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**SPATIAL DYNAMICS OF THE LIVESTOCK SECTOR IN THE UNITED STATES:
DO ENVIRONMENTAL REGULATIONS MATTER?**

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SPATIAL DYNAMICS OF THE LIVESTOCK SECTOR IN THE UNITED STATES: DO ENVIRONMENTAL REGULATIONS MATTER?

ABSTRACT

The US hog and dairy sectors are increasingly shifting production toward western states away from more traditional production regions in the east. In contrast, production levels in the fed-cattle sector have increased over the last three decades only in the three main producing states. One possible reason for the shifts in production areas is that a state may introduce or keep less stringent environmental regulations relative to neighboring states as a means to cope with inter-jurisdictional capital competition. Such differences might create "pollution havens". This study examines the factors affecting the annual growth rate in inventory for each of the hog, dairy and fed-cattle sectors using data from 48 states for 1975 to 2000. The results indicate that environmental regulatory stringency is generally not as important as other economic variables in the location choices of livestock producers. In the two sectors (hog and dairy) where significant regional production shifts have occurred, major drivers appear to be relative prices and business climate. Inventories are rising in more remote areas and regulatory stringency appears to increase *ex post* as a response to increasing livestock production levels. Thus, with the exception of the fed-cattle sector, regional differences in environmental regulations appear not to have a significant influence on livestock production decisions and consequently regional comparative advantage.

key words: environmental regulation stringency, fixed effect model, location choice, livestock production, panel data analysis, pollution havens, spatial distribution

Introduction

The industrialization of the North American livestock sector has been associated with a geographic concentration of production in fewer regions and a shift in production to areas with little prior livestock experience. For example, hog production has doubled in North Carolina and increased by over eight times in Oklahoma over the last decade. One of the reasons may be the increasingly important role of the processing sector and the integration of this sector back into production (Ogishi and Zilberman). Processing plants operating under economies of scale are becoming larger and fewer, and scattered around the country with clusters of livestock farms around them (Apland and Anderson; Abdalla, Lanyon and Hallberg). Such clusters tend to move

to localities with better natural endowments, labor market conditions, and business environment due to agglomeration economies or tax policies (Roe, Irwin and Sharp).

Changes in the spatial distribution of livestock production may also be directly affected by differences in the stringency of environmental regulations across administrative regions. A disparity in regulatory stringency among states arose in the 1980s when the federal government delegated the function of devising their own regulatory regimes to the state authorities (Kraft and Vig; Lester; Levinson, 2001). These differences might create "pollution havens" where lenient regulatory regimes in some regions may attract livestock producers to build their facilities in such localities. For instance, Martin and Zering argue that large-scale intensive pork production has shifted to southern states such as North Carolina and Arkansas because "environmental regulations, zoning regulations, and anti-corporate farming regulations did not present insurmountable barriers to siting and building production units and processing plants in the region" (p.49). It is possible that by introducing or maintaining lax environmental regulations relative to competing regions and allowing tardy enforcement of those regulations, one region can lure 'dirty' industry investments, which are important in employment creation and regional economic development (Kunce and Shogren; Levinson, 2000; Jafee, Peterson and Portney). Thus, delegating the authority to enforce environmental regulations to states, rather than controlling it nationally, may create a race to the bottom among competing states, in which states relax or do not update the stringency of environmental regulations to lure higher rates of investment to a specific geographic location.

These pollution havens may lead over time to a race to the bottom for environmental standards through intra-jurisdictional competition among states as they try to establish better opportunities for economic growth, and as a result, becomes an important policy issue (Knuce

and Shogren). Fredrickson and Millimet found that states do take into account the regulatory stringency of neighboring states when determining their own regulatory regime. If regional and state governments really do engage in a race to the bottom, certain regions would have an inefficiently high number of concentrated animal feeding operations (CAFOs). Because the assimilative capacity of the environment is deliberately undervalued in a region where a race to the bottom has occurred, the heavier concentration of livestock operations in that region may pollute at a level that is higher than the socially optimal level, and at a greater cost to society.

