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## A Look at the U.S. Hog Industry

Mark Metcalfe

*Working Paper 99-WP 219*
April 1999

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# Abstract

The U.S. hog industry is experiencing an increase in both the average size and geographical concentration of feeding operations. These increases have caused attention to focus on the environmental consequences of hog production and on the regulations imposed to limit these consequences. This study examines the effect that differences in state water quality regulations have on the location of hog production in the U.S. Farm size is an important characteristic and therefore this analysis is conducted separately on small and large farms in order to examine the differences in effects by size of operation. Results suggest greater water quality regulatory stringency has no effect on the location of hog production. The amount of production on small feeding operations seems responsive to traditional input and transportation costs, while production on larger operations is seemingly dependent on the existence of transportation and agricultural infrastructure.

**Key words:** hog industry, environmental regulation, location of production

## Abstract

The U.S. hog industry is experiencing an increase in both the average size and geographical concentration of feeding operations. These increases have caused attention to focus on the environmental consequences of hog production and on the regulations imposed to limit these consequences. This study examines the effect that differences in state water quality regulations have on the location of hog production in the U.S. Farm size is an important characteristic and therefore this analysis is conducted separately on small and large farms in order to examine the differences in effects by size of operation. Results suggest greater water quality regulatory stringency has no effect on the location of hog production. The location of production on small feeding operations shows responsiveness to traditional input and transportation costs, while production on larger operations is seemingly dependent on the existence of transportation and agricultural infrastructure.

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# Location of Production and Endogenous Water Quality Regulation: A Look at the U.S. Hog Industry

## Introduction

The level of regulation concerning the control of nonpoint source (NPS) pollution released from animal feeding operations (AFOs) differs from state to state in the U.S. Many states with large animal feeding industries are facing increased environmental pressures and are therefore moving towards increasing the stringency of their environmental regulations. These increases in regulation will be accompanied by corresponding increases in the waste management costs for AFOs as increased stringency forces producers to incur new environmental compliance costs. How important is this increase in compliance costs to the competitiveness of AFOs? Is it important enough to cause feeding operations to relocate in areas with relatively low levels of environmental regulations? This study attempts to answer this question empirically, and specifically determine if stringent environmental water quality regulations have an effect on the location of hog feeding operations in the U.S.

Production may locate in states with low regulation and correspondingly, regulation may increase in states with increased production. This endogeneity is captured in this analysis through the two-stage estimation of state hog inventory levels and state regulatory stringency. The environment is treated as an input in the production process and four different proxies are used in this study to quantify the cost of utilizing this input, which is in effect the level of state regulatory stringency in a state. A major contribution of this paper is the construction of a qualitative stringency index from the examination of 27 states' legislation concerning regulations imposed on AFOs to protect state water quality.

Results from this study find evidence for the following:

1. Increased stringency of water quality regulation has no significant detrimental effect on the location of hog production in the U.S.

2. The most important factors influencing production on small hog operations seem to be output price, feed input price, and the cost of transportation.

3. Production decisions for large hog operations seem to be driven primarily by the states' level of existing agricultural infrastructure to facilitate transportation and the slaughter of hogs.

The results of this study tend to agree with previous studies on the manufacturing sector, which have found no significant negative effects on production from increases in the stringency of environmental regulation (Bartik 1988, McConnell and Schwab 1990, Levinson 1996, Mani, Pargal, and Hug 1997). This result suggests that despite the appearance that hog production is intensifying and relocating outside the traditional hog producing areas in to take advantage of lower environmental standards, in fact, other state characteristics are driving this movement of production.

The next section of the paper will provide a brief background on the nexus between the environmental impacts and the current dynamics of hog production location in the U.S. and will also give a brief review of Federal and state legislation. The model will then be presented, followed by a description of the data and the results of empirical analysis.

## Background

The transition towards specialization and vertical coordination in the hog production industry has led to conditions that favor increases in the size and geographic concentration of hog farms. Increases in the size of hog farming operations have been dramatic in recent years as the number of farms with more than 2,000 head, which had accounted for 28 percent of U.S. inventory in December, 1993, had risen to 63.5 percent as of December, 1998. Approximately 40 percent of this growth in large farms has occurred in the State of North Carolina, and this type of increased geographical concentration is becoming characteristic of the industry (Martin and Zering 1997, Hubbell 1997).

