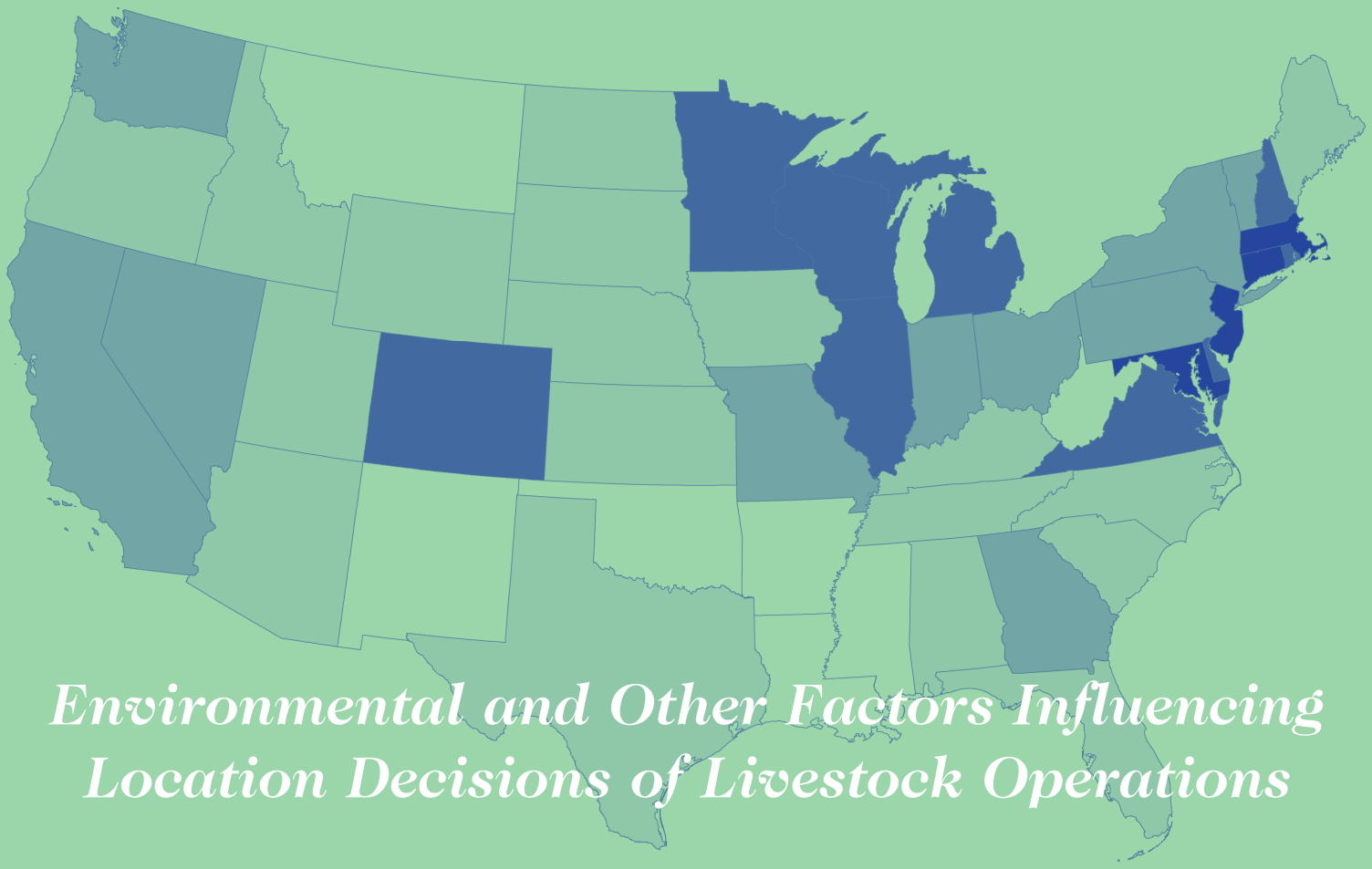


Environmental and Other Factors Influencing Location Decisions of Livestock Operations

BY CHANTAL LINE CARPENTIER
DEEPANANDA HERATH
AND ALFONS WEERSINK

WINROCK INTERNATIONAL
Putting Ideas to Work

Acknowledgements

Thanks go to Kate Clancy from the Wallace Center for Agriculture and Environmental Policy at Winrock International, for her input to and management of the project as well as Jonathan Winsten who supported her in managing the project, to Gregory Yetman at CIESIN for the maps, and to Veronique Robichaud and Stefan Reyburn for their editorial comments. The authors would also like to thank David Ervin and Rick Welsh for their useful comments on earlier drafts. We want to specifically thank project officers at the National Research Initiative and the Cooperative State Research, Education and Extension Service Research, National Research Initiative Competitive Grant Program, Market and Trade, Grant Competitive year 2000, who provided financial support for this study. This paper constitutes the final deliverable under that grant.

Introduction

The industrialization of the U.S. livestock sector has been associated with the geographic concentration of production in a smaller number of counties, and a shift in production to states with little prior livestock experience. Vertical integration and vertical and horizontal coordination are features of industrialization that encourage specialization in production and downplay regional comparative advantages, thus favoring greater mobility of the industry (Abdalla, Lanyon, and Hallberg, 1995). Increased mobility has resulted in fewer large processing plants, operating under economies of scale (Apland and Anderson, 1996), scattered throughout the country around clusters of livestock farms (Abdalla, Lanyon, and Hallberg, 1995). These clusters offer agglomeration economies by, among other things, enabling the integration of the livestock sector back into production (Ogishi and Zilberman, 1999). The concentration of production in fewer regions and the larger size of these operations have positive impact on some local economies by creating jobs and fostering economic development, while also producing negative environmental impacts, including human and environmental health problems—such as air and water pollution—as well as nuisance effects associated with foul odor. These spatial changes in animal production are the result of interactions among public policy—including agricultural support programs and environmental legislation that can provide subsidies and/or impose costs on producers—technological advances, market forces, and social factors (Abdalla, Lanyon, and Hallberg, 1995).

So far, little empirical evidence has been gathered on the drivers of livestock farm location and on the relative importance of each of these drivers. Key drivers could include natural endowments, labor market conditions, and the general business environment. Changes in the spatial distribution of livestock production may also be directly affected by differences in the stringency of environmental regulations across administrative regions. Differences in policy regimes might create "pollution havens," where lenient regulations may attract livestock producers in search of lower costs to a state or region, which in turn triggers a race to the bottom by competing states that wish to avoid losing more production to, or attract more production from, other states.

Some states are known to have sought out intensive livestock production, through financial incentives and lax environmental laws, as a potential source of rural development. Others have simply failed to review their regulations and have "inherited" the industry (Hurt and Zering, 1993). For example, with the industrialization of hog production, the geographic location of production has begun to shift from the Corn Belt to the Southern states and, more recently, toward the western part of the country (Hubbell and Welsh, 1998; McBride, 1997; Herath, Weersink, and Carpentier 2004). Some say this shift has occurred because the industry is in search of a "pollution haven" (Kunce and Shogren, 2002; Levinson, 2000; Jafee et al.1995; Martin and Zering, 1997); others like Gasteyer, Flora and Kilkenny (1999) assert that, as successful firms grow, they move to minimize their changing transaction costs. Others claim that, until very recently, environmental regulations would not have been considered in location decisions since external costs were not borne by the agriculture sector, but rather passed on as social costs. Ervin and Carpentier (1999) found that the ratio of the cost to comply with environmental regulations, to total production costs was still very low up until 1999 for most agricultural commodities, with the exception of dairy, thereby giving other sectors little incentive to move to another region because of its lower environmental standards.

Many states' environmental livestock standards are being strengthened on an almost yearly basis and we do not know whether some of these standards have now reached the threshold cost at which they influence the decision location of any, or all of, the livestock sectors in any of the states. For instance, in response to the increasing geographic concentration of production, the number of regulatory and local-interest activities has skyrocketed over the past five years. Of the 48 states surveyed by the Animal Confinement Policy National Task Force (Edelman et al. 1998), 17 had proposed new legislation in the past year, 17 had passed new

legislation in the past three years, 15 had new ordinances or policies passed by local jurisdictions, 18 had taken court action against CAFOs[1], and 39 said they had observed an increase in conflicts and media attention. A more recent study conducted by the Environmental Law Institute in 2001 in support of this study[2] confirms this dynamic regulatory environment and the variation in standards and enforcement across states. Given this variation, whether or not a race to the bottom in standards, to favor employment creation and regional economic development, can lead to "pollution havens" remains a valid empirical question (Kunce and Shogren, 2002; Levinson, 2000; Jafee et al. 1995). Fredricksson and Millimet (2002a) for instance, found that states do take into account the regulatory stringency of neighboring states when determining their own regulatory regime.

The purpose of this paper is to determine the effect of environmental regulations on changes in the spatial distribution of hog, dairy and fed-cattle operations in the United States. The null hypothesis is that environmental regulations have reached a threshold at which they can—along with other factors such as market access, other costs and labor availability—have an impact on location decisions. These three livestock sectors were chosen because they manage large quantities of manure mainly through a water-based system, leading to occasional lagoon spills, leakages, and surface and underground water problems. The poultry sector, with its dry-litter manure management, has been less controversial, producers have not relocated recently (McBride, 1997), and their concentration severely constrains access to data. Regarding the beef sector, only fed-cattle are investigated. With cattle, concentration occurs at the feedlot level, and later, in slaughtering and processing. In the earlier life stages of beef cattle, production is geographically relatively dispersed on a large number of smaller farms (ibid.). Also, the location of pasture-based beef production is still materials-oriented—i.e., dependant on locally available resources or natural comparative advantages—and takes into account grazing rights and other policies specific to cattle ranching.

No clear relationship has so far been established between environmental stringency, changes in regional livestock production, and pollution havens. The hypothesis has been tested for aggregated species (hog, beef cattle, dairy and chicken) based on standard animal units (Park, Seidl, and Davies, 2002), for hog operations (Roe, Irwin and Sharp, 2002; Metcalfe, 2001; Mo and Abdalla, 1998), and for dairy operations (Osei and Lakshminarayan, 1996), but the results of these studies are inconclusive. Several of these studies, for instance, unexpectedly find a significant positive association between environmental regulatory stringency and regional livestock inventories. Such conclusions suggest that laws tighten after production levels rise. However, these previous studies present several limitations with respect to the environmental stringency measure and specification of the model, which are addressed in the conceptual model used in the present study (see below).

The existence of this relationship is of political importance because if regional and state governments really do engage in a race to the bottom, by maintaining less stringent environmental regulations, certain regions would have an inefficiently high number of concentrated CAFOs. Where a race to the bottom has occurred in a region, the assimilative capacity of the local environment is deliberately undervalued and the heavier concentration of livestock operations may pollute at higher levels than socially optimal, imposing greater overall cost to the community. This less-than-socially-optimum outcome would in turn call into question the role of federal agencies in avoiding a race to the bottom among competing states, and in ensuring that states enforce EPA rules, under the Clean Water Act, requiring livestock operators to obtain National Pollutant Discharge Elimination Systems (NPDES) permits for CAFOs delegated to all but seven states[3].

In addition to testing the pollution haven hypothesis in the livestock sector, this paper aims to identify those factors—including environmental issues and policies—which have affected past location decisions, and identify how they might influence future location decisions. Knowing where CAFOs are most likely to relocate helps determine ex ante whether the policies in place in these locations are sufficient to protect local natural resources and environmental conditions (e.g. height of the watertable, safety in hurricane-prone areas, proximity to protected areas or endangered species, porosity of the soil).

In the past, policy makers have intervened once the environmental and social problems were already apparent, restricting siting and establishing design standards only after the industry (and its externalities) had grown and raised local opposition. These after-the-fact actions lead to a "not in my backyard" (NIMBY) attitude (ibid.), which is costly to the industry—reducing its

[1] Confined-animal feeding operations (CAFOs) are operations (AFOs) with more than 1000 animals each (USDA and EPA, 1999). An AFO is a lot or facility where animals have been, are, or will be stabled or confined, and fed or maintained for a period of 45 or more days in any 12-month period, and where crops, vegetation forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility.

[2] In addition to updating the Animal Confinement Policy National Task Force regulatory review of AFO/CAFO, a review of Canadian and Mexican regulations was compiled to allow comparisons across U.S. states and with the U.S. NAFTA partners. These two studies can be found at http://www.ciesin.columbia.edu/winrock-livestock

competitiveness and creating uncertainty. A sustainable and competitive livestock industry would require local players to take a proactive role prior to production relocation to ensure that environmental standards are such that livestock will be produced in ways sensitive to both environmental and human health, thus preserving the long-term competitiveness of the industry and the integrity of the local environment. Determining the factors that drive the relocation of livestock farms can help municipalities set the conditions that are necessary to achieving the socially optimum level of livestock production in their counties or states. For instance, these factors can be overlaid and mapped to determine the likelihood that a state will become the future location of livestock operations. This information allows rural interest groups, local environmental lobbying groups, and local decision-makers to verify whether some natural resources and ecosystems could be vulnerable to a concentration of livestock production in these areas, and whether local legislation is satisfactory to protect the areas before the industry relocates. This proactive approach is considered to be more economically efficient and environmentally sound than updating legislation on an ongoing basis as the industry grows and ecological damage is done. Targeting this review to states and counties where the industry is likely to relocate and to sensitive or unique ecosystems in these areas is less information-intensive and more cost-effective than a study and/or policies that would not take into account variations in natural endowment across counties and states. These reviews may further help resynchronize federal farm policies by encouraging the reconciliation of industrialization and the concentration of livestock production with local concerns (Abdalla, Lanyon, and Hallberg, 1995).

This paper presents five main results:

- An update of the geographic concentration of the livestock industry in the US;
- A statistical model to explain what factors affect the location decisions of the hog, dairy and fed-cattle industries;
- State-level factors conferring comparative advantage to each industry[4];
- An update of the Animal Confinement Policy National Task Force regulatory review of AFO/CAFO and a new environmental standard index to test the "pollution haven" hypothesis (at http://www.ciesin.columbia.edu/winrock-livestock);
- An Internet site with GIS maps of the data used and generated in this study (at http://www.ciesin.columbia.edu/winrock-livestock).

Documenting the relocations of livestock operations is an important first step in understanding the location decision of these enterprises. Building on Hubbell and Welsh (1998) and McBride and Key (2003), the following section presents the patterns of change in the geographic concentration of hog, dairy, and fed-cattle inventories since 1975. It begins by describing the entropy measures used to compare concentrations, both nationally and within and across the eight major production regions. The pattern of change can be categorized on the basis of trends in concentration and absolute production levels. Results are presented for the regional and national levels. The next section presents the empirical model for determining factors that affect the location decision of livestock producers. The major categories of factors include an environmental regulatory stringency measure, relative prices, livestock infrastructure support, general business climate, and climatic factors. In addition to examining more than one livestock sector over a longer period of time than previous studies, another significant contribution is the development of a state-level environmental stringency index through time. The third section discusses the econometric model and the use of instrumental variables to control for the potential endogeneity bias between livestock production levels and regulatory stringency. The results of the estimation are then presented. The final section concludes with some implications of the research findings.

[3] The seven non-delegated states are Alaska, Arizona, Idaho, Maine, Massachusetts, New Hampshire, and New Mexico. An eighth state, Oklahoma, administers the NPDES program for most purposes but has not been authorized to administer the NPDES program for CAFOs.

[4] The original proposal suggested using county-level data, but that information was not available for all states and all variables in all years necessary for the analysis.

1. Spatial and Temporal Changes in the United States Hog, Dairy, and Fed Cattle Sectors: 1975–2000[5]

While industrialization and geographic concentration have been relatively well studied, changes in geographic concentration have received relatively less research attention. This section identifies patterns of change in the geographic concentration of hog, dairy, and fed-cattle inventories in the U.S. from 1975 to 2000, both at the regional and national levels.

