sign. One explanation could be that number of personnel devoted to the program was not independent of hog industry growth (Renkow, 1997). The number of staff in a state regulatory program is likely to expand in response to swine industry growth. In other words, the direction of causality may have been different in some states and for some years. If the causal flow is reversed, the results suggest that as the industry grows, more enforcement activities are expected and thus more agency staff are needed.

The amount of fines per violation (*Levfine*) measures how much a livestock facility needs to pay when it violates a state's law. It was significant at the .05 level in model 8 and had an expected negative sign. This suggests that the greater the amount of fines a state imposed on a swine facility violating the laws, the lower its production growth. The beta coefficient of *Levfine* indicates that a one standard deviation increase of the amount of fines imposed for each violation would produce a decrease in hog inventory growth by .4 standard deviations. This impact is comparable to those of economic variables (e.g., a one standard deviation increase of hog/corn ratio would lead to an increase in hog inventory growth by .3 standard deviation).

The interaction between enforcement capability (*Staff*) and penalties (*Levfine*) was significant at the .05 level in model 8. However, the variable coefficient had an unexpected positive sign. This indicates that an increase in the number of staff would

[15] Both *Staff* and *Levfine* were included in one model, which was not reported here, due to space limitations. In that model, *Staff* is significant at .10 level with an unexpected positive sign, while *Levfine* was insignificant with an expected negative sign.

reduce the impact of the amount of fines upon hog expansion. This unexpected sign may result from the endogeneity of *Staff* mentioned above.

In summary, the results for the environmental regulatory variables were mixed. Three variables measure the stringency of state environmental policies. Two variables measuring the stringency of general environmental policies--the Green index and Lester classification--were both significant, but had opposite signs. The variable measuring the stringency of environmental laws regulating livestock industry specifically (*Regula*) was insignificant, though the sign was as expected.

The results of the variables measuring the states' enforcement capability and penalties were also mixed. The staffing level devoted to the regulatory program (*Staff*) was significant but had an unexpected sign. This may be due to a causal flow that is opposite of what was hypothesized. The amount of fines for each violation (*Levfine*) was significant and had the expected sign. This variable's marginal impact on hog industry growth is comparable to those of the economic variables, such as the hog/corn price ratio.

Conclusions

This research investigated the relationship between the stringency of state environmental regulations and the location of hog operations. Specifically, it tested the hypothesis that the stringency of state environmental regulations influences the growth rate of hog inventories across states. It was expected that the more stringent the regulations are, the lower the growth rate of hog inventory would be in a state.

Thirteen states were included in the analysis, covering the 1988/89-1994/95 period. Four categories of independent variables, including natural endowment, economic, business climate and regulatory factors, were used to explain changes in hog inventories. A variance component model was used to analyze the data.

From an overall standpoint, the results did not strongly support the hypothesis that the stringency of environmental regulations impacted hog inventory growth over the study period. Five variables were used to test this hypothesis. Two of the variables were established general environmental regulation indices which were not specific to the livestock industry and did not vary over time. The remaining three variables were obtained through surveys. These variables attempted to measure the stringency of states' animal waste management programs and their enforcement in 13 states. Among these three variables, one measured the stringency of environmental laws regulating livestock industry "on paper," while two variables measured the states' enforcement efforts.

One general environmental index variable and one variable measuring the states' penalties on facilities violating the animal waste management laws had statistically significant coefficients with the expected signs. The other general environmental index variable (*Green*) was statistically significant with an unexpected sign. A variable that was a more appropriate measurement of the laws regulating livestock industry (*Regula*)

was insignificant, though the sign was as expected. The variable measuring the states' enforcement capabilities (*Staff*) was significant but had an unexpected sign.

One explanation for the insignificance of the states' environmental laws regulating livestock industry is that the states' laws "on paper" did not differ significantly in the earlier part of the study period (Andrews, 1997; Hipp, 1997). More differences in states' regulatory programs can be found in their enforcement efforts, which possibly impacted the growth rate of the swine industry across states. One of the two variables measuring states' enforcement efforts--amount of fines per violation (*Levfine*)--was significant and had the expected negative sign. This suggests that swine producers were sensitive to the penalties imposed on facilities violating the law. However, the number of staff devoted to animal waste management (*Staff*) had an unexpected positive sign.