A consequence of the increasing geographical concentration of hog production is a heightening of the burden placed on the environment. A 1998 survey of agricultural states discovered that most of these states identify hog AFOs as a controversial environmental issue. Fifteen of the 24 states surveyed have implemented legislation within the last year to limit AFO pollution, and 16 states currently have new legislation proposed. In addition, all states except one indicated increased public media attention on hog farms and increased legal action against hog operations (NACPTF 1998). This increase in regulatory and public attention directed towards hog feeding operations makes examination of the compliance costs of waste regulation an important policy issue (Innes 1999).

Theoretically, there is no doubt that increased costs imposed exclusively on a single firm will decrease the competitiveness of that firm in an industry. It may be, however, that this theoretical effect is so small as to render it insignificant for policy considerations. Other characteristics of the state, both economic and geographical, may be more important in influencing a producer's location decision. Therefore, this study is an empirical investigation to determine if the potentially detrimental effect of increased environmental regulation is significant in determining the location of production in the U.S. hog industry.

A relevant body of literature has developed examining the effects of changes in environmental regulations on the location decisions of manufacturing industries (Jaffe, Peterson, Portney, and Stavins 1995). There is no general consensus on the relative importance of this effect at the state and local level. Some studies have found evidence that increased regulation can significantly influence industry location (Bartik 1989, Duffy-Deno 1992, Henderson 1996), while other studies find little significant evidence of such an effect or that the effect occurs only in cases were regulation is extremely severe (Bartik 1988, McConnell and Schwab 1990, Levinson 1996, Mani, Pargal, and Hug 1997). Three studies that look at the effect of environmental regulation on agricultural operations discover that a higher stringency of regulation does have a significant effect on the location of dairy farm operations (Osei and Lakshminarayan 1996, Outlaw 1993) and in the aquaculture industry (Wirth and Luzar 1998). An earlier study on the hog industry examining changes in production from 1988-1995 found mixed results (Mo and Abdalla 1997).

## Regulation

The environmental implications of hog production include the detrimental effects imposed on water, soil, and air quality by the animal waste introduced into the environment during the production process. Most states do not allow any waste discharge directly into state waterways; therefore, a common waste management practice is to use effluent from hog waste management to supplement commercial fertilizer on field crops. Excess waste application to croplands leads to leaching, and this type of pollution is called nonpoint source pollution as it is not released into the environment at a single controllable point but rather is introduced into the water, soil, and air over a diffuse area. It is estimated that nonpoint source waste from livestock production may account for up to 20 percent of the surface water pollution in the U.S. (Long 1992). Studies have also revealed that feedlots are a more important source of water pollution in rivers than are storm sewers or industrial sources (U.S. EPA 1993). Facts such as these have helped focus attention on water quality regulatory issues concerning the NPS pollution released by hog farms.

Water quality has been an important regulatory concern in the United States since the inception of the 1972 Federal Clean Water Act. This legislation placed primary responsibility for implementation of water quality programs and for the enforcement of the regulation of nonpoint sources on state and local governments (U.S. EPA 1995). NPS pollution was regulated more stringently at the Federal level in the 1987 Water Quality Act as concerns grew that state regulation alone was not providing sufficient protection for water quality (Ribaudo and Woo 1991, U.S. EPA 1995, Jones and Sutton 1996)

Federal involvement increased further through the 1990 USDA Water Quality Program and subsequent 1996 Environmental Quality Incentives Program, which formalized a commitment to protect water quality from agricultural pollution (USDA-ERS 1997). Recent joint action in 1998 by the EPA and USDA has proposed the need for a uniform national strategy implementing Federal standards for nutrient management (USDA 1998). Although Federal regulation of NPS water pollution has been steadily increasing since 1972, the majority of the regulatory and enforcement responsibilities still resides at the state level.

This history of the Federal regulatory framework empowering state agencies to set policy has allowed for variability in the extent of regulation imposed across states

(Metcalfe 1999). Waste management plans are required in 23 of the 27 states examined in this study. Among those states requiring plans, Connecticut, Illinois, Iowa, and Minnesota are the most restrictive and require specification of nutrient plans, adherence to best management practices, and implementation of a detailed description of the waste management system.