To characterize changes in livestock production across the U.S. over time, measures of geographic concentration are combined with changes in absolute livestock inventories between states and geographical regions, using the Hubbell and Welsh (1998) typology. Table 1 lists the six possible patterns of change in geographic concentration. In sum, a sector in a given region is considered to be undergoing an augmentation pattern of change if the total production and the extent of concentration are both increasing, and degeneration, if both are decreasing.

Table 1. **TYPOLOGY OF PATTERNS OF GEOGRAPHICAL CONCENTRATION**

Geographical Concentration	Absolute Inventory Level	Pattern
Increase	Increase	Augmentation
Increase	Stays the same	Reallocation
Increase	Decrease	Attrition
Decrease	Increase	Diffusion
Decrease	Stays the same	Reallocation
Decrease	Decrease	Degeneration

ABSOLUTE INVENTORY LEVELS

Total hog inventories have increased from about 49 million in 1975 to approximately 59 million in 2000 (Table 2) . After a large increase in the early 1980s, followed by a sharp fall, production levels have remained relatively constant over the last decade. However, there have been significant regional changes. The largest hog-producing area continues to be the Great Plains region which still accounts for approximately 50 percent of total hog production in the United States. The Great Lakes region had the second largest production level of hogs in 1975, but inventory levels since 1996 have been higher in the Southeast region as its share of the national production has risen from 16 percent in 1975 to 21 percent in 2000. The 54 percent increase in total production in this region is accounted for by the large increases in North Carolina and Arkansas, as all other states have reduced their share of hog inventory. The Southwest region now has the fourth-largest number of hogs among the eight U.S. regions. As with the Southeast region, the regional growth is due primarily to the large increase in production in one state (Oklahoma).

Dairy cattle inventory fell from 11.3 million to 9 million cows, or by about 20 percent, from 1975 to 2000 (Table 2). Much like the hog sector, dairy cattle inventories have fallen in the traditional dairy regions of the Great Lakes and the Great Plains regions. However, in this sector, inventories have risen in the western regions of the country. While regional differences in production have declined, there are significant concentrations of dairy cows in fewer states within many regions. All states within each of the five non-western regions of the country experienced a decrease in dairy cow inventory, and the percentage decrease was similar among states within the region. In contrast, the growth in dairy cattle numbers in the three western regions coincided with a significant increase in geographic concentration. For example, the 61 percent increase in dairy cattle inventories in the Far West region was due largely to the 90 percent increase in California, which is the largest dairy-producing state within the region.

Total fed-cattle inventories have increased by approximately 37 percent over the last 25 years, from about 10 million to 14 million head (Table 2). Three states account for the majority of this increase: Texas (1.5 million), Kansas (1.4 million), and North Dakota (1.2 million). Two of these states are in the Great Plains region, which continues to have the largest production base, and accounts for about half of the fed-cattle inventory in the United States. The second largest fed-cattle producing region in 1975 was the Southeast. Its fed-cattle numbers have increased by about 85 percent and it still ranks as the second largest producing region. Since fed-cattle numbers in the two largest production regions have expanded at a much greater rate than the rest of the regions, between-region geographic concentration has increased in the fed-cattle sector, in contrast to the other two sectors, particularly in the last decade.

GEOGRAPHIC CONCENTRATION

Geographic concentration is measured using the Theils entropy and its derivative, the relative entropy (see Annex 1 for details). The total relative entropy (R(q)) allows a comparison of concentration across different-sized regions by expressing each region's

[5] A full description of the methodology and results was published in Herath, Weersink, and Carpentier (2004).

absolute entropy measure as a ratio of its maximum entropy. If R(q) is equal to one, livestock inventories are dispersed equally among states and will tend toward zero as production becomes more geographically concentrated.

Total relative entropy values (R(q)) have fallen for all three sectors, suggesting a greater concentration of production within fewer states (Table 2). The hog sector R(q) value was initially the lowest (0.72 in 1975), down to 0.67 in 2000, but by 2000, fed-cattle was more concentrated with a R(q) of 0.64 . The R(q) for dairy inventories, which had been the highest, decreased from 0.84 in 1975 to 0.79 in 2000, while the fed-cattle R(q) decreased by the largest percentage: 16 percent. While the three livestock sectors are becoming increasingly concentrated within certain states, the nature of this geographic concentration varies widely among the eight census regions, as measured by decomposing the total relative entropy for between-region and within-region entropy.

PATTERN OF CONCENTRATION

No region shows a pattern of reallocation (Table 1) and most show attrition or augmentation—especially the dairy sector, and the hog sector since the mid-80s. Only the hog sector (between 1975 and 1980) shows patterns of diffusion (decreased concentration accompanied by increasing state inventories). The only pattern of degeneration (decrease in both values) is found in the fed-cattle sector. The fed-cattle and hog sectors have known three of the five patterns, while the dairy sector has known only two. The dominant pattern of geographic concentration within each region for the three livestock sectors during the 25-year period under study are illustrated in Figure 1. Generally, the hog sector has tended to move and concentrate inland and the dairy sector, west. Regions in the northeastern quadrant of the U.S. have tended to experience an attrition pattern of geographic concentration in livestock production. Livestock inventories have fallen in the Great Lakes, New England, and the Mideast regions. Even in the Southeast region, which has drawn public attention with its phenomenal increase in hog numbers, both fed-cattle and dairy inventories declined (more in some states than others). The decrease in absolute production levels, with production becoming more concentrated within fewer states within these regions, suggests a pattern of attrition.

Augmentation patterns of change in livestock production are found in the western regions. For example, in the Southwest region, geographic concentration has increased for all three livestock types, largely due to production increases in a few states. Oklahoma and Texas have changed their inventories in hog (670 percent, 18 percent, respectively), dairy (-24 percent, 5 percent) and fed-cattle (88 percent, 119 percent). Similarly, the Rocky Mountain region, which was a relatively unimportant region in the livestock industry a generation ago, has expanded its hog inventories by 183 percent, dairy cow inventories by 64 percent, and fed-cattle inventories by 54 percent over the last decade. The growth has been significant in a few states (e.g. dairy cow numbers up by 136 percent in Idaho and hog numbers up by 1,070 percent in Utah), resulting in greater concentration. Such an augmentation pattern is also evident in the hog and fed-cattle sectors in the Great Plains, and in the dairy sector in the Far West.

The Great Plains, Southeast and Rocky Mountain regions have exhibited an augmentation pattern of change in hog production over the last 15 years as inventory levels and geographic concentration have increased. The other five regions have exhibited varying forms of attrition in hog production over the last 15 years as total inventories have fallen and geographic concentration has increased.

The attrition and augmentation patterns of geographic concentration, which are associated with production moving to non-traditional regions, are not likely the result of natural comparative advantages within the regions. For example, it is intriguing that Colorado and Texas have expanded production in all three types of livestock, while other states in their respective regions have not, despite having similar physical characteristics. One could hypothesize that it is because these states are soft-pedaling their environmental regulations in order to lure livestock investments and expand production. Alternatively, livestock production may be relatively more profitable in these states. When we look at the environmental stringency indices developed for this study (Table 4), we see that the trend for states with augmentation patterns (Colorado, Texas, and Oklahoma) is above-average environmental stringency in 2000 (see also Figure 2), while Idaho and Utah's stringency are below the average. However, both Colorado and Texas have lower-than-average environmental stringency up to 1995–96, and Texas up to 1992. Thus it is conceivable that lower stringency levels attracted new production during these years and that, as a result of increased environmental and social impacts, their environmental stringency has been increased more recently. In contrast, Idaho started having higher-than-average stringency and then fell below the average in 1990. These findings are based on factual observations. To draw some statistically-valid conclusions on the role of environmental stringency and other variables over time, multivariate analysis is needed.

After a review of existing models and a presentation of the conceptual model, this paper addresses the question of the driver for these patterns of change in the production location for the hog, dairy and fed-cattle sectors.

2. Empirical Evidences of Pollution Havens

Research has been inconclusive with regard to the impact of environmental regulations on location decisions. Rainy and McNamara's (1999) literature review concluded that, in general, tax burden, agglomeration characteristics, labor aspects, market access, attitude toward business, quality of life, government expenditures, and other community-specific costs were important in the location decisions of firms. Duffy-Deno (1991), Bartik (1988), and Stafford (1985) found weak or no links between environmental regulations and manufacturing activities, while Gray (1997) found fewer new manufacturing plants in states with higher environmental standards.

Lopez and Henderson (1989) surveyed new food-processing plants in the Mid-Atlantic States to determine what factors affected their location decisions. For all processing plants polled, the availability of an existing plant facility was the most important determinant of location. Availability of raw agricultural supplies was ranked second.

Poultry-processing firms, the only meat-processing plants surveyed, ranked the availability of waste treatment, the availability of disposal facilities, and wastewater disposal costs as the top three environmental factors affecting location decisions. Availability of an existing plant facility, stringency of enforcement of environmental regulations, and capital expenditures for pollution abatement were ranked fourth through sixth[6]. Unlike other industries, the poultry-processing sector did not rank the availability of raw inputs, including labor, as important (ibid.). This difference can be explained by the vertically integrated structure of the poultry industry. Processors contract directly with farmers to provide them with the raw inputs, helping them become less dependent on locally provided inputs (this is also increasingly true for the hog sector). These findings indicate that processing capacity, as well as the factors that enable a plant to locate near population centers (i.e., environmental management and waste disposal services), figure heavily into the location decisions of poultry processing firms in the Mid-Atlantic states. Given the level of integration in the other livestock industries, this observation could apply to them as well.

Larger firms ranked environment and labor as the most important factors in their location decisions. Fiscal, infrastructure and market, and personal factors were ranked as the least important. In contrast, smaller firms placed market and personal factors at the top of their list. Lopez and Henderson found that food processors in the Mid-Atlantic states were less concerned with wages and labor costs than with the availability and quality of labor when making location decisions. They did not find workers' compensation insurance rates, compensation laws and unemployment insurance taxes to be important factors in their decisions.

Conversely, Vesecky and Lins (1995) found workers' compensation insurance rates, compensation laws, and unemployment insurance taxes—but not wages—to be important for farm-input supply firms to decide to reduce production in Illinois.

Few studies have dealt with livestock farms. Smith (1995) found that large hog producers surveyed ranked environmental hassles and local opposition high among their reasons not to expand. Smith and Kuch (1995) found that state population density, anti-corporate laws, fiscal resources, institutional capabilities and baseline environmental vulnerability affect how farms respond to environmental regulations.

Metcalfe (2000) reviewed the empirical analyses performed in recent years to assess whether environmental regulations had influenced the location decisions of manufacturing industries and agriculture, including the hog industry. These studies were inconclusive. He found that small hog farms are influenced by traditional factors—output and input prices, transportation costs, and existing agricultural infrastructure or agglomeration effects. The location decisions of larger hog farms were found to be affected only by the latter. Mo and Abdalla (1998) and Metcalfe (2001) conclude that economic variables are the most important factors determining the location of hog farms, along with measures of concentration. Roe, Irwin and Sharp (2002) argue that in 15 states, access to slaughtering facilities is positively correlated with the intensity of hog production. Osei and Lakshminarayan (1996) found that higher environmental regulations deterred the decision to site dairies. The next section proposes a model to test for important variables in (re)locating hog, dairy, and fed-cattle production in geographically concentrated areas.

[6] Only 4 of 56 firms sampled were poultry-processing firms, reducing confidence in the results.

3. Conceptual Model to Test the Pollution Haven Hypothesis in the Livestock Sector

If firms do migrate from one locality to another in search of areas with less stringent environmental regulations, then pollution havens exist and are a factor in farm location decisions. However, as described above, this relationship has not yet been established empirically. Previous results are not only inconclusive but unexpectedly find a positive relationship between environmental regulatory stringency and regional livestock inventories. If the pollution haven hypothesis is verified, we expect a negative correlation between the level of environmental stringency and the number and scale of new operations coming to that area. However, this relation can be blurred by the tendency to strengthen the standards once the location decision has been made and once the communities, feeling the negative environmental impacts, have asked for more stringent environmental standards (an endogeneity problem). Park, Seidl, and Davies (2002) found strong evidence that support this "industry-driven policy hypothesis," where states react to greater livestock activity by creating more regulations. This reaction, in turn, creates an endogeneity bias in the model. The present paper attempts to correct for this endogeneity bias through instrumental variables. It also uses a livestock-specific environmental stringency measure that varies across state and time. Most previous studies have modeled the state-level environmental regulatory stringency using a one period cross-sectional measure based on either a general environmental indicator (e.g. the FREE Index or the Conservation Foundation Index used by Osei and Lakshminarayan, and Mo and Abdalla, respectively), or on regulatory policies directly applicable to livestock farms—Metcalfe's (2000) index as used by Roe, Irwin, and Sharp (2002) or the index from the National Survey of State Confinement Policies, as used by Park, Seidl, and Davies (2002). However, regulatory stringency has undoubtedly varied over time and should therefore be taken into consideration in defining the variable used to proxy its affect when testing the pollution haven hypothesis.

The number of new firms entering an industry within a given region, and the intensity of production within a region are two variables that can capture spatial production changes. Bartik (1988) argued that aggregate measures of regional economic activity, such as inventory levels, reflect a number of different types of economic decisions by agents. Production levels can change due to the expansion or contraction of existing facilities, the introduction of new facilities, or the closing of old ones. Since new firms considering locating in a region tend to face harsher environmental constraints than existing firms, which can benefit from grandfathering arrangements, the inauguration of new facilities could be lower in a region with more stringent environmental regulations. While the number of new livestock operations may be the best measure of regional production changes due to environmental laws, it is not available for an extended period of time for all states. For this reason, livestock inventory is used as an aggregate measure of spatial production in this study[7]. The Theil Entropy Measure of concentration could not be used as the dependent variable since the Theil Entropy Measure is calculated for the country (or region) for a given year; thus, with the Entropy we could not get state-level variations across time.

In order to control for cyclical fluctuations of livestock inventories, annual inventory shares for each of the three livestock sectors were collected. Data on hog, dairy and fed-cattle production levels were gathered for each of the 48 contiguous states for the years between 1975 and 2000, resulting in 25 observations over time for each state and for each livestock sub-sector.

[7] Decisions to expand or contract livestock operations or to invest in a different sector altogether depend on changes in relative profitability rather than absolute profitability of raising livestock. We assume that relative profitability of raising livestock compared to other alternative investment opportunities remains equal across states. Thus, as Metcalfe (2001) noted, the model cannot explain why decisions on "when to change" production are made; instead, it assumes that a change has already been determined to be necessary (namely that relative profitability is favorable) and, thus the decision is about "in which state" production will be altered.

EXPLANATORY VARIABLES

There are several studies that have examined the location choices of firms in a variety of settings, including dairy farmers (Osei and Lakshminarayan, 1996); hog producers (Mo and Abdalla, 1998; Metcalfe, 2001; Roe, Irwin and Sharp, 2002); forest harvesting activities (Sun and Zhang, 2001); foreign investment by multinational corporations (Friedman, Gerlowski and J. Silberman, 1992; Coughlin, Terza and Arromdee, 1991; List and Co, 2000); and new branch plants openings in the manufacturing sector (Bartik, 1988; Levinson, 1996; McConnell and Schwab, 1990). Drawing on this industry location literature to formulate the general drivers of where livestock production occurs, the explanatory variables are categorized into five groups: 1) regulatory stringency, 2) relative prices, 3) livestock infrastructure, 4) general business climate, and 5) climatic factors. The variables used as proxies for these five general drivers of the spatial reorganization of livestock production and data sources are summarized in Table 3 and described in the next section.

REGULATORY STRINGENCY

In previous studies, regulatory stringency measures in previous studies have been constrained by data limitations. Rather than using a one-period cross-sectional stringency measure, as is the case in other studies testing the pollution haven hypothesis in agriculture, a variable is developed for each state over time.