The relevance of the pollution haven hypothesis in describing the relationship between environmental stringency and changes in regional livestock production has not been established. The hypothesis has been tested for both hog operations (Roe, Irwin, and Sharp; Metcalfe, 2001; Mo and Abdalla), and dairy operations (Osei and Luxminarayan) but the results are inconclusive. These studies have several limitations. First, each has been limited to only one livestock sector and there could be differences in how different livestock operations adjust to changes in policy given differing capital requirements. Second, these studies are either cross-sectional (Metcalfe, 2001; Osei and Luxminarayan) or for a limited period of time (Mo and Abdalla). Thus, they cannot capture changes in relative environmental regulations and their impact on production decisions. Third, the time-series environmental stringency measures have been general measures for any industry and have not captured all the relevant factors directly affecting farm location.

The purpose of this paper is to determine the effect of environmental regulations on changes in the spatial distribution of livestock operations in the United States. Changes in state production levels of hogs, dairy and fed-cattle are examined for the period 1975 to 2000. The report begins by describing the regional and state changes in the geographical concentration of production for the three livestock sectors over time. The third section presents the empirical

model for determining factors affecting the location decision of livestock producers. The major categories of factors include relative prices, livestock infrastructure support, natural endowment and climatic factors, general business climate, and environmental regulatory stringency. 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 fourth section discusses the econometric model. The results of the estimation are then presented. A major conclusion is that the production shifts appear to be driven by population density and unemployment rate and that the positive effect of environmental stringency suggests that tighter regulations follow after production levels have increased. The final section summarizes the major results and discusses the policy implications.

Geographical Changes in Livestock Production

An important prerequisite for testing the pollution haven hypothesis is assessing changes in the concentration of livestock operations across geographical regions. In this section, the changes in absolute production levels, concentration measures, and patterns of geographical concentration are described for the US hog, dairy, and fed-cattle sectors. Livestock inventories by state were collected from the NASS web sites from 1975 to 2000.

The Gini coefficients (G) for hog and fed-cattle inventories were much greater than the dairy sector in 1975 at 0.72 and 0.70 respectively as compared to 0.56 for the dairy sector (see Table 1). National concentration across states has increased over time as the value of G has increased at approximately the same average rate for all sectors. While the rate of increase in G values for the dairy sector has been relatively stable, the annual G value for the hog sector has fluctuated upward until 1990 and has increased rapidly thereafter. In the fed-cattle sector, G

values have been more erratic relative to the hog and dairy sectors, yet since 1995 it has also increased rapidly. Currently, fed-cattle operations are the most geographically concentrated sector with a *G* value of about 0.80, followed by the hog sector (0.77), and the dairy sector (0.62).

Total hog inventories in the United States have increased from about 49 million in 1975 to approximately 59 million in 2000 (see Table 1). 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. The seven states of the Great Plains region still account for approximately 50% of total hog production in the United States. The Great Lakes region had the second largest production levels of hogs in 1975 but since 1996 inventory levels have been higher in the Southeast region as its share of national production has risen from 16% in 1975 and to 21% in 2000. The 54% increase in total production from this region is accounted for by the large increases in North Carolina and Arkansas as all other states have reduced hog numbers. 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 from one state (Oklahoma). 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 geographical concentration has 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 geographical concentration has increased.

Dairy cattle inventory for the United States fell from 11.3 million to 9 million cows, or by about 20%, from 1975 to 2000 (see Table 1). Much like the hog sector, regional differences in

dairy cattle inventories have declined as dairy cow numbers have fallen in the traditional dairy regions of the Great Lakes and the Great Plains regions while rising in the western regions of the country. While regional differences have declined, there are significant concentrations of dairy cows in fewer states within some regions.

The five non-western regions of the country all exhibited an attrition pattern in spatial production. Dairy cow numbers declined in these regions while concentration increased slightly. All states within each of these five regions experienced a decrease in dairy cow inventory and the percentage decrease is similar among states within the region. Thus, relative production shares by state in these regions have remained relatively constant. It has been argued that technological development in the dairy sector may be a reason for the uniform reduction of dairy cattle numbers in most states (Osei and Luxminarayan).

The growth in dairy cow numbers in the three western regions coincided with a significant increase in geographical concentration implying an augmentation pattern of spatial production over time. The increase in cow numbers was due to the increase in production by a few states within each region. In the Far West region, there was a 61% increase in dairy cattle inventories due largely to the 90% increase in California, which is the largest dairy producing state within the region.