Nutrient standards are set for field application of manure in 22 states. Nitrogen standards for crops are required in Arkansas, Kentucky, Maryland, and Ohio and phosphorous standards are used in Michigan. Nutrient standards as well as set-back distances are implemented in Illinois, Iowa, Kansas, and Mississippi to better control field application of nutrients.

Some type of groundwater monitoring around AFOs is undertaken in 16 states. Colorado, Iowa, Kansas, Nebraska, and Oregon can require farms to monitor groundwater quality if the particular situation is considered a risk for contamination. Larger AFOs are required to monitor wells in Georgia, Maryland, Oklahoma, and Vermont.

Do differences such as these in state regulation affect compliance costs and influence the concentrated location of hog production? The next section introduces the methodology used to examine this question and then the empirical model and the results are provided.

## Model

A model of profit maximization for hog producers is utilized to obtain a functional relationship for hog inventory in a state. The supply and demand for the environmental input is also developed in order to obtain a functional relationship describing the shadow price of utilizing the environment in production. This shadow price is treated as the environmental input price and represents the level of stringency in state regulations. A two-stage estimation of inventory and the environmental input price allows the effect of state regulatory stringency on state inventory to be examined while accounting for the inherent endogeneity of these variables.

Assuming perfect competition and rational agents, hog farms locate in the state where expected profits are the highest. This model does not explain the decision process concerning how to change production, but rather it assumes that a change is determined necessary and the decision is in which state to change production. The production of hogs is a function of the inputs; feed, labor, land, and the environment. The environment is included in this model as an input into the production process as hog farms incur a cost to utilize the environment to dispose of hog waste. Specifically, this study will be concerned with the environmental cost of utilizing state water quality. This cost of using water quality is a function of the level of a state's environmental regulation and will be captured in the model through the input price of the environment. The production technology is represented by:

$$z_o = F(z_1, z_2, z_3, z_4) \tag{1}$$

where $z_0$ is the quantity of hog output, $z_1$ is the quantity of corn feed, $z_2$ is the quantity of labor, $z_3$ is the quantity of land, and $z_4$ is the quantity of environmental input.

Costs in this model include the unit costs of the inputs, which are represented as $p_i; i = 1, 2, 3, 4$, as well as the costs incurred transporting these inputs to the farm and the cost of transporting the finished hogs to slaughter. These transportation costs are represented as $t_i$, which represents the per-unit cost of transporting good i.[1] When an AFO chooses a state it is also choosing the prices it will face for its output and inputs as well as the per unit transportation costs that will be incurred. Therefore the firm's optimization problem in each state can be represented as follows:

$$\max_{\mathbf{z}} \pi = [p_o - t_o]F(\mathbf{z}) - \sum_{i=1}^{4}[p_i + t_i]z_i \tag{2}$$

Optimization of the profit function provides the usual first order conditions equating the marginal benefits and marginal costs of utilizing inputs. Solving this system of first order conditions provides the derived demand equations for the inputs. These derived demands are functions of the output price for hogs and all the per-unit costs in the model. Utilizing these derived demand relationships, we can obtain the optimal supply of hogs as a function of output price, all input prices, and transportation costs:

$$z_o^* = f(p_o, p_1, p_2, p_3, p_4, t_0, t_1, t_2, t_3, t_4) \tag{3}$$

where $z_o^*$ represents the optimum supply of hogs.

Given the inherent endogeneity between hog inventory and the level of regulation in a state, estimation of this functional relationship directly would be inefficient and therefore an instrument is developed and used in place of the endogenous price of the environmental input. A functional relationship for $p_4$ is obtained through development of a supply and demand model for the environmental input. The predicted values from the estimation of this relationship are then used as the instrument for $p_4$ in equation (3). This instrument is appropriate as it is correlated with $p_4$ but is obtained through estimation on variables exogenous to hog supply and therefore is itself exogenous to supply.

Using the derived demand equation for the environmental input from the profit maximization, the following demand relationship for the environmental input is obtained:

$$z_4 = l(p_o, p_1, p_2, p_3, p_4, t_0, t_1, t_2, t_3, t_4) \tag{4}$$

A supply relationship for the environmental input can be obtained by accounting for the social damage caused by the use of the environmental input. This social damage is a function of the quantity of environmental input used in hog production as well as characteristics of the state that would determine environmental attitudes and preferences.[2]

$$D = h(z_4, \mathbf{X}) \tag{5}$$

The variable D is the social damage and can be seen to be a function of environmental input use and a vector, **X** of state characteristics. Exogenous factors that are included as state characteristics affecting environmental preferences include income level, population density, and the amount of polluting industry existing within the state.