State values for 14 environmental stringency measures developed over the years by a variety of authors are listed in Table 4. These indices capture some aspect of a state's efforts in environmental protection and are not based on environmental outcomes, such as air or water quality status (for further details about these two qualitatively different indices, see List and Co, 2000). The higher the index value, the more stringent is the environmental regulatory regime of the state. Since there are index values for 14 years over the 25-year period, the values for the years without an index were estimated using the adjacent year's index value. For example, the 1975 values of per-capita environmental quality-control expenditures were used for 1976 (see the last row of Table 4). Except for Metcalfe's 1994 and 1998 indices, all other indices were developed for all the 48 contagious states. The arithmetic mean value of Metcalfe's indices was assigned for those states that were not included in Metcalfe's study of 19 states only.

The last column of Table 4 contains a measure—for the year 2000 and for all states—that was estimated based on Metcalfe's (2000) approach to estimating the regulatory pressures facing farmers for a sub-set of states. The presence (or absence) of seven regulations for each of the 48 states were was summed up to form the 2000 stringency index (Table 5). Data on regulations were obtained largely from the Environmental Law Institute and supplemented from with data from the National Survey of Animal Confinement Policies (Edelman et al. 1998),); the National Association of State Departments of Agriculture (NASDA, 1998), summarized in Spear et al. (2003),); and U.S. EPA (2001).

In order to capture the temporal changes of in regulatory stringency across states, comparisons of the indices across time must be made. However, the indices are not comparable in their absolute magnitude since these are based on dissimilar variables and on different periods. Thus, we normalized individual state values for all the above indices by dividing through with the arithmetic mean of the respective index. The normalized index values represent the position of the state relative to the arithmetic mean of each index. We have used the normalized values for all the above indices to approximate the relative regulatory stringency across time. Thus, the different indices can be combined to form a single regulatory variable with a consistent scale measure (Tables of indices over time and state can be found at www.ciesim.org/winrock).

RELATIVE PRICES

Increases in the relative profitability of livestock production as measured by an output-to-feed-price ratio are expected to intensify relative production. Hog and beef prices have cycled over time but there are no significant regional differences except that Western states tend to have higher beef prices than those in the Northeast. In contrast, dairy prices do not fluctuate significantly over time but there are persistent regional differences. Dairy prices have tended to be higher in the Southeastern states and lower in the Western states. Corn prices have varied much more than livestock prices with the highest regional corn prices generally found in the Southwest.

A second input cost used in the model was the price of energy. Energy prices peaked in 1981 and 1991, and slumped in 1988 and 1998. Prices vary somewhat from state to state according to the different types of energy production. For example, some states, such as Oregon, have an abundance of hydroelectricity and therefore lower energy prices, as compared to other states relying on fossil fuels or nuclear power to generate electricity.

A third input cost that is necessary in livestock operations is the cost of labor. These costs are measured by the average farm wage rate, which has risen constantly over time. Despite the incentive to produce where labor is cheapest, and despite the general perception that large-scale production requires cheaper labor, there are no major differences in wage rates across the states with significant livestock production.

A fourth input price used in the model is the value of farmland. Areas with lower land values, ceteris paribus, are expected to have higher shares of the national inventory. Since land is immobile, there are regional differences in the price of farmland, with the highest values found in areas with the largest urban pressures. In agriculturally intensive regions, farmland values are higher in the Corn Belt states than in the Central Plains and Rocky Mountain regions, reflecting differences in land productivity.

LIVESTOCK INFRASTRUCTURE SUPPORT

Market access and agglomeration economies are associated with livestock infrastructure support. Production shares are likely to increase in regions where the distance to market is smaller, since transportation and transaction costs will be lower. For example, access to slaughtering facilities was found to be positively related to the intensity of hog production within 15 states or counties by Roe, Irwin and Sharp (2002). Market access is measured in this study by the number of hogs and beef slaughtered within the state[8]. Iowa has the largest hog slaughtering capacity and the number slaughtered has increased significantly over time. Illinois, North Carolina and Minnesota also increased their hog slaughter capacities, but the levels are less than half of that for Iowa. Beef slaughtering capacity increased significantly over time for Kansas, Texas, Nebraska, and Colorado. These states also had the highest capacity for cattle slaughter among all states. In contrast to the situation for hog slaughter, the number of beef slaughtered in Iowa has decreased considerably. Market access for dairy processing capacity is captured by whole milk equivalent in thousand pounds capacity in each state[9]. Leading dairy states, such as Wisconsin, California, Minnesota, New York and Iowa, had much higher processing levels than other states throughout the study period, but California and Wisconsin recorded marked expansions in capacity while the dairy processing capacity in the other three leading states was almost unchanged during the 25-year period.

Agglomeration economies are the positive spillovers a farm may enjoy because of a higher concentration of farms located in the surrounding region. For example, the existence of many dairy farms in a region can attract input suppliers and other industry-specific infrastructure that lowers the transaction and input costs and the diffusion of information (Eberts and McMillen, 1999; Weersink et al. 1995). Agglomeration effects are proxied by the importance of agriculture to the state economy and the share of the population living in rural areas. The states with the largest share of income from agriculture are the Dakotas, Nebraska, and Iowa. It is expected that livestock operations meet less resistance in states where a significant part of the population is tied to agriculture. The migration of city dwellers to rural areas, leading to an increase in the percentage of rural population in approximately one-third of the states, is more likely to lead to a "Not In My Backyard or NIMBY" attitude toward large livestock operations than what is found in a population that is economically tied to agriculture.

GENERAL BUSINESS CLIMATE

The proxy measures for local business conditions conducive to the establishment of a livestock operation are the state unemployment rate and farmland area. Varying both over time and between states, the unemployment rate, which reflects the labor supply and the receptiveness toward new operations, can have an influence on farm location. A region with a high unemployment rate is more likely to have excess labor that can be employed in agriculture. In addition, areas with higher unemployment may seek to attract livestock operations as a means to generate economic opportunities.

The state's farmland is an important determinant for both the general receptivity of farming operations and the assimilative capacity for land-based manure disposal. States with greater farming areas are believed to be more receptive to livestock operations. The most important and widely practiced manure disposal method is to spread it on farmland as a valuable source of organic nutrients. However, Gollehon et al. (2001) found that about 72 percent of large livestock operations had inadequate land capacity to utilize all the manure-based organic nitrogen produced from their operations and required alternative disposal arrangements. Thus, the costs of manure disposal are likely to be lower in states with more available farmland.

CLIMATIC FACTORS

Physical features of the region are portrayed by average annual precipitation and temperature. Precipitation does not vary greatly within states when measured over several years, although precipitation does, on an annual basis, fluctuate more than temperature. Mean temperature is negatively related to both latitude and altitude, and so, does not fluctuate greatly among states over time.

[8] A more appropriate measure would be a spatially weighted average of a state's processing capacity since slaughtering facilities within a given state are likely to influence the market access of adjacent states.

[9] Whole milk equivalent is used as a common measure for dairy products. For example, the whole milk equivalent conversion factors are approximately: 22.145 pounds of whole milk for 1 pound of butter; 9.87 pounds of whole milk for 1 pound of American-type cheese; 27.27 pounds of whole milk for 1 pound of Mozzarella and other Italian-type cheeses; 0.031 pounds of whole milk for 1 pound of cottage cheese.

EMPIRICAL SPECIFICATION

Factors affecting the changes in regional livestock production were estimated through the following regression model:

(1)
$$Y_{it} = \sum_{k=1}^{K} \beta_k X_{it} + V_i + U_t + \varepsilon_{it}$$

$$i = 1,\ldots,48 \quad t = 1,\ldots,25$$

where Y_{it} is the share of national inventory for state i (for 48 contiguous states) in year t (from 1976 to 2000); X_{it} is the vector of explanatory variables (varying across state and time) affecting the relative profitability of livestock farming across states; β_{it} is the vector of coefficients associated with these explanatory variables. Unobserved state-specific time invariant (V_i) and time-specific state-invariant (U_t) and therefore omitted variables can mask the true relationship between the changes in livestock inventory and the independent variables and are captured by (V_i) and (U_t). ε_{it} is the random disturbance term.

Two specifications can be used to control for V_i and U_t: (1) the fixed effects model, which assumes that V_i and U_t are constants and conditional on the sample not randomly distributed; and, (2) the random effects model, which assumes that V_i and U_t are randomly distributed and not conditional on the sample. A random effects model is likely inappropriate for this analysis given that our sample (48 states) is not a random selection of a large sample frame. In spite of this, a Hausman specification test was used to determine if the covariance between V_i and X_i is zero, a prerequisite to produce consistent estimates when using a random effects model. This condition was not satisfied. The null hypothesis of no correlation between state-specific effects (V_i) and independent variables (X_i) was rejected for all three sectors[10]. Thus, a fixed effects model was used to run the three sector regressions.

If environmental regulatory stringency is endogenous to state livestock inventory shares—that is, states react to greater livestock activity by strengthening regulations—then, inventory shares would be correlated with the stringency variable, and least square estimators would be inconsistent. This potential endogeneity and subsequent bias (ignored in most studies) was tested using a Durbin-Wu-Hausman test with appropriate instrumental variables. (See Appendix 2 for technical details).

The null hypothesis of no endogeneity was rejected for the hog and fed-cattle sector. To correct for this bias, a fixed effects model with two-stage least squares was used for the hog and fed-cattle sectors, while an ordinary least squares was used for the dairy sector.

[10] If the model specification is correct and Xi and Vi are orthogonal, the coefficients that are estimated by the fixed effects model and the random effects model should not differ significantly. The null of zero systematic difference is rejected by the Hausman specification test with the calculated $\chi 2$ values for the hog, dairy and fed-cattle sectors of 1085, 18, and 630, respectively.

4. Results

Estimation results and elasticities evaluated at mean values of the variables are presented for all three sectors in Table 6. These results are presented below, followed by their implications for the pollution haven hypothesis, and by a discussion on the important factors involved in the decision of whether or not to locate hog, dairy, or fed-cattle operations in a given state[11].

MODEL

The 12 variables used to explain the differences in the share of national livestock production among states explained 47 percent of the variation in the share of national hog production across states, 82 percent of the dairy variation, and 36 percent of the fed-cattle variation. Seven variables were significant for the hog sector, nine for the dairy sector and five for the fed-cattle sector (see Table 6). Of these variables, two had an unexpected sign in the hog sector, five in the dairy sector, and three in the fed-cattle sector. Of the three variables that were significant for all three sectors—farmland prices, processing capacity and rural-population share—only processing capacity behaves as expected across all sectors. As expected, production shares increase with state processing capacity, which is consistent with the findings of Roe, Irwin and Sharp (2002) for the 15 states they studied. However, farmland prices have an unexpected positive sign, since high farm-real-estate value is associated with a higher share of production. An interpretation of this result is that expansion of these operations, and their need to access land to spread increasing quantities of manure on fixed amounts of land, upgrade the value of farmland as farms become concentrated in fewer states. This increase in land value, following concentration in few counties, could pose another endogeneity problem. The rural proportion of the state population has an unexpected negative impact on state shares of hog and dairy production, while fed-cattle inventory shares increase as expected with the proportion of the rural population. This can be partially explained by the pattern of geographic concentration. Hog and dairy inventories grew mainly in non-traditional states (Utah, Oklahoma, and North Carolina for hogs; Arizona, Idaho, and California for dairy), while the largest beef-production increases were in the traditional beef states of Kansas, North Dakota, and Texas[12]. These remain relatively non-populated regions, without much urban sprawl; therefore, agricultural-land scarcity is not an issue. In non-traditional production states, potential nuisance complaints and the NIMBY attitude from non-farm rural residents can deter the expansion of livestock production. The likelihood for conflict between farmers and neighbors is thus enhanced by population levels in rural areas when all other factors are constant—including land availability.

The hog and dairy sectors share another three variables that significantly affect the share of inventory for both sectors in the same direction—environmental stringency, farm-labor wage, and share of agriculture in state economy. Both sectors show a decrease in inventory share with higher environmental stringency and higher farm-labor wage. Their shares increase with a larger portion of the state economy coming from agriculture. Climate is significant in both sectors, but higher temperatures are associated with higher hog inventory and lower dairy inventory. This is consistent with the large increase in hog production in a few states that tend to be in the southern part of the country, and the increase in dairy production in relatively cooler regions, away from warmer states, particularly in the Southeast.

Mirroring the dairy shares, the fed-cattle inventory shares increase unexpectedly as land availability decreases. Unemployment rate—one of the proxy variables used for local business conditions—and precipitation seem to be irrelevant to the location decision of livestock operations.

POLLUTION HAVEN

As seen above, the coefficient for the environmental regulatory stringency is negative and statistically significant for both the hog and dairy sectors, which substantiates the pollution haven hypothesis. A ten percent[13] increase in the degree of relative stringency was estimated to decrease the state share of national hog production by three percent and the dairy share by just one hundredth of one percent. Clearly, environmental stringency affects the hog sector more than it does the dairy sector, while the coefficient for the fed-cattle sector is not significant. This difference may be explained by the fact that the dairy sector is still less concentrated (entropy measure of 0.79) and still dominated in many regions by independent production. Local citizens and groups have demonstrated more acceptance of locally controlled, large-scale production than corporate (non-local) production. The hog and dairy relationship runs counter to

[11] More detailed results can be found in Herath, Weersink, and Carpentier, 2005.
[12] New York also had a large increase (200 percent) in beef production. However, this percentage represents an increase from 10 to 30 thousand heads, while Kansas (which had the lowest production level among Kansas, Texas, and North Dakota) showed an increase of 1450 thousand head, up to 2.3 million in 2000.
[13] The interpretation of this result is blurred by the fact that the stringency measure is a relative measure.

previous studies in agriculture, which found livestock increases with environmental stringency (Metcalfe, 2001; Osei and Luxminarayan, 1996; Mo and Abdalla, 1998). These previous studies suggest that inventory levels increased, and then regulations followed, rather than the regulations being set ex ante to constrain production decisions. The divergence in the results found in this study and that support the pollution haven hypothesis could be due to the use of a time varying regulatory stringency measure and the accounting for possible endogeneity between the measure and hog production shares—two measures not taken up in previous studies. It is also plausible that environmental stringency, which may not have been significant when these studies were conducted, has significantly increased over the last five to ten years.

The environmental stringency coefficient is not significant for the fed-cattle sector. An explanation for this may again lie with the difference in the patterns of geographic concentration between the dairy and hog sectors on the one hand and the fed-cattle sector on the other. Beef production increased only in the three states that had the highest numbers a generation ago. These remain relatively non-populated regions; thus, expansion may have been influenced by factors other than environmental regulations.

DRIVERS OF LOCATION DECISION

Elasticities (Table 6) represent the responsiveness of a sector's inventory share to a change in one of the explaining variables. Clearly, processing capacity and rural-population share have the greatest consistent effect on the inventory shares of all three sectors. However, differences do exist across each sector. After rural-population share, temperature, farm-labor wage, processing capacity, and environmental stringency all have large elasticities in the hog sector. Dairy inventory shares respond most to rural-population share, processing capacity, mean temperature, farmland availability and farm-labor wages. For instance, a ten percent increase in the farm-wage rate is predicted to decrease a state's share of the national dairy inventory by 1.6 percent. In the fed-cattle sector, rural population is also the most important factor, followed by processing capacity, farmland availability, and output-to-corn-price ratio.

By using state average values for the explanatory variables instead of national averages to calculate state-specific elasticities for all significant variables by sector, and by using those elasticities as weights, a map showing the likelihood that a state might see growth in inventory can be generated. All other things being equal, Figure 3 shows, expectedly, that Iowa is the most likely state for hog inventory growth using the model above. Next in line are Kentucky, Minnesota, Nebraska, North Carolina, Missouri, South Dakota, Vermont, and West Virginia. Many other states show a medium likelihood and few show little likelihood. Surprisingly, Utah, a state with large recent increases in hog inventory, is not identified as a state with high likelihood, perhaps because the state slaughtering capacity has decreased from 1997 to 2000. Areas most likely to host additional inventory are all situated within states that have showed an augmentation pattern for the hog sector (see Figure 1a). A similar analysis puts Wisconsin in first place, closely followed by California and Minnesota, as the most likely states to receive additional dairy inventory (Figure 4). Only ten other states show a medium likelihood of receiving additional inventory. Close to 20 states have very low likelihood. Figure 5 shows Iowa, Kansas, Nebraska, and Texas as the most likely states to receive additional fed-cattle. Another seven states are somewhat likely to receive additional fed-cattle inventory.