Total fed-cattle inventories in the United States have increased by approximately 37% over the last 25 years from about 10 million head to 14 million head (see Table 1). Three states accounted for the majority of this inventory increase; Texas (1.5 million), Kansas (1.4), and North Dakota (1.2). 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% and it still ranks as the second largest producing region. Since fed-cattle numbers in the largest two production regions have expanded at a much greater rate than the rest of the regions between-region geographical concentration has increased in the fed-cattle sector in contrast to the other two sectors. The remaining question is that what cause these patterns of changes in the location of the dairy, hog, and fed -cattle industry.

Empirical Model

Dependent Variable

The decision by a farm on where to locate its operation or whether to expand its existing inventory level depends on relative profitability which in turn is a function of relative regional attributes. The numbers of new farms within a given region or the intensity of production within a region are variables that can capture spatial production changes. Bartik argued 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 due to grandfathering arrangements, the opening up of new facilities will be lower in a region with more stringent environmental regulations (Bartik). 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. Thus, the annual growth rate in inventories is used as an aggregate measure of spatial production in this study. Data on hog, dairy and fed-cattle production levels from 1975 to 2000 were collected for each of the 48 contiguous states (see Table 1). Annual inventory growth rates for each of the

three livestock sectors from 1975/1976 to 1999/2000 were calculated resulting in 25 time series observations for each state. In order to net out cyclical fluctuations and focus on patterns across states, a five-year moving average of the annual growth rates was used as the dependent variable (Grier and Tullock).

Explanatory Variables

The "change" in this dependent variable over the period is related to "levels" of the independent variables at the beginning of the period so that the framework of this study could be best explained as a dis-equilibrium adjustment model (Plaut and Pluta). The independent variables in the regressions capture differentials in profitability of raising livestock across states; differentials in this profitability then cause differentials in the rate of livestock inventory changes across states. One important assumption in this conceptual approach is that the differences in profitability of raising livestock across states at the beginning of the period are sufficiently large to cause differences in the rate of livestock inventory growth.

Decisions to expand or contract livestock operations or change into alternative enterprises depend on the changes in relative profitability rather than absolute profitability of raising livestock. However, we assumed that relative profitability of raising livestock compared to other alternative investment opportunities stays the same across states. Thus, as Metcalfe (2001) noted, the model cannot explain the decisions of "when to change" production, but rather assumes that a change has already been determined to be necessary (relative profitability is favorable) and now the decision is in "which state" to alter production.

There are several studies that have examined the location choices of firms in a variety of settings including dairy farmers (Osei and Lakshminarayan), forest harvesting activities (Sun and

Zhang), foreign investment by multinational corporations (Friedman, Gerlowski and Silberman; Coughlin, Terza and Arromdee; List and Co), and new branch plants openings in the manufacturing sector (Bartik; Levinson, 1996; McConnell and Schwab). 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) general business climate, 4) livestock infrastructure, and 5) climatic factors. The variables used to proxy these five general drivers of spatial reorganization of livestock production are summarized in Table 2 and described in the next section.

Regulatory Stringency

Regulatory stringency measures in the previous studies have been constrained by data limitations. Most of the stringency measures in these studies were not based on environmental regulations specific to livestock sector. Instead, they have used general regulatory stringency indices that are based on broader categories of environmental preservation efforts by states. For example, Osei and Luxminarayan used the Fund for Renewable Energy and the Environment (FREE) index, which was developed in 1987. Mo and Abdalla attempted to incorporate a diverse set of regulatory stringency measures including the Green index, the Lester classification, the size of staff devoted to state animal waste control programs, and the average amounts of fines imposed on the violators.

Metcalf (2001) examined 10 different manure management regulations to control livestock producers in 19 states as of 1994. Each regulation was given a score of 0, 1 or 2 depending if it was not imposed in the state (0), imposed in the state (1), or extensively imposed in the state (2). This study uses the Metcalfe approach as a base but extends it in several ways.