The marginal damage of an additional unit of environmental input use within a state is obtained by differentiating the damage function with respect to the environmental input. Assuming that the state sets regulatory policy so that compliance cost is equal to the marginal damage, then the input cost of utilizing the environment is a function of the quantity of environmental input use and the state characteristics.

$$MD = p_4 = k(z_4, \mathbf{X}) \tag{6}$$

More hog inventory can be placed in a state, but a higher regulatory cost must be paid for that placement.

This system is closed by assuming that in equilibrium the derived demand of environmental input is equal to the supply of environmental input at the given level of environmental input cost. This allows the following relationship to be obtained for the price of the environmental input:

$$p_4 = g(p_o, p_1, p_2, p_3, p_4, t_0, t_1, t_2, t_3, t_4, \mathbf{X}) \tag{7}$$

The predicted values from the estimation of this functional relationship can then be used in place of the environmental input price in the estimation of supply in equation (3) and efficient estimates of the effect of the environmental input price on supply can be obtained. The empirical model that is estimated, and the results of those estimations, are presented in the next section.

## Empirical Analysis

An annual panel data set of variables for the years 1984 through 1998 is collected representing hog inventory, output price, input prices, and transportation costs for the 27 top hog producing states. The states are grouped in five regions to capture some of the geographical variance that may exist for characteristics such as climate, soil types, and landscape. A listing of the states examined and the regions used is presented in Table 1.

The relationship of profit maximizing supply to the prices and costs as defined in Equation (3) will be used to define a supply equation to estimate the importance of these costs on hog production location. Two-stage estimation techniques will first estimate the endogenous cost of the environmental input, and then the predictions of this cost will be used as regressors in the estimation of the supply equation parameters.

The estimated equation for hog supply is represented as follows:

$$\mathbf{z_o} = \beta_0 \mathbf{P_0} + \beta_1 \mathbf{P_1} + \beta_2 \mathbf{P_3} + \beta_3 \hat{\mathbf{P}}_4 + \beta_4 \mathbf{HWY} +$$

$$\beta_5\mathbf{SLAUG} + \beta_6\mathbf{GSPFARM} + \beta_r\mathbf{R} + \beta_t\mathbf{T} + \varepsilon \quad (8)$$

where $\mathbf{z_o}$ is the vector of percentage share of total U.S. hog inventories for the states, $\mathbf{P_o}$ is the price of output, $\mathbf{P_1}, \mathbf{P_3}$ are input prices for feed and land, $\hat{\mathbf{P_4}}$ is the vector of predicted values used as an instrument for the endogenous environmental input price (discussed below), $\mathbf{HWY}, \mathbf{SLAUG}, \mathbf{GSPFARM}$ are the proxies for cost of transportation, $\beta_r\mathbf{R}$ is a matrix of parameters and dummy variables for the regional characteristics, $\beta_t\mathbf{T}$ is a matrix of the parameter estimates and dummy variables for the effects of time periods, and $\varepsilon$ is a vector of the overall random disturbance. The variable representing labor costs is found to be highly co-linear with other price variables in the model and is dropped. Labor costs can be justifiably dropped from the analysis as they represent only a small portion of the total costs in hog production.

Transportation costs could not be obtained directly as firm level location data is not available. Instead, the number of rural highway miles, state gross state product (GSP) from agriculture, and the percentage of total U.S. hog slaughter in a state are used as the proxies of transportation costs. The inclusion of the number of rural highway miles captures the availability of roads in rural areas, the percentage of hogs slaughtered in the state attempts to capture the level of availability of an output market for hog operations within the state, and the inclusion of state GSP derived from agriculture is used to capture the benefits that may be available to farms locating within the state from existing state infrastructure for agricultural operations.

Regional and time effects are included in the model as fixed effect dummy variables. Specification tests found these fixed effects to be highly significant for the models using state spending and nutrient measure proxies. The same test did not find significant fixed effects for the model using the qualitative proxy, and therefore these effects are not included in that model. The summary statistics for all of the variables used in the model are presented in Table 2.

