The locational determinants of large livestock operations:

Evidence from the U.S. hog, dairy, and fed-cattle sectors

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1. Introduction

The marked expansion of concentrated animal feeding operations (CAFOs) together with clusters of vertically linked firms have generated concerns regarding environmental quality, sustainable rural communities, food safety, and regulatory efforts in the United States. For instance, numbers of large hog feeding operations (>2000 heads) and large dairy operations (>500 heads) have doubled from 1992 to 2003 (USDA, 2004). Along with the expansion in CAFOs, the U.S. livestock sector has experienced a geographical shift in production to areas with little prior livestock experience (McBride and Key; Drabnestott).

The interaction of technological advances, market forces, social factors, and public policy have shaped the spatial changes and scale of operation in animal production within the United States (Abdalla, Lanyon, and Hallberg). Technological advances have introduced components of industrialization, such as systemization and coordination, into agriculture thereby encouraging specialization and size economies in production. Constraints on livestock production due to physical factors (climate and land availability) and other infrastructure (feed availability) have been alleviated by technological advances and hence weakened regional comparative advantages in livestock production (Abdalla, Lanyon, and Hallberg). Increasingly important to livestock location are the location of processing plants that attract clusters of livestock farms around them (Pagano and Abdalla). The primary impetus for clustering is economic coordination, economies of size in production and processing technologies, and savings in transportation costs (Purvis). Relative prices of inputs such as land and labor can also influence the location of livestock production (Eberts and McMillen). Population density can not only influence market prices for land but may also increase both regulatory and public pressure against livestock production (Martin and Norris, Purvis). Public policy efforts include both commodity support programs and environmental legislation that can either provide subsidies or impose costs on producers depending upon their location. For example, production may shift to regions with lower environmental standards and thus lower costs (pollution havens).

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). 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; Jafee, Peterson and Portney). 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). Fredrickson and Millimet found that states do take into account the regulatory stringency of neighboring states when determining their own regulatory regime. 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.

Despite the claim of its importance, 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 aggregated species (hog, beef cattle, dairy and chicken) based on standard animal units (Park, Seidl and Davies), for hog operations (Roe, Irwin, and Sharp; Metcalfe, 2001; Mo and Abdalla), and for dairy operations (Osei and Luxminarayan) but the results are inconclusive. Several of these studies have unexpectedly found significant positive association between environmental regulatory stringency and regional livestock inventories.

These studies have several limitations. First, almost all these studies focus on the temporal and spatial changes in livestock inventories as their dependent variable (Park et al, 2003; Roe et al, 2002; Metcalfe 2001; Mo and Abdalla 1998). However, total livestock inventories in a state can be altered in the same way through different production decisions. For instance, inventory in a given state could increase due to small production expansions by many existing operations or through the entrance of one mega-farm. These extreme scenarios would likely have different economic and social consequences and would be brought about by different causal factors. It is assumed that increases in inventory associated primarily with CAFOs would be more likely to threaten local environmental assimilative capacities and prompt more odor related nuisance complaints than if the increased production was due to the expansion of smaller, existing operations. Since reactions to changes in regulations and other economic variables do vary across farm size classes, undifferentiated aggregate inventory data is an inappropriate response variable to capture the impact of differences in the stringency of environmental regulations across states. Not only are larger farms more likely to be targeted with environmental standards but they are also relatively more mobile and thus more sensitive to regulations than smaller, family-based operations.

Second, most of the above studies have modeled the state level regulatory stringency using a one period cross sectional measures which could be either general environmental indicators (e.g., FREE index, Conservation Foundation Index as used by Osei and Luxminarayan; Mo and Abdalla) or regulatory policies directly applicable to livestock farms (e.g., Metcalfe (2000) 1994 and 1998 index as used by Roe et al; 1998 National Survey of State Confinement Policies as used by Park et al). However, such cross sectional regulatory stringency values could be correlated with time invariant state specific aspects such as lobbying efforts, educational status and affinity with agricultural operations within a state, which are not explicitly incorporated into the above indices. One can control such time-constant, unobserved attributes with a panel data approach, yet attempts to use such an analysis in testing the pollution haven hypothesis have been constrained due to the lack of time series values for the stringency variable (e.g., see Mo and Abdalla, and Park et al).