5. Conclusions

Industrialization has given the livestock sector mobility. This increased mobility, in turn, has allowed livestock farms to cluster, presumably in localities with superior natural endowments, better labor-market conditions, and a business environment that offers strong agglomeration economies and favorable tax policies. These factors have given rise to a geographic concentration of production around fewer large processing plants scattered throughout the country. The aim of this paper was to shed light on the relatively little-known patterns of geographic concentration that result from this industrialization, and to improve the understanding of the main drivers behind location choices in the livestock sector.

This geographic concentration can be accompanied by positive local-labor and economic impacts and negative environmental and human-health problems, such as air and water pollution, as well as nuisance effects associated with foul odor. Patterns of spatial changes in animal production within the U.S. result from the interactions between public policy, including federal- and state-level farm programs and environmental regulations, technological advances, market forces, and social factors. In a context of increasing disparity among the sub-national environmental regulations for livestock operations (Environmental Law Institute, 2001; Speir et al. 2003) and among the patterns of enforcement of these regulations (Speir et al. 2003), special attention was paid to the importance of state environmental-regulation stringency in explaining this location choice over the last 25 years.

It was important, however, to weigh the importance of environmental stringency relative to other factors affected by federal, but especially state, policies such as the state's general business climate, relative input and output prices, and livestock infrastructure, in addition to natural endowment factors that create "natural" comparative advantages for a state. This paper first documented the patterns of change in the geographic concentration of production in U.S. hog, dairy and fed-cattle production in the 48 contiguous states for the 1976–2000 period, and then used multivariate analysis to identify those factors that can best explain these patterns.

PATTERNS

Concentration continues in the three sectors, with the largest increase in the fed-cattle sector, which was the least concentrated in 1975. At the U.S. level, hog production has shown a diffusion pattern between 1975 and 1980, an attrition pattern between 1980 and 1990 and, since the 1990s, an augmentation pattern (a situation when both concentration and absolute production level increase). In contrast, the dairy sector has shown a pattern of attrition (increased concentration and decreased production levels) since 1975, and the fed-cattle sector, a pattern of augmentation over the same period. Regional changes show generally that the Eastern states are losing to the Central and Western states. The hog and dairy sectors are relocating production toward the Western states while fed-cattle production is less mobile and therefore continues to grow in the Western states. What is interesting is that hog and dairy production is moving away from traditional production regions while fed-cattle production continues to grow in its traditional regions. The question remains: what are the drivers of the geographic shifts in the hog and dairy sector toward the Central and Western states and of the continued production of fed-cattle in the East? Are these shifts the result of livestock producers responding to differences in environmental regulatory stringency, to natural endowment that could not be taken advantage of before the industrialization of a given sector, or to favorable relative prices and livestock infrastructure support? A multivariate analysis helped us answer that question.

DRIVERS

In addition to testing the pollution haven hypothesis in the livestock sector, this paper aimed to identify those factors—including environmental regulations, natural endowment, policies etc.—that have affected past location decisions. Previous studies have tended to reject the pollution haven hypothesis in agriculture—that livestock production operations relocate to areas with less stringent environmental regulations to lower their costs—but found that inventory-level increases were followed by the ratification of stringent environmental regulations. These studies did not benefit from a time series of environmental stringency to account for the relative stringency of state regulation over time. Most previous studies also did not correct for the tendency of states to enact more stringent environmental regulations once state inventories are already high, and when environmental and human impacts rallied neighboring citizens to ask for stricter regulations and/or for the banning of new operations in their neighborhood—the

NIMBY factor. By developing state-specific measures of regulatory stringency over time and accounting for the potential endogeneity between inventory levels and environmental regulations, the present study arrived at different results: that regional production shares for hogs, and to a lesser extent dairy, have increased in those regions with relatively more lenient regulatory regimes. Thus state environmental regulations have risen to a level that does affect the location decisions of the hog and dairy sector. Environmental regulation stringency was not important in explaining variations in fed-cattle inventory across states. Perhaps this is because this industry keeps growing in traditional states, where earlier stages of animal growth are material-based—relying mainly on locally available natural comparative advantages such as abundant and inexpensive pasture. Another explanation might lie with the organizational arrangements. Whether, for instance, states where fed-cattle are concentrated have a culture of relying on family or local labor and inputs as opposed to contractual arrangements should be explored in the future.

Recent revisions of federal regulations have imposed a broader federal mandate on CAFOs than previously existed, but state-level regulation still adds significantly to the federal scheme, and regulations still vary significantly from state to state. Results of this study show that these variations in environmental regulations influence the siting decisions of the hog and dairy sectors. Pollution havens in the hog and dairy sectors may lead to a race to the bottom. Indeed, if states relax or do not enhance the stringency of environmental regulations despite high environmental and social costs, in order to lure higher rates of investment, the resulting allocation of livestock production across states will be less than optimal. A social optimum allocation does not call for harmonization of requirements and incentives across states, but this broader federal role might be warranted, especially when transboundary or intergenerational environmental and social problems result from these pollution havens.

A few other conclusions can be drawn. First, no single factor affecting the location decision of livestock production dominates, be it environmental stringency, relative prices, livestock infrastructure, business climate, or natural environment. Instead the important variables are spread across these types of factors. Second, farmland prices, processing capacity, and rural-population share affect the location decisions of all three sectors though not necessarily in the same direction. Roe, Irwin and Sharp (2002) had also found that market access measured by the state processing capacity was an important factor for location decision in the hog sector. This study extends these results to the dairy sector. Third, farm-labor wage and temperature are important in the location decision of both hog and dairy operations.

IMPLICATIONS

Past environmental and health problems arose because (1) prior knowledge was lacking about the relationship between livestock-farm concentration and its environmental impacts; and (2) national standards were not tailored to local environmental sensitivity. Now that the potential environmental impacts of concentrated livestock farms are more clearly defined (Copeland and Zinn, 1998; US Senate Committee on Agriculture, Nutrition and Forestry, 1997; Abdalla, Lanyon, and Hallberg, 1995), there is good reason to be proactive and to avoid future conflict, unnecessary environmental damage, and reactive regulations that are costly to the industry and to society.

However, the question remains as to how to tailor national and state standards to local environmental sensitivity. Tailoring standards to each area of the country would be prohibitively expensive. Instead, efforts could be targeted to environmentally sensitive areas with high probabilities of becoming future livestock operation sites. This approach would be more cost effective (Carpentier, Bosch and Batie, 1998), and the information would be valuable to rural interest groups and decision makers who are already devoting resources to determine which industry to attract in their pursuit of sustainable economic development (Gasteyer, Flora and Kilkenny, 1999). Knowing where the livestock sector is most likely to be located would help determine ex ante whether local policies are sufficient to protect natural resources and environmental conditions in these locations (e.g. height of the water table, safety in hurricane-prone areas, proximity to protected areas or endangered species, porosity of the soil). By overlaying these variables, following the Kellogg, Maizel and Goss (1992) approach, we would generate maps of areas where the industry is likely to locate but where the natural-resource base may not assimilate the wastes that will be generated. In these cases, proactive action could be taken to prevent production in these sensitive areas or to limit production intensity to levels below the area's assimilative capacity. Production could then naturally gravitate to areas resilient enough to support these productions, providing opportunities for sustainable livestock development. In addition, consulting and engaging the local population at the onset, where inventories are likely to increase, would also help overcome the NIMBY syndrome and increase acceptance by building a climate of trust and understanding. Costly environmental regulations aimed at protecting those resources and at reducing local pressure to ban production can be avoided. The industry can also decide, with greater certainty, whether to locate in the region and, if so, have a better and more constant estimate of their production and compliance costs. Paraphrasing Abdalla, Lanyon, and Hallberg (1995), this

study's findings can help resynchronize state and federal farm-policies by encouraging the reconciliation of industrialization and the concentration of livestock production with local concerns. Results can also help state and local players engage in designing realistic, enforceable and proactive policies to ensure sustainable livestock development. Rules can also be created to ensure that policies are properly enforced and to avoid jurisdictional issues between environmental and agricultural agencies.

We cannot predict with certainty where each livestock sector will be relocated, but we now know more about the important factors that seem to be associated with larger inventories of livestock. The above results suggest, for instance, that local and state decision-makers can influence the likelihood of the concentration of production in their jurisdiction by influencing the siting of processing facilities. This and other significant factors influencing the location decisions of each livestock type at the state level have been mapped using geographic information systems (GIS). Rural-population share, temperature, farm-labor wage, processing capacity, and environmental stringency were all significant and all have large elasticities in the hog sector. The state elasticities were computed and used to weight each of these variables. The results are presented in Figure 3. Rural-population share, processing capacity, temperature, farmland availability, and farm-labor wages were weighed the same way to map important factors in the location decision of dairy operations (Figure 4). For the fed-cattle sector, rural population, processing capacity, farmland availability, and output-to-corn-price ratio were weighed to create Figure 5. Maps for each of these variables can also be found on the Website created to support this document: http://www.ciesin.columbia.edu/winrock-livestock.

6. Remaining Limitations and Future Research Needs

As in Park, Seidl, and Davies (2002), modeling difficulties arose because of the endogeneity between the dependent variables and the level of regulation. As was explained above, in the Results section, the stringency of regulation tends to increase once the inventory level has increased. However, by correcting for this endogeneity, it was possible to show that once these regulations are stringent enough, they do affect the location decision of hog and dairy operations.

Except for the dairy sector, a large part of the variation in the models remains, however, unexplained. Further improvements in these models would be needed to improve the ability to explain these variations and thus predict future movements. One major improvement would be to have access to series of farms decisions, over a long period of time, to enter or expand production across states or better yet, counties. This would be preferable to the inventory levels as a dependent variable, which do not discriminate between expansion or contraction of existing facilities, between the introduction of new facilities or the closing of old ones.

Model improvements may also help us better understand the direction of the relation between the share of livestock inventory and the various explanatory variables. Indeed, four of the ten significant variables explaining dairy variations had unexpected signs: three out of five for the fed-cattle sector, and two out of seven for the hog sector. In light of this, we can argue that either some endogeneity remains or that these signs are right and our predictions much change. One remaining potential endogeneity is between farmland prices and inventory. Farmland prices were consistently significant but unexpectedly positive, indicating that, subsequent to the expansion and geographic concentration of these operations—with associated limited access to land on which to spread manure—land value increases.

An other model improvement would be to include omitted variables. Welsh, Carpentier, and Hubbell (2001) and Smith and Kuch (1995) found that corporate farming laws did have an effect on patterns of geographic considerations, while Smith (1995) found that large hog producers consider environmental hassles and local opposition in deciding not to expand. Given that state and counties with anti-corporate laws are more likely to show local opposition, information about anti-corporate laws could be used directly, as an additional explanatory variable, rather than including it in the stringency measure. Anti-corporate laws may reflect a preference for a type of ownership and the management of farms across farms. Measures of affinity for a production type, such as production knowledge or cultural affinity, might also be developed to explain variation, relocation, and concentration of livestock across states. In addition to anti-corporate laws, Smith and Kuch (1995) found that baseline environmental vulnerability affects how farms respond to environmental regulations. Measures of natural endowment, such as depth to the water table, soil porosity, and local ecosystem tolerance to excess nitrogen and phosphorous, could also be added as explanatory variables. Finally, Metcalfe (2000) found that small hog farms are influenced by traditional factors—output and input prices, transportation costs, and existing agricultural infrastructure or agglomeration effects. The location decisions of larger hog farms were found to be affected only by the latter. Given that small and large farms' decisions appear to be affected by different drivers, future research should attempt to segment the sample into small and large or CAFO operations.

Given the importance of the processing-capacity variable, one way to improve these models would be to take advantage of GIS-based data to account for distance to processing plants. Indeed, some processing capacity might be located nearby but in a neighboring state, and thus not captured by the model.

Despite substantial efforts to collect the information, the absence of time-series data across counties, of environmental regulations and of new farm operations remains a major obstacle to testing the pollution haven hypothesis for livestock farming in general. Nevertheless, we now have established a reasonable model to test the hypothesis for the hog, fed-cattle and dairy sectors and have developed a theoretically-based environmental stringency measure to include in this model. To be useful for local decision-making, this model would ideally have been applied at the county level, as planned in the original proposal. However, if state-level data remain elusive, obtaining county-level data is not feasible without a concerted effort to include this type of information in the Census and other data-collection efforts. Ideally, a NASDA review of state livestock environmental regulation studies would be conducted periodically and would include estimates, by county and state, of the costs to producers of meeting environmental regulations. This measure could then be used directly in the regression instead of using a proxy environmental stringency measure.

As we learn more about the underpinning of the theoretical model that captures the location decision of the livestock sector, more effort could be expended into collecting the data and estimating a simultaneous equation system in which inventory levels could be regressed against environmental regulation stringency and other factors, and a second equation would regress environmental regulatory stringency against livestock inventories, income levels, and other variables.

Though much improvement has been accomplished, the stringency of environmental regulations does not account for the enforcement level. Enforcement of environmental regulations at livestock operations varies widely (Speir et al., 2003). The agencies responsible for enforcement are frequently understaffed, and their staff is often not specifically trained to respond to livestock issues. Also, in some cases, jurisdictional issues arise between environmental agencies and agricultural agencies. Thus the stringency measure that captures regulation may not reflect actual stringency. Further work needs to be done to capture variation in enforcement.

Clearly, stringency has increased in states with increased livestock production. It would be interesting to study whether stringency also increases in states where attrition was found. It will also be interesting to see if these operations relocate in states with lower environmental stringency, and if the other factors identified in this paper turn out to be important for the location decision in each of the livestock sectors under study.

Annex 1: THEIL'S ENTROPY MEASURE

Theil's entropy measure has been used as an index of industrial concentration in several studies (Horowitz, 1970; Sporleder, 1974; Hubbell and Welsh, 1998). Given n states in the data set with θ_i representing the share of livestock inventory in state *i*, absolute entropy, $H(\theta)$, is defined as:

(1) $$H(\theta) = \sum_{i=1}^{n} \theta_i \log_2 \theta_i^{-1}$$

The absolute entropy measure is bounded between $0 \leq H(\theta) \leq \log_2 n$. If all production is concentrated in one state so that $\theta_i = 1$ for that state, then $H(\theta) = 0$ (minimum dispersion). If production is spread equally among all states so that all qi are equal, then $H(\theta) = \log_2 n$ (maximum dispersion). $H(\theta)$ can be used effectively to discern patterns of temporal change in geographic concentration for a region in which the number of subunits (i.e., number of states in a region) are comparable across time. However, $H(\theta)$ cannot be used to compare the geographic concentration across two regions with a different number of states.

Relative entropy, ($R(\theta)$), allows a comparison of concentration across different-sized regions by expressing each region's absolute entropy measure as a ratio of its maximum entropy.

(2) $$R(\theta) = H(\theta) / \log_2 n$$

If this ratio is equal to one, livestock inventories are dispersed equally among states and will tend toward zero as production becomes more geographically concentrated.