## Stringency Proxies

The vector $\hat{\mathbf{P}}_4$ is the predicted values for the cost of environmental inputs obtained from the estimation of the relationship derived in Equation (7):

$$\begin{aligned} \mathbf{P_4} &= \gamma_0\mathbf{P_0} + \gamma_1\mathbf{P_1} + \gamma_2\mathbf{P_3} + \gamma_3\mathbf{HWY} + \gamma_4\mathbf{SLAUG} + \gamma_5\mathbf{GSPFARM} + \\ &\quad \gamma_6\mathbf{POPDEN} + \gamma_7\mathbf{INC} + \gamma_8\mathbf{GSPALL} + \gamma_r\mathbf{R} + \gamma_t\mathbf{T} + \nu \end{aligned} \tag{9}$$

where **POPDEN** is state population density, **INC** is state per capita income, **GSPALL** is the percentage of gross state product derived from all water pollution intensive industries, and $\nu$ is a vector of random disturbances.

The cost of environmental inputs, $p_4$, is included through regulatory stringency proxies. Obtaining an accurate price for the environment as an input is difficult and, therefore, four separate proxies of this cost are utilized and their results are compared.

The first proxy examined is the amount of state spending on water quality. Spending on water quality is defined as monies spent by states on managing water quality programs and on enforcement of water quality regulations. A higher value of spending would be expected to be representative of a state with more regulation and enforcement and therefore a higher compliance cost. This spending value is normalized by two different measures in order to create a relative measure of stringency: total state expenditure and total water area. The two separate normalizations are used to confirm that the results are not dependent on the normalization variable.

The second measure used is that of the nitrogen levels found in rivers located within the high pork-production areas of the states. Rivers are located within counties with the highest hog production in each of the states, and these rivers are cross-referenced with the United States Geological Survey water quality inventory database to identify nutrient monitoring stations located in these areas. One station is identified for each of the states and the maximum annual recorded nitrogen levels at these stations are collected. These values should capture some measure of compliance costs in the state as higher relative maximum values would suggest a more lenient regulatory system and therefore lower environmental compliance costs.

The third measure used is a qualitative measure constructed through examination of the waste management regulations imposed on AFOs. Regulations are examined for the years 1994 and 1998 and a listing of the various regulations imposed to protect water quality from animal waste is constructed. Each state is then rated; 1=low, 2=average, or 3=high in terms of the state regulatory environment. These qualitative measures and the individual state regulation information can be found in Figures 1 and 2.

The estimation above was run four times. The first two models utilize state water quality spending normalized by total spending and total water area as the index of the environmental input price. The third run uses the maximum nitrogen measure and the fourth uses the qualitative stringency measure. Two-stage least squares is the estimation technique used to obtain parameters for the two continuous endogenous stringency measures; water quality spending and the maximum nitrogen measure. Parameter estimates using the qualitative stringency measure are obtained through the methodology developed for endogenous qualitative variables developed by Heckman (Heckman 1978, Murphy and Topel 1985).

## Results: Water Quality Spending Measure

The data collected for water quality spending was available for the years 1986, 1988, 1991, 1994, and 1996. All of the major hog producing states were examined for these years. In order to examine scale effects, the data is disaggregated into small farms, under 500 head, and large farms, over 500 head, and estimation of effects is conducted on these groups separately. Limited data on inventory by farm size and confidentiality of state slaughter data removes some observations, leaving 64 useable observations. Water quality spending is normalized by total state expenditures in the first model run and by total state water area in the second run. These two normalizations show similar results. The model is run in log-log form and parameter estimates are provided in Table 3.[3]

The effect of water quality spending normalized by total state spending is found to be significantly positive for small farms with less than 500 head. This suggests that as water quality spending per dollar of total state spending increases, the percentage share of hogs produced on small farms increases within the state. The effect for large farms is not determined to be significant. The unexpected positive effect of regulation on small farm production may be indicating that there is some benefit to small hog operations when a state has a more structured regulatory system. This is an observation made in other studies using environmental spending as a proxy (Tannenwald 1997). It may also be a result of anti-large-farm sentiment within states with more spending on water quality.