First, the regulatory stringency measure is calculated for 2000 and for all 48 states. Second, the relative cost differences of regulatory stringency among states, which is the ultimate test for the impact of regulatory stringency on location choice for livestock producers, are incorporated. For example, the same set back distance would be less costly in a state that has cheaper agricultural lands relative to a state with expensive farmland. Data on regulations were obtained largely from the Environmental Law Institute and supplemented from three other reports (National Survey of Animal Confinement Policies; State Compendium; National Association of State Departments of Agriculture). The regulations considered for the 2000 environmental stringency index and the results for each state are listed in Table 3. Oregon and California have the lowest index values of 0.03 and 0.08 respectively and Colorado has the highest value of 6.99. New York (1), Utah (2.00), Wyoming (2.36) also have relatively low stringency values while Minnesota (5.35), Georgia (5.24) are states with higher index values.

In order to capture the temporal changes of regulatory stringency across states, one has to compare the indices across time. However, the Conservation Foundation Index (1984), Renew America Index (1987/1989), and Green Index (1991/1992), Metcalfe's (2000), 1994 and 1998 index, and the index developed in this study for year 2000 are not comparable in their absolute magnitude since these are based on dissimilar variables in different periods. However, one can use the relative positioning of a given state in a given index assuming the relative stringency of a given state is comparable among different indices. Thus, we have normalized all the above indices by dividing through by the mean value of each index. The normalized index values represent the position of the state relative to the mean of each index. We have used the normalized index values for the above five indices together with normalized values of the index developed in this study (for year 2000) to approximate the relative regulatory stringency with

time. Time is regressed against the five normalized index values (linearly) for each state and the resulting regression coefficient is used to estimate the relative regulatory stringency values for the other years.

Relative Prices

Increases in the relative profitability of livestock production as measured by an output to feed price ratio are expected to increase production intensity. 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 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 do vary somewhat from state to state possibly due to different means of production. For example, some states such as Oregon have an abundance of hydro-electricity and 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 operation is the cost of labor. Labor costs for this study are measured by the average farm wage rate, which has risen constantly over time to reflect inflationary trends. Despite the incentive to produce where labor is cheapest and the general notion that large-scale production requires cheaper labor, there are no major differences in wage rates remain across the states.

A fourth input price that is used in the model is the value of farmland. Areas with cheaper land prices *ceteris paribus* are expected to have higher growth rates in production. Since land cannot migrate, there are regional differences in the price of farmland. Farmland values are greatest in the areas with the largest urban pressures. In agricultural intensive regions, farmland values are higher in the Corn-belt states than those in the Central Plains and Rocky Mountain regions reflecting differences in land productivity.

In addition to the purchase price, another cost associated with land is the annual property tax. Farm property taxes are assumed to be negatively related to livestock production intensity. There has been a steady increase in taxes over time but increased significantly in Arizona, Wisconsin, and Nebraska.

Livestock Infrastructure Support

Market access and agglomeration economies are two externalities associated with livestock infrastructure support. Production intensity would likely increase in regions where the distance to market is smaller, since transportation and transaction costs will be lower. Access is particularly important for the meat sectors since it has been hypothesized that the spatial changes in hog and beef production are partially due to the location of slaughtering plants. Access to slaughtering facilities was found to be positively related to the intensity of hog production within 15 states by Roe, Irwin and Sharp. Market access is measured in this study by the number of hogs and beef slaughtered within the state. Iowa has the largest hog slaughtering capacity and the number slaughtered has increased significantly over time. Illinois, North Carolina and Minnesota also increased hog slaughter capacity, 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 decreased dramatically.

Agglomeration economies are the positive spillovers a farm may enjoy because of a higher concentration of farms in the region. For example, the existence of many dairy farms in a given region can attract input suppliers and other industry-specific infrastructure that lowers the transaction costs of exchange and the diffusion of information (Eberts and McMillen; Weersink *et al*). Roe, Irwin, and Sharp found such agglomeration economies had a positive effect on the total number of hogs raised at the county level. Agglomeration effects are proxied by the importance of agriculture to the state economy and the share of the population living in rural areas. States with the largest share of income from agriculture are the Dakotas, Nebraska, and Iowa, but this percentage is declining for all states. Large livestock operations are assumed to meet less resistance in states with a greater percentage of the population tied to agriculture. Unlike farmland area, which is declining for all states, the percentage of rural population is increasing for approximately one-third of the states.