This paper introduces a novel approach to examine the locational determinants of livestock across states. It uses the number of large farms (farms with more than 2000 hogs, more than 200 dairy cows and more than 1000 fed-cattle) as the dependent variable instead of state-level inventory data thereby mitigating the problem of inventory aggregation across different size classes. The paper also develops an environmental regulatory stringency measure for each state over approximately a decade and carries out a rigorous panel data analysis. After controlling for all other important location determinants, we find that stringent environmental regulations are one of the most important repellents of large hog farms in the United States. The magnitude of the effect of environmental regulatory stringency on the location decisions of large hog farms are significantly larger than such effects estimated in other studies with aggregate inventory data. The paper is organized as follows; the next section describes the empirical specifications for the dependent and independent variables and the expected association between these. Section 3 describes the econometric specification and panel data analysis. Section 4 provides a description of estimation results and the final section provide some concluding remarks and policy implications.

2. Empirical Model

Dependent Variable

The decision by a concentrated animal feeding operation (CAFO) 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. There is a debate in the business location literature (Bartik, 1991) as to whether the local business growth should be modeled based on the levels of the regional attributes (the levels model) or changes in the regional attributes (the change model). The intuition of the change model is that the existing business activities are in equilibrium and changes in regional attributes would change this equilibrium to a new level. One has to explicitly introduce the dynamic adjustments of the economic variables (specific lag structures) with the changes in the regional attributes. Because of the lag structure in the independent variable, region specific unobserved fixed effects are dropped out. The level model needs much less information about dynamic adjustment processes yet is shrouded with the difficulty of unobserved region specific fixed effects that are correlated with measured regional attributes (Bartik, 1991). Hence, econometric estimates are likely to have omitted variable biases. However, one could use a panel data approach with the level model, which facilitates the removal of region specific fixed effects and provides unbiased econometric estimates. This paper uses the level model assuming that the level of the dependent variable among locations is a function of the levels of regional attributes.

The number of large livestock operations can change due to the expansion or contraction of existing operations, the introduction of new facilities, or the closing of existing ones. Since new CAFOs considering locating in a region tend to face harsher environmental constraints than existing farms due to grandfathering arrangements, the opening up of new facilities will be lower in a region with more stringent environmental regulations (Bartik, 1988). While the number of new CAFOs may be the best measure of changes due to environmental laws, it is not available for an extended period for all states. Thus, the number of large hog farms (farms with >2000 hogs for the period of 1992 to 2000 for 19 states), dairy farms (farms with >200 dairy cows for the period of 1993 to 2000 for 29 states), and fed-cattle farms (farms with >1000 beef cows for the period of 1994 to 2000 for 12 states) are used as the dependent variables in this paper (Table 1). The farm sizes were selected as the closest possible approximation, according to the availability of annual data, to the EPA's definition of CAFOs (see EPA 2001 p. 4). All the states that have farms falling into the above size classes have been taken into the sample resulting in 171 observation for hog sector (19 states by 9 years), 232 observations for the dairy sector (29 states by 8 years) and 84 observations for the fed-cattle sector (12 states by 7 years).

Explanatory Variables

The independent variables in the regressions capture differentials in profitability of large livestock operations across states; which then cause differentials in the number of large livestock operations across states. 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. Assuming that relative profitability of raising livestock compared to other alternative investment opportunities stays the same across states implies 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 (Metcalfe, 2001).

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, 1988; Levinson, 1996; McConnell and Schwab). Drawing on this industry location literature to formulate the general drivers of where large livestock farms operate, 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. Water quality standards by state have been used by Metcalfe (2001) in developing a proxy for state level effort in preserving environmental quality. One can use the number of water quality standards introduced by a given states such as the use classifications, numeric criteria, and anti-degradation criteria as a measure of regulatory stringency (for detail see National Water Quality Inventory Report to the Congress, 1996).

Metcalfe (2000) 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 to develop a stringency index for 2000 but extends it in several ways. 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; EPA (State Compendium); National Association of State Departments of Agriculture). Oregon and California have the lowest index values of 0.03 and 0.08 respectively and Colorado has the highest value of 6.99 in the year 2000. 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 Green Index (Hall and Kerr), Metcalfe's 1994 and 1998 index, the 1996 Water Quality Standard 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 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 from 1992 to 2000. We have used the normalized values of the above six indices in the following manner; Green index (1991/1992) for 1992, Metcalfe's 1994 index for both 1993 and 1994, water quality standard index for both 1995 and 1996, Metcalfe's 1998 index for both 1997 and 1998, and finally the index developed in this paper for 1999 and 2000. Except for Metcalfe's 1994 and 1998 indices, all other indices are developed for all the 48 contagious states. Some states are in our sample are not included in the 19 states of Metcalfe's studies so we have assigned the mean value of Metcalfe's1994 and 1998 indices for those states.