Total relative entropy, $R(\theta)$, can be disaggregated into between-set and within-set entropies. For example, if the *n* states of the sample are categorized to *s* sets or regions, one can calculate the entropy for these *s* regions (regions are indexed by *m*) by taking each region's share of the national production level as Ψ_m, where $\sum_{m=1}^{s} \Psi_m = 1$. If Ψ_m is expressed in terms of θ_i, $\Psi_m = \sum_{i=1}^{t} \theta_i$, where *t* is the number of states in the mth set (region), the between-region relative entropy measure, $R_{BR}(\theta)$, is:

(3) $$R_{BR}(\theta) = \sum_{m=1}^{s} \psi_m \log_2 \psi_m^{-1}$$

Similarly, the within-region relative entropy measure, $R_{WR}(\theta)$, is calculated as:

(4) $$R_{WR}(\theta) = \sum_{m=1}^{s} \psi_m H_m(\theta)$$

where $H_m(\theta)$ is defined as:

(5) $$H_m(\theta) = \sum_{i \in m} [(\theta_i / \psi_m) \log_2 (\psi_m / \theta_i)]$$

Total relative entropy is the sum of between-region entropy $R_{BR}(\theta)$ and within-region entropy $R_{WR}(\theta)$.

Annex 2: TEST AND ADJUSTMENT TO ESTIMATORS

To test for endogeneity between livestock inventories and environmental regulatory stringency, a Durbin-Wu-Hausman test is used. This test requires the specification of appropriate instrumental variables for the endogenous right-hand-side variables (Davidson and MacKinnon, 1993). As sources of exogenous variation in environmental regulatory stringency, we have used one-year-lagged values of the growth rate in aggregate livestock units[14], two-year-lagged values of the growth rate in aggregate livestock densities[15], total residential population of the state, and the state median income of a four-member family. If the intensity of livestock operations were to influence a state's environmental regulatory stringency, it must be manifested through the potential hazards of manure disposal and odor-related nuisances, as captured by the growth rates in aggregate livestock inventories and their densities. Higher growth rates in aggregate livestock inventories and/or higher growth rates in aggregate inventories relative to the available manure-disposal area could prompt harsher regulatory regimes. Concerns over environmental quality increase with income, and generally, families that are better off will not want polluting industries in their backyard. Moreover, nuisance complaints regarding livestock farms from neighbors are likely to increase the greater the residential population in rural areas.

Using these four instrumental variables, the Durbin-Wu-Hausman test is performed[16]. The test is performed in two steps or by running two regressions. The first regresses environmental stringency on all the explanatory variables including four instrumental variables. Residuals of this first regression are then used in a second regression as an explanatory variable, along with all other explanatory variables, with the exception of the instrumental variables. In this latter regression the dependent variable is the livestock share. The null hypothesis is that there is a bias, in which case the coefficient of the residual variable (from the first regression) is zero and not statistically significant. The p-value for the coefficients of the residuals for the hog sector (p=0.27) and the fed-cattle sector (p=0.24) were not significant. The fixed effects model was thus estimated for these two sectors with two-stage least squares. The p-value for the coefficients of the residuals for the dairy sector (p=0) was significant. Thus an ordinary least squares was used to estimate state shares for the dairy sector.

[14] Aggregate livestock inventories are calculated with the EPA (2001) approach of taking 1000 animal units as equivalent to 1000 slaughter and feeder cattle, 700 mature dairy cattle, and 2,500 swine, each weighing more than 25 kilograms.

[15] Livestock density is calculated by dividing aggregate livestock units by the state farmland area.

[16] The results of the first-stage regression (with p-values in parentheses) are:

Stringency Index =	1.927 −	0.409 Growth Rate$_{-1}$ +	0.053 Density$_{-2}$ +	0.0006 Popn −	0.0004 Income
	(0.00)	(0.04)	(0.21)	(0.01)	(0.00)

Table 2. **CHANGES IN US HOG, DAIRY AND FED-CATTLE INVENTORIES, 1975-2000 ('000 heads)**

	HOGS			DAIRY			FED-CATTLE		
NEW ENGLAND	**1975**	**2000**	**%**	**1975**	**2000**	**%**	**1975**	**2000**	**%**
CT Connecticut	8	4	-52	54	26	-52	0	0	0
ME Maine	7	7	-6	61	40	-34	0	0	0
MA Massachusetts	50	20	-60	55	23	-58	0	0	0
NH New Hampshire	8	4	-51	33	18	-45	0	0	0
RI Rhode Island	8	3	-64	6	1.8	-70	0	0	0
VT Vermont	5	3	-40	193	159	-18	0	0	0
Sub Total	**87**	**41**	**-53**	**402**	**267.8**	**-33**	**0**	**0**	**0**
MIDEAST									
DE Delaware	50	29	-42	11.7	10	-15	0	0	0
MD Maryland	182	58	-68	141	84	-40	22	17	-23
NJ New Jersey	81	14	-83	47	16	-66	5	3	-40
NY New York	110	80	-27	917	686	-25	10	30	200
PA Pennsylvania	660	1030	56	699	617	-12	83	75	-10
Sub Total	**1083**	**1211**	**12**	**1815.7**	**1413**	**-22**	**120**	**125**	**4**
GREAT LAKES									
IL Illinois	5600	4150	-26	243	120	-51	500	230	-54
IN Indiana	3900	3350	-14	215	145	-33	250	120	-52
MI Michigan	700	950	36	411	300	-27	200	200	0
OH Ohio	1675	1490	-11	400	262	-35	290	190	-34
WI Wisconsin	1150	610	-47	1812	1344	-26	135	160	19
Sub Total	**13025**	**10550**	**-19**	**3081**	**2171**	**-30**	**1375**	**900**	**-35**
GREAT PLAINS									
IA Iowa	12600	15100	20	401	215	-46	1200	1100	-8
KS Kansas	1650	1520	-8	142	91	-36	920	2370	158
MN Minnesota	3000	5800	93	884	534	-40	380	285	-25
MO Missouri	3200	2900	-9	302	154	-49	200	100	-50
NE Nebraska	2700	3050	13	152	77	-49	36	70	94
ND North Dakota	350	185	-47	174	102	-41	1160	2440	110
SD South Dakota	1400	1320	-6	174	102	-41	345	350	1
Sub Total	**24900**	**29875**	**20**	**2229**	**1275**	**-43**	**4241**	**6715**	**58**
SOUTHEAST									
AR Arkansas	302	685	127	88	42	-52	21	11	-48
AL Alabama	680	165	-76	90	25	-72	42	4	-90
FL Florida	240	40	-83	197	157	-20	60	0	-100
GA Georgia	1300	380	-71	129	87	-33	68	3	-96
KY Kentucky	1000	430	-57	287	132	-54	37	15	-59
LA Louisiana	155	29	-81	136	58	-57	10	0	-100
MS Mississippi	300	315	5	122	36	-70	10	0	-100
NC North Carolina	1900	9300	389	145	71	-51	45	5	-89
SC South Carolina	480	290	-40	58	23	-60	26	6	-77
TN Tennessee	920	230	-75	215	95	-56	10	10	0
VA Virginia	660	425	-36	173	120	-31	31	27	-13
WV West Virginia	50	10	-80	41	17	-59	11	7	-36
Sub Total	**7987**	**12299**	**54**	**1681**	**863**	**-49**	**371**	**88**	**-76**
SOUTHWEST									
AZ Arizona	97	9	-91	67	139	107	319	272	-15
NM New Mexico	53	3	-94	47	16	-66	135	116	-14
OK Oklahoma	300	2310	670	119	91	-24	232	435	88
TX Texas	780	920	18	333	348	5	1327	2910	119
Sub Total	**1230**	**3242**	**164**	**566**	**594**	**5**	**2013**	**3733**	**85**
ROCKY MOUNTAINS									
CO Colorado	290	840	190	74	89	20	755	1200	59
ID Idaho	60	24	-60	147	347	136	185	315	70
MT Montana	165	155	-6	26	18	-31	79	70	-11
UT Utah	47	550	1070	79	96	22	52	35	-33
WY Wyoming	30	108	260	11.8	5.6	-53	38	90	137
Sub Total	**592**	**1677**	**183**	**337.8**	**555.6**	**64**	**1109**	**1710**	**54**
FAR WEST									
AK Alaska	1	1	0	90	25	-72	0	0	0
CA California	138	150	9	800	1523	90	688	415	-40
WA Washington	63	27	-57	181	247	36	11	0	-100
HI Hawaii	58	26	-55	13.1	8.1	-38	36	21	-42
NV Nevada	9	8	-17	14	25	79	68	50	-26
OR Oregon	95	32	-66	91	90	-1	135	235	74
Sub Total	**364**	**243**	**-33**	**1189.1**	**1918.1**	**61**	**938**	**721**	**-23**
Grand Total	**49268**	**59138**	**20**	**11301.6**	**9057.5**	**-20**	**10167**	**13992**	**38**
Relative Entropy	**0.72**	**0.67**	**-7**	**0.84**	**0.79**	**-6**	**0.76**	**0.64**	**-16**

Source: USDA, NASS

Table 3. **DEFINITION AND SOURCES OF EXPLANATORY VARIABLES AFFECTING LOCATION CHOICE OF LIVESTOCK PRODUCTION**

DEPENDENT VARIABLE	DEFINITION	NUMBER OF OBSERVATIONS	MEAN	STANDARD DEVIATION	SOURCE
Share	State inventory (thousand heads) of each sector (hog, dairy, fed cattle) divided by total national inventory	1200 (each sector)	0.02081 (hog) 0.02083 (dairy) 0.02083 (beef)	0.0424 (hog) 0.0308(dairy) 0.0402(beef)	Agricultural Statistics (USDA) NASS 1975-2000; (http://usda.mannlib.cornell.edu/reports/nassr/other/plr-bb)
Independent Variables					
Regulatory Stringency					
Stringency Index	Relative Regulatory Stringency Index	1200	1.00	0.64495	Per capita environmental quality control expenditure- 1975, 1978, 1979, 1986, 1988, Conservation Foundation Index-1984; Renew America Index-1987/89; Status of 50 state policies (in Green Index 1991/92); Southern Studies Index 1994; Metcalfe (2000)- 1994 and 1998; Authors-2000 and years without an index were filled with adjacent years index values. Normalized by dividing through arithmetic mean.
Relative Prices					
Output/input price	Hog, beef, dairy and corn price ratio (hog prices are $/cwt.; dairy prices are are $/cwt. for all milk; beef prices are $/head and corn prices are $/bushels)	1200 (each sector)	17.33 (hog) 5.296 (dairy) 21.238 (beef)	4.14 (hog) 1.14 (dairy) 6.92 (beef)	Agricultural Prices (USDA) 1975-1997; Agricultural Prices Summary for 1998-2000 http://usda.mannlib.cornell.edu/reports/nassr/price/zap-bb.
Energy Price	State electricity prices for farms ($/K.W hr) Energy costs are proxied by the industrial sector energy price and expenditure estimate ($/million BTU)	1200	11.47	3.82	Energy Information Administration (EIA) http://www.eia.doe.gov/neic/historic/seperelectric.htm.
Labor Price	Farm labor wage rate ($/hr)	1200	4.18	0.47	Agricultural Statistics (USDA) 1975-1979; USDA 1980-1990, (http://usda.mannlib.cornell.edu/datasets/inputs/91005); NASS 1991-2000 (http://usda.mannlib.cornell.edu/reports/nassr/other/pfl-bb/2000/fmla1100.txt).
Farmland Price	Value of farmland ($/ac)	1200	1044	844	Agri. Statistics (USDA) 1975-1997 NASS 1998-2000; (http://usda.mannlib.cornell.edu/reports/nassr/other/plr-bb)
Livestock Infrastructure					
Processing Capacity	Number of hogs and beef slaughtered (000 head) for hog and fed-cattle sector. Whole milk equivalent of manufactured dairy products (000 lbs.) for dairy sector	1200 (each sector)	17.33 (hog) 1731301 (dairy) 745 (beef)	4.14 (hog) 3548710 (dairy) 1489 (beef)	Livestock Slaughter Summary (USDA,) for hog and beef Dairy Products: Annual Summary (USDA), for dairy
Agriculture's Economic Importance	Agriculture's share of Gross State Product	1200	0.0246	0.02854	Bureau of Economics Analysis (http://www.bea.doc.gov/bea/regional/gsp).
Business Climate					
Unemployment rate	Percent of workforce unemployed	1200	6.16	2.11	Bureau of Labor Statistics (http://data.bls.gov/labjava/outside.jsp?survey=la).
Land Availability	Farmland area (000 acres)	1200	20742	22474	Agricultural Statistics (USDA) NASS 1975-2000; (http://usda.mannlib.cornell.edu/reports/nassr/other/plr-bb)
Natural Endowment					
Precipitation	Mean annual precipitation (mm)	1200	36.47	14.75	Economic Research Service 1975-1994 (http://usda.mannlib.cornell.edu): National Climatic Data Center 1995-2000 (http://lwf.ncdc.noaa.gov/oa/climate/research/cag3/state.html).
Temperature	Mean annual temperature (F)	1200	52.38	7.57	Same as for precipitation
Instrumental Variable for regulatory stringency					
Resident Population	State resident population (000)	1200	5070	5313	
Family income	Median annual income of 4 member family ($)	1200	30777	4264	US Census Bureau (http://www.census.gov/hhes/income/4person.html).
Growth rate of aggregate livestock unit (one year lagged)	Annual growth in aggregate animal units (700 dairy cows, 1000 beef cattle, 2500 hogs are equivalent to 1000 animal units)	1200	-0.007	0.088	from the same source for livestock inventories and farm land area
Growth rate of aggregate livestock densities (two years lagged)	Annual growth in aggregate animal units per acre of farm land area	1200 1200	-0.007 0.0174	0.088 0.409	from the same source for livestock inventories and farm land area from the same source for livestock inventories and farm land area