Parameter estimates for hog price, corn price, rural highways, percentage slaughter, and farm GSP are all significant for small farms and all provide the expected effects. Results for large farms suggest that existing infrastructure is important as parameter estimates for percentage slaughter and farm GSP are positive and significant.

The second model run is performed on the same data set with water quality spending normalized by water area instead of total state spending. The results are similar. Small farms are found to experience a significant positive effect on the percentage share of hog production while large farms do not seem to be affected by increased water quality spending.

## Results: Maximum Nitrogen Measure

The data collected for maximum nitrogen measures includes the years 1984-1994. The nutrient measure used is the maximum level of nitrogen recorded during the year in a river located within a high hog production area of the state. Again, operations are divided into over and under 500 head, and also, again, the available data on inventory by farm size is a limiting factor and reduces the analysis to 112 observations. The model is run as a log-log specification and the parameter estimates are presented in Table 4.

Results for small farms suggest that environmental stringency as measured by the nutrient proxy is significant, and less stringency leads to an increase in production.[4] This is the only evidence in this study that suggests increased environmental stringency has a negative effect on production. Results for regulatory stringency on production for large farms are again insignificant.

Input costs for land as well as transportation costs and infrastructure are found to be significant factors in determining production on small farms. Large farms are, again, found to be most influenced by existing agricultural operations and infrastructure.

## Results: Qualitative Measure

The years examined in the qualitative stringency model include 1991-1998. The qualitative stringency measures are created for regulations in the years 1994 and 1998 and in order to increase the number of observations examined, the years 1991-1994 are examined using 1994 stringency and the years 1995-1998 are examined using 1998 stringency. This is reasonable because hog operations are forward looking and therefore should be following expected future trends in regulation. In order to examine scale effects, farms are separated into under and over 1,000 head, which provides 128 observations for this analysis. This model is not logged and the results are provided in Table 5.

Water quality regulation as proxied by the stringency measure does not have a significant effect on either small or large farms. Small farms are influenced by output and input prices as well as transportation costs and availability of slaughter capacity. Large farms are also influenced by the availability of slaughter capacity.

## Conclusions

The effect of increased water quality regulation on the concentration of hog production is an important environmental policy question. A profit maximization for hog producers is developed to examine this issue and four stringency proxies are included in the model to represent environmental compliance costs. One of the proxies is a qualitative measure developed exclusively for this study through examination of state legislation regulating AFO waste management. The inherent endogeneity of state hog inventory and the level of state regulation is accounted for in the analysis.

Overall results for the water quality spending proxy would seem to suggest that production on smaller farms is influenced by increased regulatory stringency but the effect is, unexpectedly, positive. This result may be capturing benefits to small farms from increased spending that are not related to increased compliance costs. Large farms do not seem to be affected by increased regulatory stringency as measured by water quality spending. Results for the maximum nitrogen proxy suggest small farms are influenced by input costs and water quality stringency. States that seem to have lower stringency also seem to have higher production levels on small farms within the state. This is the only evidence of a negative effect on production and, given the other results in the paper, this evidence is not substantial. Large farms are influenced by agricultural infrastructure and not by the maximum nitrogen water quality regulatory stringency proxy. The qualitative stringency measures are not significant for either large or small farms.

In general, the traditional input and output prices as well as transportation costs seem to influence production on smaller farms. Production on larger farms seems to respond to existing agricultural infrastructure but not to the input or output prices. It is obvious that input and output prices must play some role in the location of large farms, but it may be that these newer larger farms are responding more to factors other than the traditional input cost considerations. For example, these operations may be locating to minimize distances to export points and gain an advantage in the newly expanding pork export market. This type of new location consideration may explain movement of the industry to the west and therefore closer to the points exporting to the large Asian market.

Throughout the course of my research on this topic, a large set of specifications (functional forms, variable transformation, and four proxies of stringency) have been examined and the econometric evidence consistently fails to establish a link between the stringency of state water quality regulation and the location of hog production. Therefore, it seems that, from a policy perspective, the current trend of increasing environmental regulation does not have a significant impact on the location of hog production.

# Endnotes

[1] The variable $t_4$ is the per-unit transportation cost for the environmental input. This value may be thought of as the transportation costs for moving hog wastes from storage to fields and will be captured in the regulatory stringency measure. More stringent regulation increases these transportation costs through more strict regulation on where and when manure may be applied to fields.