General Business Climate

Local business conditions conducive for the establishment of a livestock operation are proxied by several economic variables: population density, unemployment rate and median family income.

Population density has uncertain effects on livestock production intensity. Increasing the number of people and businesses can increase the amount of available labor, increase the demand for associated products, and reduce costs by increasing the extent of public infrastructure

(Eberts and McMillen). However, nuisance complaints regarding livestock farms from neighbors are likely to increase the greater the population density (Rhodes). The increasing role of the “not in my backyard” (NIMBY) attitude is expected to dominate any positive economies of urbanization so that population density is hypothesized to have a negative effect on livestock production density.

The unemployment rate can have an influence on farm location through the labor supply and receptiveness towards new operations. A region with a high unemployment rate is more likely to have excess labor available to work in agriculture. In addition, areas with higher unemployment may seek livestock operations to locate as a means to generate economic opportunities. The unemployment rate varies both over time and between states.

Another variable related to the NIMBY hypothesis is the average per capita state income. Concern over environmental quality generally increases with income, and generally, families that are better off will not want polluting industries in their backyard. Furthermore, higher income states can rely on other sources of economic growth besides livestock production. Thus, median income is assumed to have a negative relationship with livestock production intensity.

Climatic Factors

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

Results

The factors affecting the changes in regional livestock production were estimated through the following regression model,

$$(1) \quad Y_{it} = \sum_{k=1}^K \beta_k X_{it} + V_i + U_t + \varepsilon_{it} \quad i=1,\dots,48 \quad t=1,\dots,25$$

where Y_{it} is the growth rate in production intensity for state i in year t , X is the vector of exogenous variables affecting the relative profitability of livestock farming across locations, β is the vector of coefficients associated with the explanatory variables, V_i is the time-invariant, unobserved state specific effect, U_t is the state-invariant, unobserved time specific effects, and ε_{it} is the random disturbance term. The independent variables (X_i) that are included in the analysis do vary across states and time. However, there may be many other unobservable, therefore omitted, variables that may be state specific (V_i) or time specific (U_t), which affect changes in livestock inventory and mask the true relationship between the dependent variable and independent variables already in the model. In this analysis, it is assumed that V_i and U_t are constants and conditional on the sample. This fixed effects model assumes that differences across cross sectional units or time can be captured by differences in the constant term (Dielman). The fixed effects model does not require unobservable state-specific effects to be uncorrelated with the explanatory variables (Hsiao). The estimated coefficients for the fixed effects model with state dummies are given in Table 4.

Hog Sector

The data explain about 27% of the variability of inventory growth rate among states (see Table 4). Out of the 16 explanatory variables, eleven were significant at a 10% or lower significance level. The coefficient for the environmental regulatory stringency is positive and

statistically significant. The result runs counter to the pollution haven hypothesis and suggests that inventory growth increases with environmental stringency. Similar findings in agriculture have been obtained by Metcalfe (2001), Osei and Luxminarayan, and Mo and Abdalla. The positive relationship suggests that inventory levels increase first and regulations follow rather than the regulations being set *ex ante* and production decisions constrained by those laws.

Relative prices generally have signs consistent with theory and are statistically significant. The one year-lagged value of hog corn price ratio is positively related with the growth rate of hog inventory, which is consistent with the findings of Metcalfe (2001), and Mo and Abdalla. A one percent change in hog-corn price ratio would increase the hog inventory growth rate by about 2% keeping everything else the same. The estimated negative effect of input prices on hog inventory growth rates is consistent with the *a priori* effect. Keeping all else equal, a 1% increase in energy prices would lead to an approximate 12% drop in the hog inventory growth rate. With a 1% increase in wage rates (farm property taxes), one can expect about a 2.4% (0.9%) decline in the inventory growth rate for hogs. The only coefficient with an unexpected sign is that associated with the price of farmland. It was expected that increases in the value of farm real estate would curtail hog production. The opposite result suggests hog farmers bid up the price of land as part of their expansion and potential concerns regarding land availability relative to the volume of manure generated.