Table 4. **ENVIRONMENTAL STRINGENCY INDEXES FROM 1975 TO 2000**

STATE	Per capita environmental quality control expenditure a				Conservation Foundation Index 1984	Per capita environmental quality control expenditure 1986a	FREE index 1987b	Per capita environment quality control expenditure 1988a	Renew America Index 1987/1989	Status of 50 State Policies (Green Index 1991/1992)	Southern Studies 1994e	Metcalfe Index 1994f	Metcalfe Index 1998f	Index 2000
	1975	**1978**	**1979**	**1980**										
Alabama	1.107	1.637	1.897	1.730	10	15.47	16	15.73	53	10	681	6	9	2.59
Arkansas	0.948	2.371	2.332	2.430	27	13.29	18	18.24	48	9	579	3.63	7.16	4.46
Arizona	2.260	3.965	4.355	4.140	24	15.19	27	13.45	72	13	567	3.63	7.16	1.03
California	3.774	5.855	7.216	8.120	46	50.7	48	52.76	134	38	423	3.63	7.16	0.08
Colorado	4.723	5.420	5.727	5.930	26	22.26	24	23.15	75	19	377	3.63	7.16	6.99
Connecticut	6.129	7.058	5.792	5.650	32	12.44	44	19.13	117	32	442	3.63	7.16	2.96
Delaware	5.181	6.873	12.027	38.200	29	47.74	24	50.26	78	17	518	3.63	7.16	0.12
Florida	5.195	2.019	2.011	1.960	31	17.57	41	37.62	114	25	461	3.63	7.16	1.21
Georgia	2.231	2.213	2.377	4.330	25	12.63	26	14.58	80	16	544	6	9	5.24
Iowa	2.097	2.787	2.431	3.010	29	16.16	29	31.07	107	23	491	4	9	3.25
Idaho	6.150	6.017	5.834	6.860	16	51.97	16	61.5	68	13	425	3.63	7.16	2.00
Illinois	4.376	7.949	8.626	7.210	28	15.92	28	34.03	97	22	563	2	8	4.00
Indiana	1.882	3.018	3.940	4.610	36	8.48	36	9.46	79	20	687	4	6	2.62
Kansas	1.316	2.165	2.150	2.030	23	12.88	29	19.23	74	18	625	4	9	4.71
Kentucky	2.362	2.917	3.470	4.210	34	24.16	28	32.33	66	16	594	2	7	2.66
Louisiana	0.788	1.302	1.785	2.400	21	17.38	21	43.85	52	19	708	3.63	7.16	1.00
Massachusetts	5.676	8.772	11.069	11.100	44	21.32	41	40.53	123	27	389	3.63	7.16	0.00
Maryland	10.189	10.135	9.181	11.220	37	20.33	34	32.32	101	26	413	3.63	7.16	4.51
Maine	8.507	8.403	8.295	7.890	32	22.31	36	32.61	101	33	331	3.63	7.16	0.00
Michigan	3.402	2.746	4.601	5.900	30	18.68	43	23.81	107	28	541	1	3	2.00
Minnesota	3.571	6.557	12.327	5.690	47	18.03	38	29.32	114	31	381	8	9	5.35
Missouri	1.888	3.767	3.541	6.570	14	25.07	31	23.33	79	22	530	6	7	3.33
Mississippi	1.709	2.549	3.349	1.730	15	24.38	14	20.61	47	15	612	5	10	4.32
Montana	4.021	6.640	6.570	6.570	37	69.55	23	86.52	70	13	559	3.63	7.16	2.00
North Carolina	3.124	3.474	5.611	4.320	25	14.62	42	14.85	111	24	578	1	8	4.98
North Dakota	1.570	3.110	3.063	3.460	22	31.08	16	49.06	61	12	458	3.63	7.16	2.49
Nebraska	3.886	3.863	6.406	3.700	22	13.32	31	17.48	82	16	520	3	7	5.20
New Hampshire	9.852	30.69	24.73	23.010	21	32.41	32	30.62	92	19	310	3.63	7.16	1.00
New Jersey	5.182	3.953	15.145	5.480	45	27.25	47	67.86	125	31	464	3.63	7.16	1.00
New Mexico	3.497	5.137	4.202	5.600	18	24.59	23	29.66	61	36	533	3.63	7.16	2.00
Nevada	1.695	13.115	4.739	4.070	22	21.77	23	34.42	56	12	434	3.63	7.16	2.00
New York	7.247	7.244	7.420	9.510	37	12.94	43	13.21	113	32	424	1	2	1.00
Ohio	15.836	25.164	21.120	35.280	30	8.54	36	11.56	88	24	586	5	7	3.63
Oklahoma	1.105	2.169	2.490	2.420	19	14.51	29	12.52	65	13	588	4	6	4.73
OR Oregon	3.065	7.299	9.259	8.780	42	49.01	35	68.02	116	33	395	3.63	7.16	0.03
Pennsylvania	4.384	4.721	4.497	4.940	28	28.03	32	24.01	91	21	511	2	7	3.08
Rhode Island	5.371	9.404	9.626	12.220	26	26.16	30	36.06	95	31	397	3.63	7.16	0.00
South Carolina	1.776	3.160	3.129	3.340	25	16.02	31	20.36	79	15	611	3.63	7.16	0.09
South Dakota	1.468	2.915	2.903	4.010	30	75.9	23	29.74	63	5	396	2	8	2.11
Tennessee	2.157	2.848	3.024	3.760	23	15.45	29	16.5	60	14	698	3.63	7.16	2.00
Texas	1.634	2.002	2.182	2.330	22	7.09	26	6.78	66	18	703	3.63	7.16	2.09
Utah	1.663	2.443	2.366	2.570	23	24.6	16	30.41	57	13	556	3.63	7.16	2.00
Virginia	4.015	2.981	3.116	3.000	28	16.33	33	25.38	95	19	521	3	5	1.06
Vermont	8.475	19.068	12.371	13.830	32	42.94	28	36.37	91	28	282	3.63	7.16	2.05
Washington	5.620	7.198	6.561	9.240	39	38.8	29	53.45	91	28	430	3.63	7.16	2.00
Wisconsin	5.884	4.132	4.730	8.400	37	55.31	49	34.54	131	29	379	3.63	7.16	4.00
West Virginia	2.223	3.295	3.765	6.110	23	23.68	15	29.82	56	11	652	3.63	7.16	1.00
Wyoming	2.660	5.128	4.926	5.850	23	135.33	16	271.87	46	13	601	3.63	7.16	2.36
Mean	4.02	5.99	6.21	7.18	28	27.70	30	36.04	85	21	510	3.63	7.16	2.47
Used for years	1976	1977		1981 1982	1983	1985			1990	1992	1993	1995 1996	1997 1998	1999 2000

Sources: a. U.S. Department of Commerce (1998)
b. Duerkson (1984)
c. Scott (1987)
d. Renew America (1991)
e. Hall and Kerr (1991)
f. Institute of Southern Studies (1994)
g. Developed by authors and available in Table 4 below and available in Table 5 below

Table 5. **ENVIRONMENTAL STRINGENCY MEASURE BY STATE FOR 2000**

	Environmental Regulation							
STATE	**ANTI-CORPORATE**	**MORATORIA**	**LOCAL CONTROL**	**BONDING**	**COST SHARE**	**NUTRIENT STDS**	**SET-BACK**	**TOTAL**
AL Alabama	0	0	0	0	0	2	0.59	2.59
AR Arkansas	0	1	0	0	1	2	0.46	4.46
AZ Arizona	0	0	1	0	0	0	0.03	1.03
CA California	0	0	0	0	0	0	0.08	0.08
CO Colorado	0	1	1	1	1	2	0.99	6.99
CT Connecticut	0	0	1	1	0	0	0.96	2.96
DE Delaware	0	0	0	0	0	0	0.12	0.12
FL Florida	0	0	0	0	1	0	0.21	1.21
GA Georgia	0	1	1	1	1	1	0.24	5.24
IA Iowa	1	0	0	1	0	1	0.25	3.25
ID Idaho	0	1	1	0	0	0	0.00	2.00
IL Illinois	0	0	0	1	0	2	1.00	4.00
IN Indiana	0	0	1	0	0	1	0.62	2.62
KS Kansas	1	0	0	1	0	2	0.71	4.71
KY Kentucky	0	1	0	0	0	1	0.66	2.66
LA Louisiana	0	0	0	0	1	0	0.00	1.00
MA Massachusetts	0	0	0	0	0	0	0.00	0.00
MD Maryland	0	1	1	0	0	2	0.51	4.51
ME Maine	0	0	0	0	0	0	0.00	0.00
MI Michigan	0	0	0	0	0	2	0.00	2.00
MN Minnesota	1	1	1	0	0	2	0.35	5.35
MO Missouri	0	0	1	1	0	1	0.33	3.33
MS Mississippi	0	1	1	1	1	0	0.32	4.32
MT Montana	0	0	1	0	0	1	0.00	2.00
NC North Carolina	0	1	1	0	0	2	0.98	4.98
ND North Dakota	1	1	0	0	0	0	0.49	2.49
NE Nebraska	1	1	1	0	0	2	0.20	5.20
NH New Hampshire	0	0	0	0	1	0	0.00	1.00
NJ New Jersey	0	0	0	0	1	0	0.00	1.00
NM New Mexico	0	0	0	0	1	1	0.00	2.00
NV Nevada	0	0	1	0	1	0	0.00	2.00
NY New York	0	0	0	0	0	1	0.00	1.00
OH Ohio	0	0	1	0	0	2	0.63	3.63
OK Oklahoma	0	1	0	1	0	2	0.73	4.73
OR Oregon	0	0	0	0	0	0	0.03	0.03
PA Pennsylvania	0	0	1	0	0	2	0.08	3.08
RI Rhode Island	0	0	0	0	0	0	0.00	0.00
SC South Carolina	0	0	0	0	0	0	0.09	0.09
SD South Dakota	1	0	1	0	0	0	0.11	2.11
TE Tennessee	0	0	0	0	0	2	0.00	2.00
TX Texas	0	0	0	0	0	2	0.09	2.09
UT Utah	0	0	1	0	0	1	0.00	2.00
VA Virginia	0	0	0	0	0	1	0.06	1.06
VT Vermont	0	0	0	0	0	2	0.05	2.05
WA Washington	0	1	1	0	0	0	0.00	2.00
WI Wisconsin	1	0	1	0	0	2	0.00	4.00
WV West Virginia	0	0	0	0	1	0	0.00	1.00
WY Wyoming	0	0	0	1	1	0	0.36	2.36

Anti-Corporate- corporation prohibited from owning farmland or engaging in confined livestock operations (yes=1, no=0)
Moratoria- limits on total production or number of operations within state (yes=1. no=0)
Local Control- government agencies that administer and enforce major policies and regulations affecting confined livestock operations (county/township=1, other=0)
Bonding- bonding or financial assurance requirements to pay for costs of clean up of any spills or for closure of abandoned facilities (yes=1, no=0)
Cost Share-cost sharing or incentive programs provide by state to encourage compliance with regulations not including EQIP (yes=0, no=1)
Nutrient Stds- restrictions on manure application or timing (N,P, or other standard=2, N standard=1, no restrictions=0)
Set Back-minimum set back distance required by state multiplied by average farmland price in state (value normalized by dividing through by maximum set back measure
Total= sum of numerical values of the scores in all seven regulations

Note: The final index captures intensity of some variables (set back distance and nutrient standard). However, in the process of estimating time series values for the environmental regulatory stringency variable, the index is normalized along with other stringency indices representing relative position of the states where absolute values do not have implications for the relative stringency.

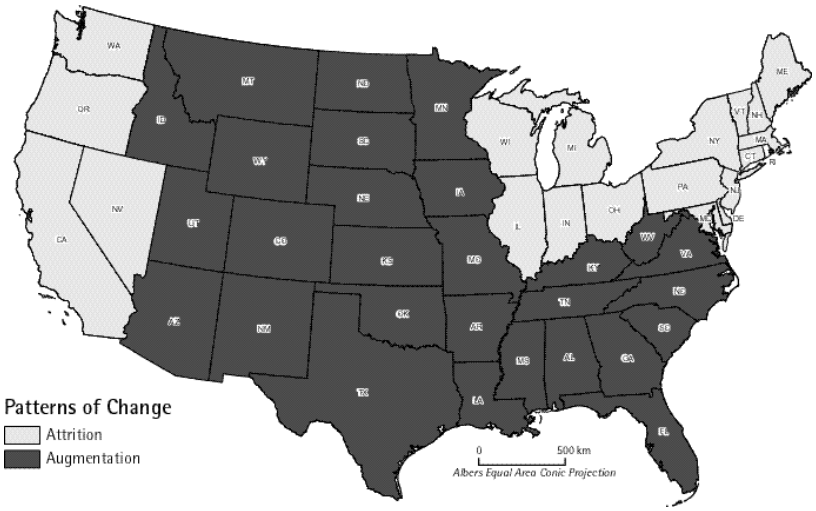
Table 6. **REGRESSION RESULTS OF MODEL EXPLAINING ANNUAL INVENTORY CHANGES IN THE US HOG, DAIRY AND FED-CATTLE SECTORS**

	HOGS	ELASTICITY	DAIRY	ELASTICITY	FED-CATTLE	ELASTICITY
Regulatory Stringency						
Relative regulatory stringency	-0.0062 (0.020)**	**-0.3019**	-0.0003 (0.023)**	**-0.0160**	0.0027 (0.119)	0.1284
Relative Prices						
Output-corn price ratio	0.0001 (0.145)	0.0805	-2.24e-04 (0.012)**	**-0.0571**	0.0001 (0.000)***	**0.1175**
Energy price	0.0002 (0.327)	0.0852	0.0002 (0.001)***	**0.0995**	-0.0001 (0.141)	-0.0797
Farm labor wage	-0.0024 (0.02)**	**-0.4910**	-0.0008 (0.005)***	**-0.1633**	-0.0007 (0.258)	-0.1453
Farmland price	2.57e-06 (0.02)**	**0.1287**	1.57e-06 (0.000)***	**0.0786**	1.38e-06 (0.045)**	**0.0690**
Livestock Infrastructure						
Processing capacity	4.08e-06 (0.000)***	**0.3638**	5.06e-09 (0.000)***	**0.4200**	1.34e-05 (0.000)***	**0.4805**
Agriculture's economic importance	0.0932 (0.001)***	**0.1103**	0.0536 (0.000)***	**0.0634**	0.0085 (0.645)	0.0100
Rural population share	-0.0008 (0.002)***	**-1.307**	-0.0003 (0.000)***	**-0.4235**	0.0007 (0.000)***	**1.1520**
Business Climate						
Unemployment rate	0.0001 (0.797)	0.0140	1.25e-06 (0.984)	0.0003	0.0001 (0.242)	0.0404
Farm land availability	-1.78e-07 (0.235)	-0.1774	-1.82e-07 (0.000)***	**-0.1812**	-3.93e-07 (0.000)***	**-0.3917**
Natural Endowment						
Temperature	0.0004 (0.079)*	**0.8866**	-1.20e-04 (0.078)*	**-0.3036**	-0.0000 (0.911)	-0.0358
Precipitation	0.0000 (0.573)	0.0458	-0.0000 (0.389)	0.0235	0.0000 (0.127)	0.0773
Wald X^2 (12 D.F.)	7714 (0.0000)	F-test (12, 1140)	208.2 (0.0000)	Wald X^2 (12 D.F.)	20278 (0.000)	

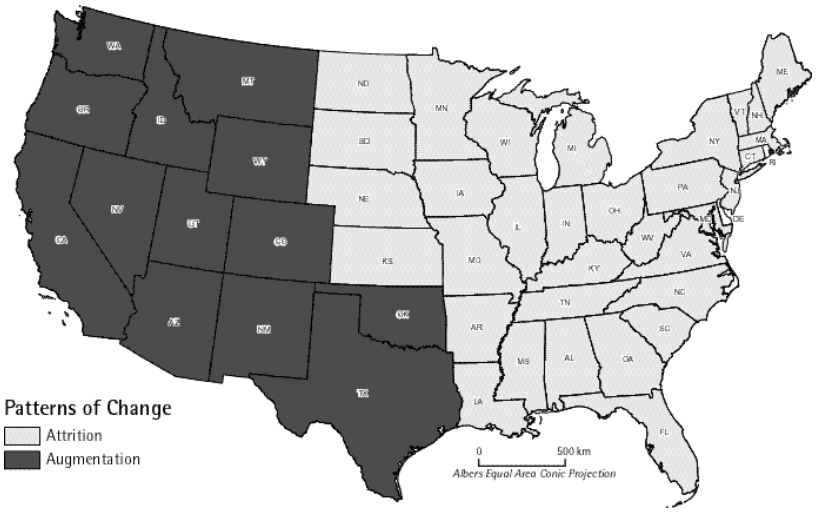
*, **, and *** are significant at .1, .01, .001 level respectively.
Values in bold are significant at at least 10% and values underlined are significant with an unexpected sign.