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. Large farms with highly integrated production may be relatively less sensitive to the feed-output price ratio than their smaller counterparts. 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. Large farms are generally energy intensive. 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 a positive impact on siting decisions of large livestock operations since large livestock operations are often constrained by the availability of farmland to spread large quantities of manure. 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 these have increased significantly in Arizona, Wisconsin, and Nebraska.

Livestock Infrastructure Support

Market access and agglomeration economies are two externalities associated with livestock infrastructure support. Large livestock operations 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. For the state level dairy processing capacities, we have used whole milk equivalent for manufactured dairy products. While Wisconsin maintained the largest share of national milk processing capacity (about 25%), both Minnesota and California have expanded their processing capacities significantly.

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;). 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, median family income and ratio between total farm land area to total livestock (in animal units) inventory.

Nuisance complaints regarding large livestock operations from neighbors are likely to increase the greater the population density (Rhodes). Thus, population density has a negative effect on the siting of large livestock operations. On the other hand, 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, 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 siting of large livestock operations.

The unemployment rate can have an influence on large livestock operation 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. Since it is a normal good, concern over environmental quality 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.

Large livestock operations are often constrained by availability of farmland to spread large quantities of manure. The scarcity of farmland relative to livestock inventories could be reflected by the ratio of total farmland area to total livestock inventory (in animal units). A large value of the land-animal ratio indicates a relative abundance of farmland for manure spreading, and is expected to have a positive effect on the siting decisions of large livestock operations.

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. It is assumed that climatic factors had an effect on the initial location of livestock production but have had little effect on changes in the siting decisions over the last decade, particularly given technological advances (Abdalla, Lanyon and Hallberg).

3. Econometric Specification

The factors affecting the number of large livestock operations at the state level were estimated through the following regression model,

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

where Y_{it} is the number of large livestock operations in a given livestock sector for state *i* in year *t*, ***X*** is the vector of exogenous variables affecting the siting decisions of the large livestock operations across states, 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.

In order to select between a random and fixed effect approach in the panel data analysis, a Breusch and Pagan test was carried out first to ascertain whether the variance due to V_i is zero. For all the three livestock sectors, the null hypothesis of zero variance of state specific effects was rejected. In order to the estimate random effect model, the correlation between state specific effects (V_i) and independent variables with a Hausman specification test (Mundlak, 1978). The null hypothesis of no correlation between state specific effects (V_i) and independent variables (X_i) was rejected for all three sectors. Therefore, a fixed effects model was used in the panel data regression in the three sectors. The fixed effects model does not require unobservable state-specific effects to be uncorrelated with the explanatory variables (Hsiao).

4. Results

Hog Sector

The data explain about 52% of the variability in the number of large hog operations among states (see Table 3). Out of the 16 explanatory variables, six were significant at a 10% or lower significance level. However, the economic significance of many of the statistically significant variables is small and this observation is consistent with many location choice studies reported in the literature (see Bartik 1991). The coefficient for the environmental regulatory stringency is negative and highly significant, yet the magnitude of the effect (economic significance) is small. Thus, there is evidence to confirm that large hog operations are siting in the states with the laxest regulatory regimes. Many previous studies that tested pollution haven hypothesis using the inventory data often found a positive association between regulatory stringency and livestock inventory levels suggesting laws arise after production increases (see Park et al; Matcalfe; Mo and Abdalla and Roe et al). However, once the responses to regulatory stringency were analyzed in terms of large farms only, a more plausible response to regulatory stringency is found.

The effects of relative prices on the number of large hog operations were squarely opposite of the expected relationships with farm labor wages and farmland price being statistically significant. Previous studies using inventory levels as the dependent variable found that relative prices played an important role in explaining changes in state production (see Metcalfe 2001; Park et al and Roe et al). One plausible explanation is that highly integrated large livestock operations (both in upstream and downstream activities) might not be exposed to the same market pressures as smaller, more independent farms. The positive and statistically significant association between farm labor wages and the number of large hog farms may be due to the reliance of large farms on qualified personnel to manage these operations. Such individuals may be more likely in states with higher farm wages. It was also expected that increases in the value of farm real estate would curtail the siting of large hog operations. The opposite result suggests that large hog operations may bid up the price of land as part of their expansion in an effort to ensure sufficient land availability relative to the volume of manure generated that are increasingly part of regulations faced by the sector.