Livestock infrastructure has significant effects on changes in hog production levels. Hog slaughtering capacity is positively related to production increases, which is consistent with the findings of Roe, Irwin and Sharp for 15 states. The result supports the “animal clusters” argument that states with a larger inventory density tend to have a greater slaughtering capacity (Pagano and Abdalla). States with a larger proportion of agricultural output in its gross state

product tend to have a larger inventory growth rate and the result is statistically significant at the 1% significance level. Availability of common agricultural infrastructure (veterinary services, feed availability, other input supplies) seems to be important for hog industry expansion. All else equal, a 1% change in the agricultural share of gross state product increases the hog inventory growth rate by about 9%. This variable also proxies the level of support for agriculture within a state and the likelihood of resistance to production expansion. It was expected that states with a larger share of total population that is rural are more likely to have a larger growth rate in hog inventory. However, not only do the regression results reject this assertion but strongly support the opposite effect. A possible explanation for this result is that the likelihood for conflict between farmers and neighbors is enhanced the population in rural given all other factors are constant including land availability and population density. Potential nuisance complaints from non-farm rural residents could deter the expansion of livestock production capabilities.

Business climate variables also have considerable explanatory power. Population density appears to curtail inventory growth rates in hogs and the result is significant at the 99% confidence level. A 1% increase in population density decreases the hog inventory growth rate by about 45%. Thus, densely populated states are likely to put greater pressures on hog farmers and curb production increases. Unemployment rate has a negative effect on hog inventories. The area of farmland and total state population are positively related with inventory growth rate as expected. States with larger populations may have the infrastructure to support any business but, if there is land and labor available, the site is more attractive for hog expansion. Per capita income has the expected negative sign yet it is not significant at the 5% significance level. The overall results of the business climate variables suggest that the NIMBY effect is important in

hog farm location. Inventory growth is highest in states where agriculture is important but also in which there is significant land to site production facilities and a population potentially more concerned about economic growth than any potential negative consequences from livestock expansion. Both temperature and precipitation have negative statistically insignificant effects. Natural endowment variables are not important in determining the hog inventory growth rate.

Dairy Sector

As with the hog sector, the coefficient on environmental regulatory stringency is positive and statistically significant for the dairy sector. The result suggests a reverse causality where inventory growth occurs first and regulatory stringency follows. While additional time series data points would be required to conduct tests to determine the direction of causality between livestock production levels and the severity of local environmental laws, the positive relationship is consistent with previous studies in the hog and dairy sectors.

Relative prices do not appear to have the effect on annual changes in state dairy numbers as prices did in the hog sector. The milk-corn price ratio is statistically significant but has an unexpected negative sign. Similarly, energy prices have an unexpected positive effect on inventory levels. The unexpectedly positive sign on farm real estate values suggests that perhaps the growth rate in cow numbers may be due to profitability that is also associated with the value of major assets in production such as land. Higher farm property taxes, *ceteris paribus*, decreases the rate of change in dairy cow numbers and the result is statistically significant.

There is no variable to capture the processing capacity of dairy sector as there was for slaughtering capacity in the hog sector. The coefficients for the other livestock infrastructure variables, percentage of rural population and agriculture's share of gross state product, have the

expected positive sign. These regression results for infrastructure are similar to those found for the hog sector. The results are also consistent with Weersink *et al* who found that dairy farmers place a significant level of importance on the availability and quality of farm support services.

As expected, the state unemployment rate is positively related with inventory growth rates and statistically significant at 5% level. The result is consistent with the suggestion that available labor, as proxied by the unemployment rate, is a major constraint on the expansion of dairy farms. Farmland area is also statistically significant but has an unexpected negative effect. The inverse relationship is consistent with the shift of dairy farming to the western states which have less agricultural land as a share of total area due to the mountains as compared to traditional dairy regions in the central and north-eastern regions of the country. Per capita income also has an unexpected effect on changes in dairy inventory levels. However, the decline in dairy numbers has occurred most significantly in relatively low income states (see section II). As with the hog sector, both temperature and precipitation have insignificant effects on the annual growth rate in dairy production numbers by state.