Figure 1. ***Dominant Patterns of Trends in Spatial Distribution for the Hog, Dairy and Fed-Cattle Sectors***

A. HOG SECTOR



B. DAIRY SECTOR



C. FED-CATTLE SECTOR

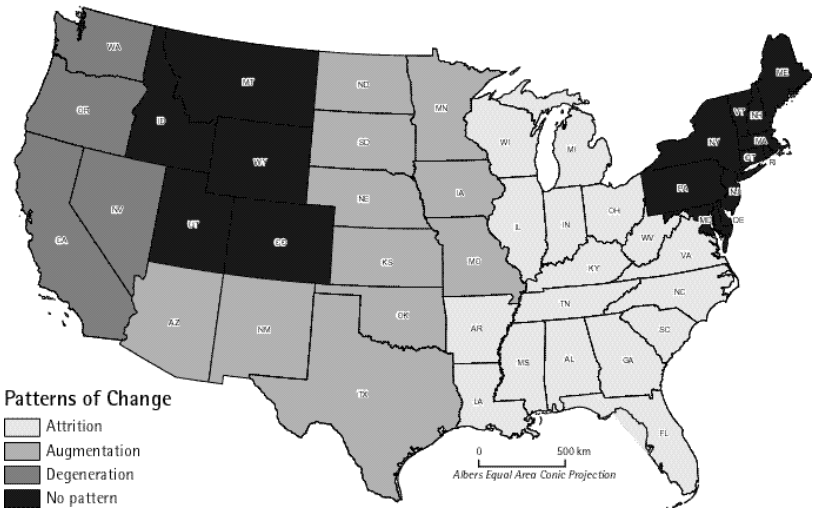


Figure 2. ***Environmental stringency indices by state***

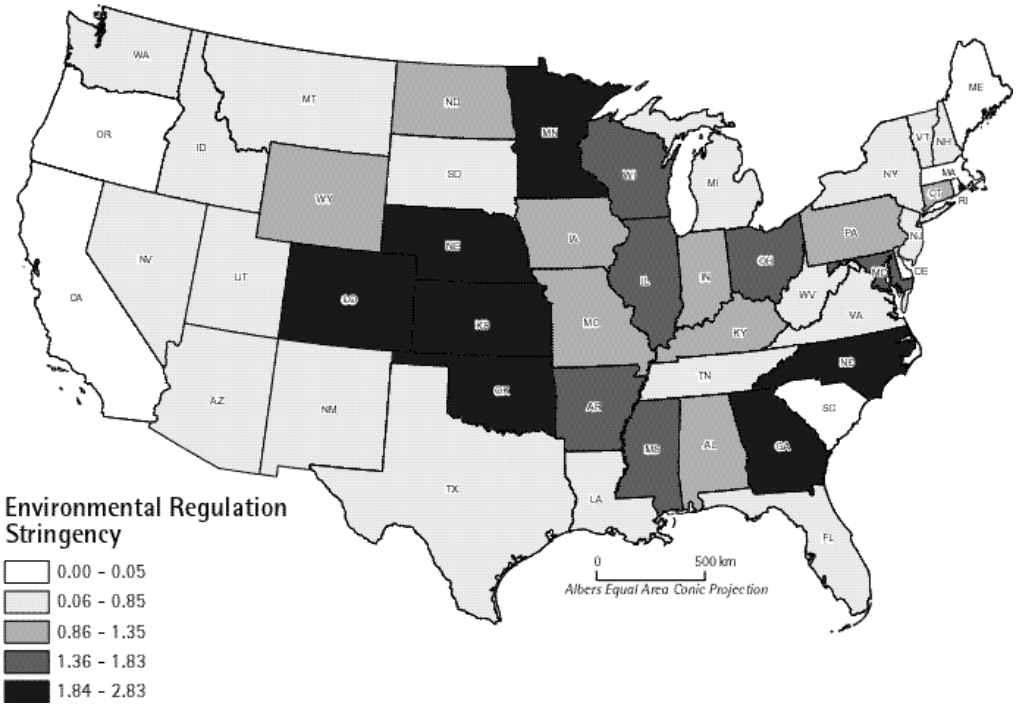


Figure 3. ***Likelihood of a state being selected for hog production using significant explanatory variables weighted by state-specific elasticities***

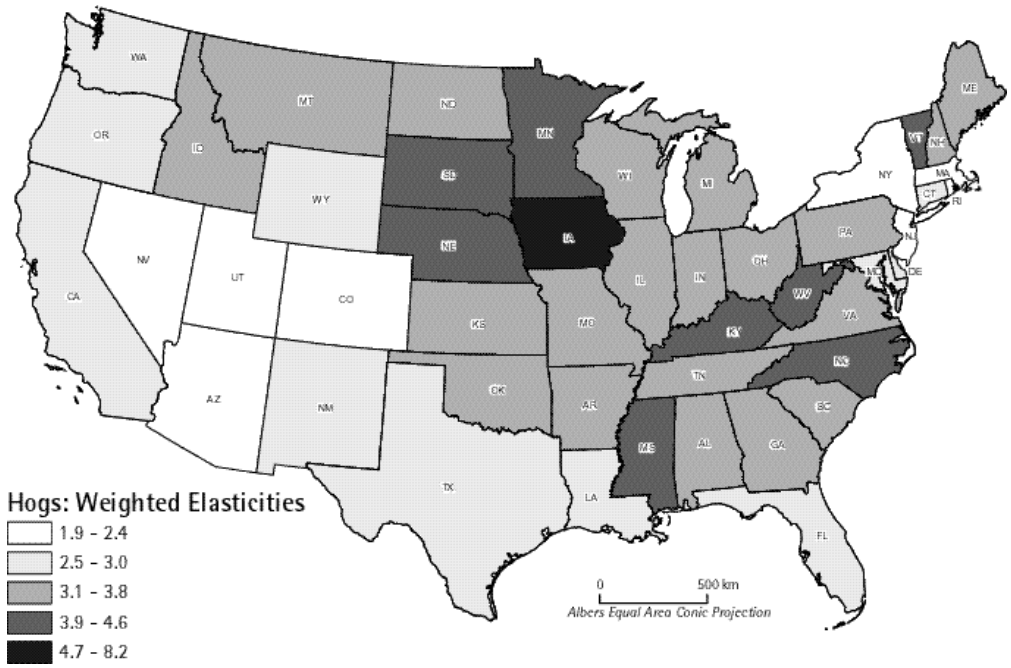


Figure 4. ***Likelihood of a state being selected for dairy production using significant explanatory variables weighted by state-specific elasticities***

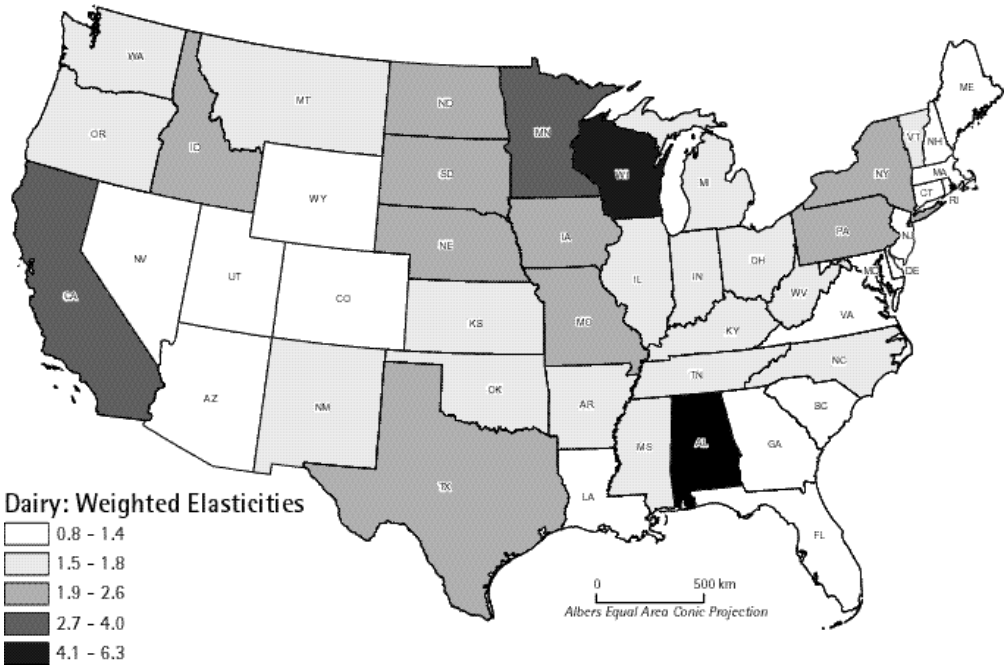
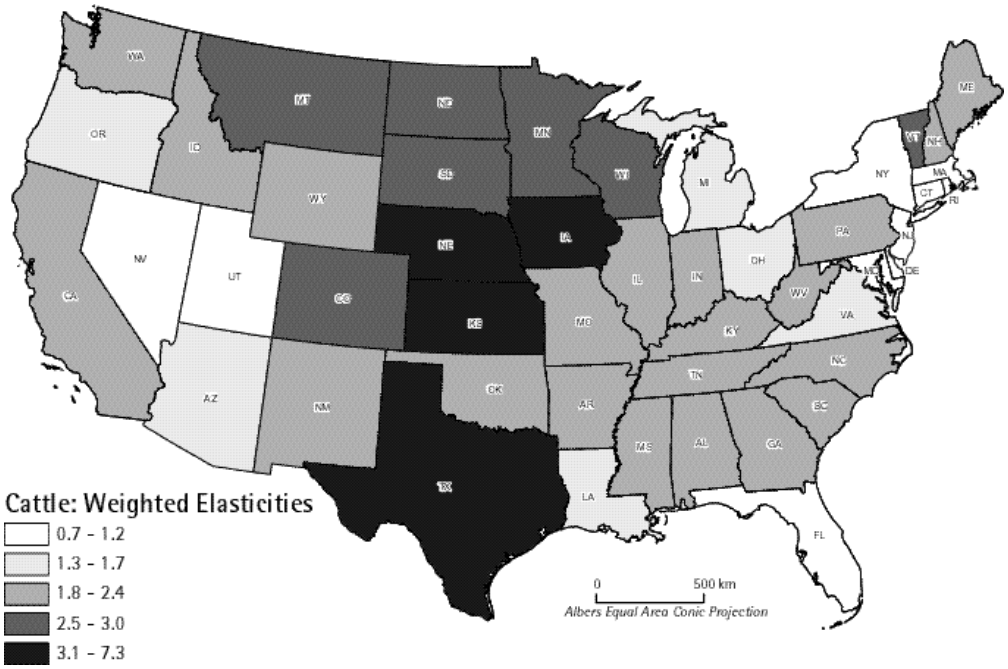


Figure 5. ***Likelihood of a state being selected for fed-cattle production using significant explanatory variables weighted by state-specific elasticities***



References

Abdalla, C.W., L.E. Lanyon and M.C. Hallberg. 1995. What we know about historical trends in firm location decisions and regional shifts: Policy issues for an industrializing animal sector, in *American Journal of Agricultural Economics*. 77: 1229-1236.

Apland, J. and H. Anderson. 1996. Optimal location of processing plants: Sector modeling considerations and an example. in *Review of Agricultural Economics*. 18: 491-504.

Bureau of Economic Analysis (BEA), U.S.Department of Commerce. 2002. Gross State Product Data [Data Series]. Retrieved June 2002 from the World Wide Web: http://www.bea.doc.gov/bea/regional/gsp

Bureau of Labor Statistics (BLS), U.S. Department of Labor. 2002. Consumer Price Index - All Urban Consumers, Current Series [Data Series]. Retrieved June 2002 from the World Wide Web: http://data.bls.gov/labjava/outside.jsp?survey=cu

Bureau of Labor Statistics (BLS), U.S. Department of Labor. 2002. Local Area Unemployment Statistics [Data Series]. Retrieved June 2002 from the World Wide Web: http://www.bls.gov/data and http://data.bls.gov/labjava/outside.jsp?survey=la

Carpentier, C.L., D.D. Bosch and S.S. Batie. 1998. Using spatial information to reduce costs of controlling agricultural nonpoint source pollution. in *Agricultural and Resource Economics Review.* 27(1 April): 72-84.

Copeland C. and J. Zinn. 1998. Animal Waste Management and the Environment: Background for Current Issues. Congressional Research Service, Washington, DC. Available online at Committee for the National Institute for the Environment's Website, http:/www.cnie.org/nle/ag-48.html.

Coughlin, C.C, J.V. Terza and V. Arromdee. 1991. State characteristics and the location of foreign direct investment within the United States. in *Review of Economics and Statistics*. 73: 675-683.

Davidson, R. and J.G. Mackinnon. 1993. *Estimation and Inference in Econometrics*. New York: Oxford University Press.

Duerkson, C.J. 1984. *Environmental Regulation of Industrial Plant Siting: How to make it work better.* Washington, D.C.: The Conservation Foundation.

Duffy-Deno, K.T. 1991. Pollution abatement expenditures and regional manufacturing activity. in Journal of Regional Science. 32: 419-436.

Eberts, R. W. and D. P. McMillen. 1999. Agglomeration economies and urban public infrastructure. in P. Cheshire and E. S. Mills (eds). *Handbook of Regional and Urban Economics, Volume 3 Applied Economics.* New York: North-Holland.

Economic Research Service (ERS). 1984. Farm Real Estate Market Developments No. CD-89. U.S. Department of Agriculture.

Economic Research Service (ERS). 1985. Agricultural Resources - Agricultural Land and Markets No. CD-6. U.S. Department of Agriculture.

Economic Research Service (ERS). 1987. Agricultural Resources - Agricultural Land and Markets No. AR-6. Economic Research Service, U.S. Department of Agriculture.

Economic Research Service (ERS). 1993. Agricultural Resources - Agricultural Land and Markets No. AR-31. U.S. Department of Agriculture.

Economic Research Service (ERS). 1996. Weather in U.S. Agriculture [Data Series #92008]. U.S. Department of Agriculture. Retrieved June 2002 from the World Wide Web: http://usda.mannlib.cornell.edu

Economic Research Service (ERS). 2000. Agriculture in Harmony with the Environment: Agricultural Resources and Environmental Indicators [Data Series in Online Paper, Section 1.2 (Adobe Acrobat File) p. 13]. Resource Economics Division, U.S. Department of Agriculture. Retrieved June 2002 from the World Wide Web: http://www.ers.usda.gov/Emphases/Harmony/issues/arei2000 http://www.ers.usda.gov/Emphases/Harmony/issues/arei2000/1.2farmrealestatevalues.pdf

Economic Research Service (ERS). 2000. Farm Real Estate Values [Data Series #86010]. U.S. Department of Agriculture. Retrieved June 2002 from the World Wide Web: http://www.ers.usda.gov/data/sdp/view.asp?f=land/86010

Edelman, M., H. Harris, A. Seidl and M. Warner. 1998. *National Survey of State Animal Confinement Policies.* Report of Animal Confinement Policy National Task Force. Colorado.

Energy Information Administration (EIA). 2001. Links to State Energy Price and Expenditure Tables: Official Energy Statistics from the U.S. Government [Data Series]. Retrieved June 2002 from the World Wide Web: http://www.eia.doe.gov/neic/historic/seperelectric.htm

Environmental Law Institute. 2001 (December). Regulations of Concentrated Animal Operations in the United States of America. draft.

Ervin, D.E. and C.L. Carpentier. 1999. Environmental and health standards: Compliance costs for U.S. agriculture. Report prepared for the European Commission. in *Effects of Environmental and Health Standards on the Trade Competitiveness of European Union Agriculture vis a vis Its Main Competitors.* Greenbelt, MD: Henry A. Wallace Institute for Alternative Agriculture.

Fredriksson, P.G. and D.L. Millimet. 2002a. Strategic interaction and the determination of environmental policy across the U.S. states. in *Journal of Urban Economics.* 51: 101-122.

Friedman, J., D.A. Gerlowski and J. Silberman. 1992. What attracts foreign multinational corporations? Evidence from branch plant location in the United States. in *Journal of Regional Science.* 32: 403- 418.

Gasteyer S., C.B. Flora and M. Kilkenny. 1999. Firm type, size, and location: Value-added agriculture and rural community development. Iowa State University, North Central Regional Center for Rural Development, Ames: IA. draft.

Gollehon, N., M. Caswell, M. Ribaudo, R. Kellogg, C. Lander and D. Letson. 2001. *Confined Animal Production and Manure Nutrients.* AIB No. 717. U.S. Department of Agriculture. Economic Research Service. Washington, DC.

Gray, W.B. 1997. Manufacturing plant location: Does state pollution regulation matter?. NBER Working Paper 5880. Cambridge, MA: National Bureau of Economic Research.

Hall, B. and M. Kerr. 1991. Renew America Index cited in *Green Index: A State by State Guide to the Nation's Environmental Health.* Washington, DC: Island Press.

Herath, D., A. Weersink, and C. L. Carpentier. 2004. An analysis of spatial and temporal changes in the United States hog, dairy, and fed-cattle sectors: 1975 to 2000. in *Review of Agricultural Economics.* 27(1):1-21.