As expected, livestock infrastructure has significant effects on the number of large hog operations. Hog slaughtering capacity is positively related to the number of large hog operations, 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). However, the economic significance of the effect of processing capacity as an independent variable is small. States with a larger proportion of agricultural output in its gross state product tend to have a greater number of large hog operations though the result is not statistically significant at the 10% significance level. It was expected that states with a larger share of total population that is rural are more likely to have tolerated large hog operations. However, not only do the regression results reject this assertion but strongly support the opposite effect (a 1% increase in the share of the total population that is rural would decrease the number of large hog operations by 22%). A possible explanation for this result is that the small family farms may feel their livelihoods are threatened by "factory farms". Moreover, the rural population is rising generally due to the increase in the number of non-farm rural resident rather than the number of farmers. Potential nuisance complaints from non-farm rural residents could deter the large livestock operations (Thu and Durrenberger).

Business climate variables generally have estimated coefficients with signs that are consistent with a priori expectations. An exception is the statistically significant negative effect of the farmland-animal ratio, which may perhaps affect the siting of large operations initially but then other economic forces dominate. When combined with other business climate variables, the effect of farmland-livestock production is consistent with the observation that large livestock operations are moving to non-traditional, less-populated areas that are likely to have smaller farm area (Drabenstott). Population density, total population and median family income all appear to curtail the siting of large livestock operations. The overall results of the business climate variables suggest that the NIMBY effect is important in large hog farm location. Large hog operations seem to be responding to both regulatory and social pressure in a more consistent manner than they are responding to relative prices or natural endowment factors in deciding their location choice.

Dairy Sector

In contrast to the hog sector, the coefficient on environmental regulatory stringency is positive yet statistically not significant for the dairy sector. The result suggests a reverse causality where large dairy operations occurs first and regulatory stringency follows. Additional time series data points would be required to conduct tests to determine the direction of causality between the siting of large dairy operations and the severity of state environmental laws.

As with the hog sector, relative prices do not appear to have a significant effect on the siting decisions of large dairy operations. The negative signs for the coefficients on energy price and property tax rate are consistent with theory but insignificant. The only significant variable is farm labor wage rate and it has an unexpected positive effect. As with the large hog farms, the result may be due to the need for qualified managers on large dairy farms rather than just laborers. Processing capacity of the dairy sector in the state is highly significant for large dairy operation location decisions as was the case with slaughtering capacity in the hog sector. However, the economic significance of this variable is small (elasticity is 0.35). The share of the population that is rural has a statistically significant positive effect, which is opposite to the estimated sign for this variable on the number of large hog farms. The results suggests that the increasing non-farm population is more supportive of dairy farms than hog operations due to fewer nuisance concerns (Brown).

As in the hog sector, business climate variables generally have signs consistent with the expectations. Community characteristics such as population density and total residential population seem to discourage the siting of large dairy operations, while the state unemployment rate has a positively, albeit not statistically significant, effect. The only statistically significant business climate variable in median family income and it has an unexpected positive sign. The relationship may be due to the increase in the number of large dairy farms in the western states with higher average family incomes. As with the hog sector, natural endowment factors (temperature and precipitation) have insignificant effects on the number of large dairy operations by state.

Fed-cattle Sector

The regression model for the number of large fed-cattle farms has the weakest explanatory power among the three livestock sectors examined. It explains about 28% of the variability in the number of large fed-cattle operation among states (see Table 3). Similar to the dairy sectors, there is no empirical support for the pollution hypothesis in the beef sector. The number of large beef operations is positively related to the stringency of environmental regulations but the result is not 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 large hog and dairy farms 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. Irrespective of environmental regulatory stringency, large beef feeding operations have expanded in these three states.

As with the hog and dairy sectors, large beef operations are non-responsive to relative price variables. All the relative price variables, except, the beef-corn price ratio, have unexpected sign albeit none of these coefficients are statistically significant. Livestock infrastructure had little effect on the number of large fed cattle operations. Strangely, the coefficient is negative on processing is negative and significant at the 1% level. The same effect is found in the share of agriculture in state gross production. The relevancy of business climate variable in siting decisions of large beef operations is not as pronounced as in the hog and dairy sectors. Population density has a negative effect on number of large fed cattle operations yet this is not statistically significant. As with the dairy sector, unemployment rate is associated with the number of large fed-cattle operations yet it is not statistically significant. Natural endowment factors have little effect.