Fed-cattle Sector

The regression model explains about 24% of the variability in the inventory growth rate of fed-cattle among states (see Table 4). In contrast to the hog and dairy sectors, there is empirical support for the pollution have hypothesis in the beef sector. Changes in state beef inventory levels are inversely related to the stringency of environmental regulations and the result is statistically significant. The difference in effects across livestock types associated with the regulatory stringency index may be due to the nature of the production changes by sector. The increase in hog and dairy inventory has been in non-traditional production regions where

environmental laws related to livestock farming may not have been put in place until after the establishment of a significant livestock sector. In contrast, beef production increased in only the three states that had the largest numbers a generation ago. These remain relatively non-populated regions so that expansion may have been influenced by factors such as environmental regulations.

The beef-corn price ratio has a positive and statistically significant effect as expected. The supply response is similar to that found for the hog sector. The only other price variable that is statistically significant is that for farm land. The negative effect of the value of farm land on beef numbers suggests the importance of low-cost and available land on regional production movements.

Livestock infrastructure had little effect on fed cattle numbers. Although positive and consistent with the suggestions that regional shifts in production have coincided with shifts in beef packing location, slaughtering capacity does not have a statistically significant effect. The larger the share of total population that is rural and the larger the share of agriculture in the state economy, the lower the growth rate in fed cattle but these unexpected effects are not statistically significant. Beef production numbers are driven by other factors.

Population density has a significant negative effect on annual changes in fed-cattle numbers. The result suggests that changes in production levels for the beef sector may be related to the NIMBY attitude or to the need for open areas for the expansion of large feed lots. As with the dairy sector, unemployment rate is directly associated with the growth rate in fed-cattle inventory growth and it is statistically significant. Farmland area also has a positive effect suggesting the fed-cattle sector is associated with regions having large areas available for

expansion. Consistent with this effect and a possible NIMBY effect, total population has a statistically significant negative effect on beef production levels.

Conclusions

This paper has investigated the factors on the location choice of hog, dairy and fed-cattle production in the 48 contiguous states of the US from 1975-2000. The hog and dairy sectors are increasingly siting production towards western states and away from traditional production regions in the east. In contrast, production levels in the fed cattle sector have increased over the last generation only in the three main producing states. The shifts could be due to livestock producers responding *ex ante* to the differences in environmental regulatory stringency or to factors such as livestock infrastructure support.

The empirical results suggest that the pollution haven hypothesis is rejected for the two sectors experiencing significant changes in spatial production patterns. In the hog and dairy sectors, inventory levels appear to increase first and environmental regulations follow rather than the regulations being set *ex ante* and production decisions constrained by those laws. This interpretation is supported by the support of the pollution haven hypothesis found in the beef sector where the major beef producing regions have not changed and continue to be in sparsely populated regions. The positive association between the stringency of environmental measures and livestock production levels has been found by others (Mo and Abdalla; Metcalfe 2001) but the analysis here considered different sectors over multiple years. Instead the major drivers of location choice for livestock production appear to be relative prices and business climate, particularly the availability of cheap farmland in less densely population regions. Livestock

infrastructure support in the form of market access to slaughtering capacity is also a major driver of change in the hog sector.

¹ The broiler sector is not included in this study. Broiler producers have not relocated recently (McBride, 1997), and their concentration severely constrains access to data.

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Table 1. Changes in US Hog, Dairy and Fed-Cattle Inventories, 1975-2000 ('000 heads)

	Hogs			Dairy			Fed-Cattle		
	1975	2000	%)	1975	2000	%)	1975	2000	%)
New England									
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
Midwest									
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
Gini-Coefficient	0.72	0.77	7	0.56	0.62	11	0.70	0.80	14

Source: USDA, NASS

Table 2. Definition and Sources of Explanatory Variables Affecting Location Choice of Livestock Producers.