One way to interpret the above finding is that state environmental agencies may have gone through a learning process as they attempted to regulate the swine industry during the study period. The strong positive relationship between the number of staff devoted to animal waste management programs and hog inventory growth suggests the following: as environmental concerns became more serious with expansion of the industry in the early 1990s, greater efforts were devoted to the regulatory program in an attempt to reduce environmental damage. This argument was supported by a survey of industry experts. The results of the survey indicated that the regulatory programs of most states had greater impact later in the study period. Further research is needed to fully understand the evolution of the changing relationships between environmental regulatory programs and hog industry expansion.

Another interesting finding relates to local institutions and public policies. The existence of the capability of local governments to regulate the swine industry through local zoning ordinances appears to have impacted the growth of the hog industry. This result supported the argument that states with local governments that had legal authority to regulate the hog industry have made their regulatory environments less uniform and possibly less stable over time. Such states may discourage operators' investment in the hog business. Recent support for the importance of this variable is also provided by heated debate among state law makers over local control issues in North Carolina and Iowa (Vansickle, 1997). However, since this public policy influence was measured through a dummy variable, it is not possible to draw a conclusion about the magnitude of the impact of this policy factor.

The analysis also provides insight into other factors influencing the recent growth of hog production in the U.S. The models explored in this study indicated that a natural endowment factor (precipitation), economic factors (hog/corn price ratio and the percentage of large farms) and business climate (percentage of rural people) consistently performed well in explaining the variation in a state's hog production over the 1988-94 period. Growth in swine production was found to be associated with lower precipitation, possibly due to decreased costs due to manure management in dryer environments.

The importance of the hog/corn price ratio in explaining the industry growth verified the economic theory of firm behavior. The number of larger farms was found to be a significant factor influencing growth in all models, providing additional evidence of the role of economies of scale in hog facility expansion. Also, land values were positively related to increases in hog industry growth in most models, suggesting that such measures reflected a benefit, such as in securing capital needed for expansion, rather than acting as a cost factor. A state's business climate had an important bearing upon growth in hog production. Thus, hog facilities were more likely to pursue expansion in a state with more rural people.

Policy Implications

The study results have implications for policy makers and others who are interested in understanding the emerging locational patterns of the swine industry. There are at least two major policy issues. The first concerns where hog facilities locate and expand, and thus has implications for state or local policies. A second policy issue concerns the relationship between swine industry expansion and the stringency of environmental laws.

This research provides insight into where swine facilities are likely to locate and expand.

- Based on the spatial patterns observed in the 1988-94 period, drier states are likely to see growth in their swine sectors. If other conditions are the same, drier states, which are expected to have a less vulnerable environment for hog production, are likely to grow. Given that expansion in swine production continues to occur in drier states, states and local governments in these areas should take steps to prepare for this growth.

- States with existing larger swine facilities are likely to grow. Larger swine facilities that benefit from economies of scale have lower costs per unit than smaller swine facilities and thus are more competitive. These facilities may have some advantages in terms of manure management and ability to meet state environmental rules as well. Consequently, states with a higher proportion of these highly competitive facilities are likely to see more growth in the future.

- States with more rural people are more likely to see growth in swine production. This prediction is based on the belief (supported in this analysis) that such states are more likely than more urban states to have a positive business climate for hog production. In such states, the transactions cost of dealing with concerned or irate neighbors or community groups will be avoided or reduced when swine facility operators locate or expand their facilities.

- States in which local governments have less authority to regulate livestock operations are more likely to see growth in their swine sectors. In particular, the states that exempt

agriculture from local zoning ordinances may encourage investment in the hog business. There has been much debate between state and local interests in traditional as well as new hog production states over the question of "who gets to decide" about livestock facility siting and related issues. The outcome of these debates, which are largely being determined in state and local legislative and judicial bodies, will have important consequences for where future industry growth occurs and appears likely to play a key role in state-to-state or regional shifts in hog production.

• States that are more lenient toward violators of environmental laws are more likely to see growth in swine production. This results of this study suggests that the size of the penalties a state applies to violators influences the rate of swine industry growth in that state. It appears that the larger the penalties applied, the slower the industry growth will be in that jurisdiction. State policy-makers desiring to influence hog production growth should pay greater attention to the enforcement of their laws and in particular to the penalties associated with violation of their environmental rules.

In terms of the relationship between swine industry growth and the stringency of environmental laws, it is difficult at this time to draw a definitive conclusion and policy implication. States' enforcement of environmental laws appears to be an important variable influencing swine industry expansion. Given that more personnel have been devoted to the animal waste management programs in some states (e.g., Minnesota and Pennsylvania), the impact of enforcement on swine production and expansion can be expected to be greater in these states.

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