Herath, D., A. Weersink, and C. L. Carpentier. 2005. Spatial dynamics of the livestock sector in the United States: do environmental regulations matter?. in *Journal of Agricultural and Resource Economics.* 30(1):45-68.

Horowitz, I. 1970. Employment concentration in the common market: An entropy approach. in *Journal of Royal Statistical Society.* A (part 3): 463-479.

Hubbell, B.J. and R. Welsh. 1998. An examination of trends in geographic concentration in U.S. hog production 1974-96. in *Journal of Agricultural and Applied Economics*. 30(2): 285-299.

Hurt, C. and K. Zering. 1993. Hog production boom in North Carolina: Why there? Why now?. in *Purdue Agricultural Economics Report.* August: 11-13.

Institute of Southern Studies. 1994. Green and Gold. Durham, N.C.: Institute for Southern Studies.

Jafee, A.B., S.R. Peterson, P.R. Portney and R.N. Stavins. 1995. Environmental regulation and international competitiveness: What does the evidence tell us?. in *Journal of Economic Literature*. 33: 132-163.

Kellogg, R.L, M.S. Maizel and D.W. Goss. 1992. *Agricultural Chemical Use and Ground Water Quality: Where Are the Potential Problem Areas?* U.S. Department of Agriculture, Soil Conservation Service, Economic Research Service, Cooperative State Research Service, National Center for Resource Innovations, Washington, DC.

Kunce, M. and J.F. Shogren. 2002. On environmental federalism and direct emission control. in *Journal of Urban Economics.* 51: 238-245.

Levinson, A. 1996. Environmental regulations and manufacturers' location choices: Evidence from the census of manufacturers. in *Journal of Public Economics.* 62: 5-29.

Levinson, A. 2000. The missing pollution haven effect: Examining some common explanations. in *Environmental and Resource Economics.* 15(4): 343-364.

List, J.A. and C.Y. Co. 2000. The effects of environmental regulations on foreign direct investment. in *Journal of Environmental Economics and Management.* 40: 1-20.

Lopez, R.A. and N.R. Henderson. 1989. The determinants of location choices for food processing plants. in *Agribusiness*. 5: 619-632.

Martin, L.L. and K.D. Zering. 1997. Relationships between industrial agriculture and environmental consequences: The case of vertical coordination in broilers and hogs. in *Journal of Agricultural and Applied Economics.* 29(1): 45-56.

McBride, W.D. 1997. *Change in U.S. Livestock Production, 1969-1992.* Agricultural Economic Report 754. U.S. Department of Agriculture, Economic Research Service. Washington, DC.

McBride, W.D. and N. Key. 2003. *Economic and Structural Relationships in U.S. Hog Production.* Agricultural Economic Report 818. U.S. Department of Agriculture, Economic Research Service. Washington, DC.

McConnell, V.D. and R.M. Schwab. 1990. The impact of environmental regulation on industry location decisions: The motor vehicle industry. in *Land Economics*. 66: 67-81.

Metcalfe, M. 2000. State legislation regulating animal manure management. in *Review of Agricultural Economics.* 22(2): 519-532.

Metcalfe, M. 2001. U.S. hog production and the influence of state water quality regulation. in *Canadian Journal of Agricultural Economics.* 49: 37-52.

Mo, Y. and C.W. Abdalla. 1998. Analysis of swine industry expansion in the US: The effect of environmental regulation. Staff Paper 316. Department of Agricultural Economics and Rural Sociology. Pennsylvania State University. University Park: PA.

National Association of State Departments of Agriculture (NASDA). 2001. *State Survey on Waste and Manure Management Regulations.* Update. Washington, DC.

National Agricultural Statistics Service (NASS). 1991. *Farm Employment and Wage Rates 1910-1990* [Data Series #91005]. National Agricultural Statistics Service, Estimates Division, U.S. Department of Agriculture. Retrieved June 2002 from the World Wide Web: http://usda.mannlib.cornell.edu/data-sets/inputs/91005 http://usda.mannlib.cornell.edu/data-sets/inputs/91005/flbulwg3.wk1

National Agricultural Statistics Service (NASS). 2000. *Farm Labor* [Data Series]. National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture. Retrieved June 2002 from the World Wide Web: http://usda.mannlib.cornell.edu/reports/nassr/other/pfl-bb/2000/fmla1100.txt

National Agricultural Statistics Service (NASS). 2000. *Farms and Land in Farms* [Data Series]. National Agricultural Statistics Service Agricultural Statistics Board, U.S. Department of Agriculture. Retrieved June 2002 from the World Wide Web: http://usda.mannlib.cornell.edu/reports/nassr/other/zfl-bb

National Agricultural Statistics Service (NASS). 2000. *Livestock Slaughter Annual Summary* [Data Series]. National Agricultural Statistics Service Agricultural Statistics Board, U.S. Department of Agriculture. Retrieved June 2002 from the World Wide Web: http://usda.mannlib.cornell.edu/reports/nassr/livestock/pls-bban

National Agricultural Statistics Service (NASS) (previously published by ERS). 2001. *Agricultural Land Values and Agricultural Cash Rents* (Summary) [Data Series PLR-BB]. National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture. Retrieved June 2002 from the World Wide Web: http://usda.mannlib.cornell.edu/reports/nassr/other/plr-bb

National Agricultural Statistics Service (NASS). various years (see links). *Agricultural Prices Monthly* [Data Series]. National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture. Retrieved June 2002 from the World Wide Web: http://usda.mannlib.cornell.edu/reports/nassr/price/pap-bb

National Agricultural Statistics Service (NASS). various years (see links). *Agricultural Prices Summary* [Data Series]. National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture. Retrieved June 2002 from the World Wide Web: http://usda.mannlib.cornell.edu/reports/nassr/price/zap-bb
http://usda.mannlib.cornell.edu/reports/nassr/price/zap-bb/agpran01.txt http://usda.mannlib.cornell.edu/reports/nassr/price/zap-bb/agpran00.txt

National Agricultural Statistics Service (NASS). various years (see links). *Prices Received by Farmers for Field Crops* [Data Series #92151]. Agricultural Statistics Board, U.S. Department of Agriculture. Retrieved June 2002 from the World Wide Web: http://usda.mannlib.cornell.edu/data-sets/crops/92151
(See 1984-1987 in file pr1-8487.wk1)
(See 1988-1996 in file pr2-8896.wk1)

National Climatic Data Center (NCDC. 2002. U.S. *Statewide Analysis* [Data Series]. Ashville, North Carolina. Retrieved June 2002 from the World Wide Web: http://lwf.ncdc.noaa.gov/oa/climate/research/cag3/state.html

Ogishi, A. and D. Zilberman. 1999. Integrator's liability for animal waste. Berkeley: University of California, Department of Agricultural and Resource Economics. draft.

Osei, E. and P.G. Lakshminarayan. 1996 (December). *The determinant of dairy farm location.* Livestock Series Report 7. Working Paper 96-WP 174. Center for Agricultural and Rural Development. Iowa State University. Ames: IA.

Park, D., A. Seidl, and S. Davies. 2002. Environmental policy and industry location: The case of U.S. livestock industry. in *The Review of Regional Studies.* 32(2): 293-307.

Rainey, V.D. and K.T. McNamara. 1999. Taxes and location decisions of manufacturing establishments. in *Review of Agricultural Economics.* 21: 86-98.

Renew America. 1991. *The State of the States, 1989.* Washington, D.C.:1400 16th Street NW.

Roe, B., E.G. Irwin and J. S. Sharp. 2002. Pigs in space: Modeling the spatial structure of hog production in traditional and nontraditional production regions. in *American Journal of Agricultural Economics.* 84(2): 259-278.

Scott, R., 1987. *The State of the States 1987.* Funds for Renewable Energy and the Environment. Washington, D.C.

Smith, R. 1995. Fewer pork producers producing more; contracting, networking, integration up. in *Feedstuffs.* 67(44) October 23. pp. 11

Smith, K.R. and P. J. Kuch. 1995. What we know about the opportunities for intergovernmental institutional innovation: Policy issues for an industrializing animal agriculture sector. in *American Journal of Agricultural Economics.* 77: 1244-1249.

Speir, J., M-A. Bowden, D. Ervin, J. McElfish, R Perez Espejo, T. Whitehouse and C.L. Carpentier. 2003. Comparative standards for intensive livestock operations in Canada, Mexico and the United States. North American Environmental Law and Policy. Montreal: Commission for Environmental Cooperation.

Sporleder, T.L. 1974. Entropy measures of spatial concentration in poultry processing. in *Southern Journal of Agricultural Economics*. 6: 133-137.

Stafford, H.A. 1985. Environmental protection and industrial location. in *Annals of the Association of American Geographers.* 75: 227-240.

Sun, C. and D. Zhang. 2001. Forest resources, government policy, and investment location decisions of the forest product industry in the Southern United States. in *Forest Science.* 47: 169-171.

U.S. Census Bureau. 1976-2000. *Statistical Abstract of the United States.* editions 97-120.

U.S. Census Bureau. 1995. *Table 1: Urban and Rural Population 1900-1990* [Data Series]. U.S. Census Bureau, Population Division. Retrieved June 2002 from the World Wide Web: http://www.census.gov/population/censusdata/urpop0090.txt

U.S. Census Bureau. 2002. *Median Income for 4-Person Families, by State* [Data Series]. U.S. Census Bureau, Income Surveys Branch, HHES Division. Retrieved June 2002 from the World Wide Web: http://www.census.gov/hhes/income/4person.html

U.S. Census Bureau. 2002. *United States Census 2000 Resident Population* [Data Series]. U.S. Census Bureau, Population Division. Retrieved June 2002 from the World Wide Web: http://www.census.gov/population/www/cen2000/respop.html

U.S. Department of Agriculture (USDA). 1969-1979. *Livestock Slaughter Annual Summary*. Statistical Reporting Service, Crop Reporting Board, U.S. Department of Agriculture.

U.S. Department of Agriculture (USDA). 1975-1997. *Agricultural Prices.* Statistical Reporting Service, Crop Reporting Board, U.S. Department of Agriculture.

U.S. Department of Agriculture (USDA). 1978-81, 1982, 1983-84, 1985, 1986. *Livestock Slaughter.* Statistical Reporting Service, Crop Reporting Board, U.S. Department of Agriculture.

U.S. Department of Agriculture (USDA). 1980, 1982-90, 1992-94. *Livestock Slaughter Summary.* Statistical Reporting Service, Crop Reporting Board, U.S. Department of Agriculture.

U.S. Department of Agriculture (USDA). 1989. *Farms and Land in Farms Final Estimates 1979-87*. USDA Statistical Bulletin No. 792. National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture.

U.S. Department of Agriculture and U.S. Environmental Protection Agency. 1999. *Unified National Strategy for Animal Feeding Operations.* Washington, DC. March 9. Accessed April 1999. Available online at http://www.epa.gov/owm/finafost.htm

U.S. Department of Commerce, Bureau of the Census. 1997-98, 5th Edition, *State and Metropolitan Area Data Book,* Washington, D.C.: U.S. Government Printing Office

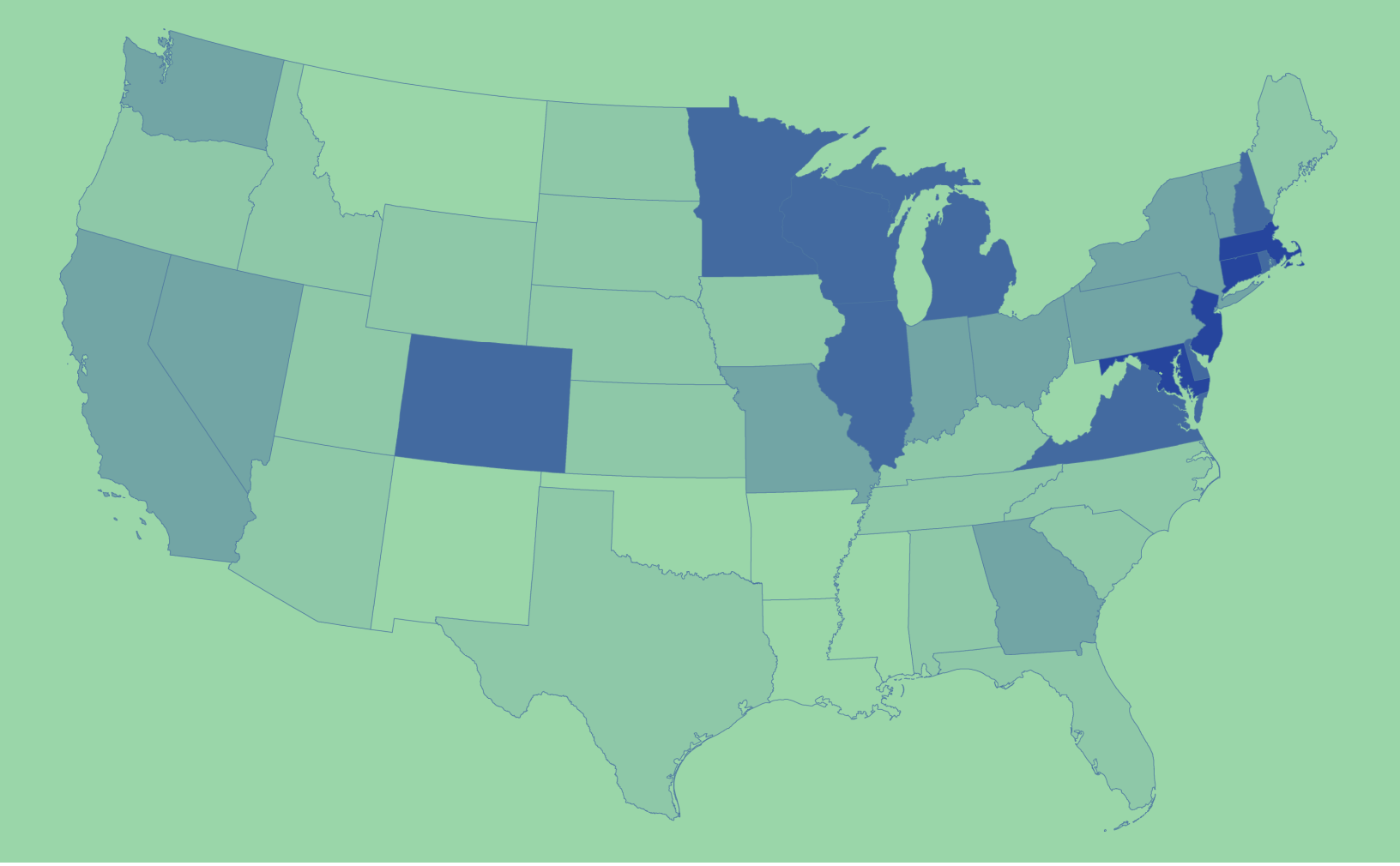
U.S. Environmental Protection Agency. *State Compendium: Programs and regulatory activities related to animal feeding operation.* Office of Waste Water Management, 2001 http://extension.agron.isatate.edu/immag/ppstothreg.html)

US Senate Committee on Agriculture, Nutrition and Forestry. 1997. *Animal Waste Pollution in America: An Emerging National Problem: Environmental Risks of Livestock & Poultry Production.* Washington, DC. Accessed January 1999. Available online at http://www.senate.gov/~agriculture/animalw.htm

Vesecky, M. and D. Lins. 1995. Factors influencing expansion and contraction decisions by Illinois agribusiness firms. in *Agribusiness*. 11: 405-413.

Weersink, A., P.H. Coughler, C. Nicholson and A. Novakavic. 1995. Satisfaction with farm input services by dairy farm households in New York and Ontario. in *Journal of International Food and Agribusiness Marketing.* 7(3):65-88.

Welsh, R., C.L. Carpentier, and B. Hubbell. 2001. "On the Effectiveness of State Anti-Corporate Farming Laws in the United States." *Food Policy* 26: 543-548.



WINROCK INTERNATIONAL

Putting Ideas to Work