Factor	Definition	Source
Regulatory Stringency		
Stringency Index	Relative Regulatory Stringency Index	Conservation Foundation Index-1984; Renew America Index-1987; Green Index 1991; Metcalfe (2000)- 1994 and 1998; Authors-2000, and interpolated between.
Relative Prices*		
Output/input price ratio	Hog, beef, dairy and corn price ratio	<i>Agricultural Prices</i> (USDA) 1975-1997; <i>Agricultural Prices Summary</i> 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)	Energy Information Administration (EIA) http://www.eia.doe.gov/neic/historic/seperelectric.htm .
Labor Price	Farm labor wage rate (\$/hr)	<i>Agricultural Statistics</i> (USDA) 1975-1979; USDA 1980-1990, (http://usda.mannlib.cornell.edu/data-sets/inputs/91005); NASS 1991-2000 (http://usda.mannlib.cornell.edu/reports/nassr/other/pfl-bb/2000/fmla1100.txt).
Farmland Price	Value of farmland (\$/ac)	<i>Agricultural Statistics</i> (USDA) 1975-1997 NASS 1998-2000; (http://usda.mannlib.cornell.edu/reports/nassr/other/plr-bb)
Property Tax	Real estate taxes on farm (\$/ac)	USDA (http://www.ers.usda.gov/data/sdp/view.asp?f=land/92002)
Livestock Infrastructure		
Slaughtering Capacity	Number of hogs and beef slaughtered (000 head)	<i>Livestock Slaughter Summary</i> (USDA,).
Agriculture's Economic Importance	Agriculture's share of Gross Product	Bureau of Economics Analysis (http://www.bea.doc.gov/bea/regional/gsp).
Rural Population Share	Rural population/Total population	<i>Statistical Abstract of the United States</i> (US Census Bureau) for census years and interpolated for other years
Business Climate		
Population Density	Resident population/total state land area	Population from above and state land area from Netstate.com website.
Unemployment rate	Percent of workforce unemployed	Bureau of Labor Statistics (http://data.bls.gov/labjava/outside.jsp?survey=la).
Land Availability	Farmland area (000 acres)	
Resident Population	State resident population	
Family income	Median income of 4 member family (\$)	US Census Bureau (http://www.census.gov/hhes/income/4person.html).
Natural Endowment		
Precipitation	Mean annual precipitation (mm)	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	Same as for precipitation

*energy price, labor wages, farmland price, property tax, family income were deflated using consumer price index (BLS, 2002)

Table 3. Environmental Stringency Measure by State for 2000

State	Environmental Regulation							Total
	Anti-Corporate	Moratoria	Local Control	Bonding	Cost Share	Nutrient Stds	Set-Back	
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 (see p.11).

Table 4. Regression Results of Model Explaining Annual Inventory Changes in the US Hog, Dairy and Fed-Cattle Sectors

	Hogs	Dairy	Fed-Cattle
<i>Regulatory Stringency</i>			
Relative regulatory stringency	0.0414 (0.000)	0.0033 (0.050)	-0.0272 (0.002)
<i>Relative Prices</i>			
Output-corn price ratio	0.0018 (0.001)	-0.0015 (0.011)	0.0014 (0.001)
Energy price	-0.004 (0.001)	0.0006 (0.087)	0.0016 (0.227)
Farm labor wage	-0.0137 (0.052)	0.0012 (0.478)	-0.0192 (0.781)
Farmland price	2.42e-05 (0.008)	1.22e-06 (0.593)	-3.18e-04 (0.000)
Property tax	-0.0057 (0.463)	-0.0048 (0.016)	-0.0099 (0.212)
<i>Livestock Infrastructure</i>			
Slaughtering capacity	8.93e-06 (0.000)	n/a	1.51e-06 (0.801)
Agriculture's economic importance	1.355 (0.000)	0.1883 (0.000)	-0.0459 (0.826)
Rural population share	-0.000178 (0.000)	0.000031 (0.752)	-1.67e-05 (0.662)
<i>Business Climate</i>			
Population density	-0.00091 (0.000)	0.001 (0.109)	-4.07e-03 (0.093)
Unemployment rate	-0.0056 (0.001)	0.0170 (0.000)	0.0298 (0.082)
Land availability	1.17e-06 (0.366)	-9.64e-06 (0.003)	1.67e-05 (0.202)
Family income	-1.01e-06 (0.524)	7.16e-07 (0.083)	1.69e-05 (0.284)
Total population	8.85e-06 (0.015)	-3.68e-07 (0.688)	-6.76e-06 (0.058)
<i>Natural Endowment</i>			
Temperature	0.0006 (0.691)	-4.06e-05 (0.927)	-0.0044 (0.008)
Precipitation	-0.00024 (0.529)	6.60e-05 (0.502)	0.00025 (0.508)
Adjusted R-Square	0.27	0.53	0.24
<i>p</i> -value in parentheses			