[2] It is assumed that environmental input use in hog production is a significant environmental concern in the state. Since we are examining water quality regulation specifically in the major hog producing states, this assumption seems appropriate.

[3] Parameter estimates of dummy variables while important to capture unexplained variation are not crucial to the model interpretation and therefore are not presented in the interest of simplifying the presentation of the results.

[4] Remember, increases in the maximum nitrogen measure indicate decreases in regulatory stringency.

**Table 1**
**Twenty Seven Major Hog Production States**

| **Region** | **State** |
|---|---|
| Northeast | Maryland, New York, Pennsylvania |
| Midwest | Michigan, Minnesota, Wisconsin,<br>Illinois, Indiana, Iowa, Missouri, Ohio |
| Southern | Kentucky, North Carolina, Tennessee, Virginia<br>Georgia, South Carolina, Arkansas, Mississippi |
| Central | Oklahoma, Texas, Kansas, Nebraska,<br>South Dakota |
| Western | Arizona, Colorado, Oregon |

## Table 2
## SUMMARY STATISTICS
## 1984-1994

| Variable | Mean | Standard Deviation |
|---|---|---|
| Percentage Share of Total US Inventory | 0.027 | 0.03 |
| Price of Hogs ($ per c-wt) | 48.96 | 5.12 |
| Price of Corn ($ per bushel) | 2.59 | 0.53 |
| Land Value ($ per acre) | 777.04 | 388.91 |
| Expenditure on Water Quality ($ per total exp.) | 0.003 | 0.003 |
| Maximum Nitrogen (mg/L)/(inv) | 0.007 | 0.013 |
| Rural Roads (miles per square mile) | 0.0013 | 0.00039 |
| Population Density (persons per sq. mi.) | 0.099 | 0.08 |
| Percentage of US Slaughter | 0.023 | 0.025 |
| Median Income ( $) | 26,426 | 4,738 |
| Percentage GSP from Agriculture | 0.028 | 0.027 |
| Percentage GSP from Water Pollution Industries | 0.079 | 0.038 |

**Table 3**
**Structural Equation Results**
Water Quality Spending

Normalized by Total Spending
N=64

| | Small Farms | | Large Farms | |
|---|---|---|---|---|
| | $R^2 = .89$ | | $R^2 = .87$ | |
| **variable** | **parameter** | **t-ratio** | **parameter** | **t-ratio** |
| Hog Price | 10.92 | 3.4*** | -0.34 | -0.1 |
| Corn Price | -4.62 | -4.08*** | 3.57 | 3.07*** |
| Land Value | 0.38 | 1.38 | 1.19 | 4.19*** |
| Highway | 1.73 | 3.44*** | -0.32 | -0.64 |
| Slaughter | 0.21 | 2.9*** | 0.4 | 5.42*** |
| Farm GSP | 0.26 | 2.25** | 0.64 | 5.5*** |
| WQ Spending | 0.35 | 2.34** | 0.11 | 0.73 |

Normalized by Water Area
N=64

| | Small Farms | | Large Farms | |
|---|---|---|---|---|
| | $R^2 = .89$ | | $R^2 = .87$ | |
| **variable** | **parameter** | **t-ratio** | **parameter** | **t-ratio** |
| Hog Price | 10.24 | 3.38*** | -1.68 | -0.53 |
| Corn Price | -4.35 | -4.18*** | 4.14 | 3.8*** |
| Land Value | -0.11 | -0.32 | 1.33 | 3.53*** |
| Highway | 1.00 | 2.4** | -0.52 | -1.19 |
| Slaughter | 0.21 | 3.01*** | 0.41 | 5.54*** |
| Farm GSP | 0.33 | 3.07*** | 0.67 | 5.88*** |
| WQ Spending | 0.28 | 2.6*** | -0.035 | -0.31 |

* significant at 10% ** significant at 5% *** significant at 1%

### Table 4
### Structural Equation Results

Maximum Nitrogen Measure

N=112

| | Small Farms<br>$R^2 = .92$ | | Large Farms<br>$R^2 = .87$ | |
|---|---|---|---|---|
| **variable** | **parameter** | **t-ratio** | **parameter** | **t-ratio** |
| Hog Price | -0.55 | -0.47 | -2.19 | -1.38 |
| Corn Price | -0.97 | -1.38 | 2.56 | 2.69*** |
| Land Value | -0.82 | -4.03*** | 1.58 | 5.71*** |
| Highway | 0.61 | 2.5** | 0.29 | 0.88 |
| Slaughter | -0.08 | -0.71 | 0.69 | 4.51*** |
| Farm GSP | 0.51 | 6.79*** | 0.93 | 9.17*** |
| Max N | 1.79 | 4.9*** | -0.73 | -1.47 |

* significant at 10% ** significant at 5% *** significant at 1%

## Table 5

## Structural Equation Results

Qualitative Stringency Measure

N=128

| | Small Farms<br>$R^2 = .90$ | | Large Farms<br>$R^2 = .65$ | |
|---|---|---|---|---|
| **variable** | **parameter** | **t-ratio** | **parameter** | **t-ratio** |
| Hog Price | .00047 | 1.86* | 0.00024 | 0.57 |
| Corn Price | -0.0096 | -2.26** | 0.0079 | 1.12 |
| Land Value | -0.000015 | -3.6*** | 0.0000074 | 1.03 |
| Highway | 30.65 | 4.72*** | -7.88 | -0.73 |
| Slaughter | 0.86 | 26.32*** | 0.7 | 12.9*** |
| Farm GSP | -0.15 | -1.49 | -0.27 | -1.55 |
| Stringency Index | -0.0031 | -1.14 | -0.0014 | -0.31 |

* significant at 10% ** significant at 5% *** significant at 1%

## State AFO Regulations 1994

| | Local Control | Facility Design Approval | Waste System Approval | Geological Testing | Public Notice | Facility Loc. Requirements | Land App. Loc Req. | Nutrient Management Plan | Proof of Land Availability | Regs in addition to NPDES | Limitations on Land App. | Records Required | Nutrient Testing | Land App. Soil Testing | Bonding | Inspections | Distinguish Large v. Small | Cost Share | **Stringency Rank** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arkansas | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | **3** |
| Georgia | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **3** |
| Illinois | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | **1** |
| Indiana | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **2** |
| Iowa | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | **2** |
| Kansas | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **2** |
| Kentucky | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | **1** |
| Michigan | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | **1** |
| Minnesota | 1 | 1 | 2 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **3** |
| Mississippi | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | **2** |
| Missouri | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | **3** |
| Nebraska | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | **1** |
| New York | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | **2** |
| North Carolina | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | **1** |
| Ohio | 0 | 0 | 2 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | **3** |
| Oklahoma | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | **3** |
| Pennsylvania | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | **2** |
| South Dakota | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | **1** |
| Texas | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | **3** |
| Virgina | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **2** |
| Wisconsin | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **1** |

0=none 1=exists 2=extensive
Source: Copeland, 1994

Figure 1: 1994 Regulations

# State AFO Regulations 1998

| | Local (County) Control | Public Hearings | Geological Testing | Setbacks | Facility Design Approval | Waste System Approval | Fees | Nutrient Standards | Bonding | Groundwater Monitoring | More Stringent than NPDES | Training Required | Moratoria | Cost Share Programs | **Stringency Rank** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arizona | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | **1** |
| Arkansas | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 2 | **3** |
| Colorado | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | **1** |
| Georgia | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | **3** |
| Illinois | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | **2** |
| Indiana | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | **2** |
| Iowa | 0 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | **3** |
| Kansas | 0 | 1 | 0 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 0 | 1 | 0 | 0 | **3** |
| Kentucky | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | **1** |
| Maryland | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | **2** |
| Michigan | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | **1** |
| Minnesota | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | **3** |
| Mississippi | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | **3** |
| Missouri | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | **2** |
| Nebraska | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | **2** |
| New York | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **1** |
| North Carolina | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | **3** |
| Ohio | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | **1** |
| Oklahoma | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | **2** |
| Oregon | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | **2** |
| Pennsylvania | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | **2** |
| South Carolina | 0 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | **3** |
| South Dakota | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | **3** |
| Tennessee | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | **2** |
| Virgina | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | **2** |

0=none 1=exists 2=extensive
Source: NACPTF, 1998

Figure 2: 1998 Regulations

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