5. Conclusions

Although differences in environmental stringency have been given as a reason for the growth of the livestock sectors, particularly hogs, in non-traditional production regions, there is little empirical evidence to support the existence of pollution havens. Indeed, instead of finding a negative relationship between environmental stringency and inventory levels, many of the previous studies have obtained a positive effect suggesting that production increases first and tougher regulatory standards follow. This paradoxical result may be due to the specification of the dependent variable. Rather than using state production, this study uses the number of large farms. These operations are more likely to be targeted by environmental regulations and are also relatively more mobile and willing to move in response to differences in environmental standards across regions than established, family-based farms.

The results obtained under this specification are consistent with the suggestion that large hog farms are more likely to locate in states with the laxest environmental standards. Livestock infrastructure support in the form of processing capacity is also a driving factor as has been found by previous studies. This variable was found to be significant for the dairy sector where the number of large farms has increased primarily in western states. Environmental stringency is not a factor influencing the siting decisions of either large dairy or fed-cattle farms. The latter has increased in only the three states where beef production has been concentrated for the last generation. In contrast, economic factors, associated with a harsher regulatory environment and market access, along with community characteristics opposed to factory farms, seem to be important determinants of where large hog farms locate.

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Table 1. Number of large farms in U.S. hog, dairy and fed-cattle sectors

State	Hogs (>2000)			Dairy (>200)			Fed Cattle (>1000)		
	1992	2000	% increase	1993	2000	% increase	1994	2000	% increase
Arizona				100	110	10	10	7	-30
Arkansas	0	140	33						
California				1800	1830	2	38	22	-42
Colorado	0	25	-	130	130	0	172	161	-6
Georgia	70	0	-	150	130	-13			
Illinois	460	540	17	40	70	75			
Indiana	370	450	22	60	70	17			
Iowa	900	1700	89	50	100	100	275	310	13
Idaho				210	340	62	60	50	-17
Kansas	80	115	44				305	225	-26
Kentucky	60	0	-	50	50	0			
Maryland				60	65	8			
Michigan	110	160	45	200	270	35			
Minnesota	260	850	227	70	300	329			
Missouri	100	220	120	50	50	0			
Nebraska	250	320	28				650	695	7
North Carolina	500	1350	170	110	90	-18			
New Mexico				110	145	32	0	10	-
New York				400	600	50			
Ohio	30	150	400	90	130	44			
Oklahoma	0	90	-				20	28	40
Oregon				190	150	-21			
Pennsylvania	100	185	85	170	280	65			
South Dakota	80	150	88	0	60	-	100	120	20
Tennessee	30	0	-	100	95	-5			
Texas				560	530	-5	137	137	0
Utah				130	145	12			
Virginia				110	130	18			
Vermont				100	160	60			
Washington				380	370	-3	20	16	-20
Wisconsin	50	60	20	300	800	167			
Total	3450	6505	89	5720	7200	26	1787	1781	0

Source (NASS, 2004).

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	Green Index 1991; Metcalfe (2000)- 1994 and 1998; Watre Quality Standard Index 1996, Authors-2000.
Relative Prices*		
Output/input price ratio	Hog, beef, dairy and corn price ratio	*Agricultural Prices* (USDA) 1992-1997; *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)	Energy Information Administration (EIA) http://www.eia.doe.gov/neic/historic/seperelectric.htm.
Labor Price	Farm labor wage rate ($/hr)	NASS 1992-2000 (http://usda.mannlib.cornell.edu/reports/nassr/other/pfl-bb/2000/fmla1100.txt).
Farmland Price	Value of farmland ($/ac)	*Agricultural Statistics* (USDA) 1992-1997 NASS 1998-2000; (http://usda.mannlib.cornell.edu/reports/nassr/other/plr-bb)
Property Tax	Real estate taxes on farm ($/ac)	USDA (http://www.ers.usda.gov/data/sdp/view.asp?f=land/92002)
Livestock Infrastructure		
Slaughtering Capacity	Number of hogs and beef slaughtered (000 head)	*Livestock Slaughter Summary* (USDA,).
Dairy processing	Whole milk equivalent for manufactured dairy products (1000 lb)	*Dairy products: Annual Summary* (USDA) various years 1993 to 2000.
Agriculture's Economic Importance	Agriculture's share of Gross Product	Bureau of Economics Analysis (http://www.bea.doc.gov/bea/regional/gsp).
Rural Population Share	Rural population/Total population	*Statistical Abstract of the United States* (US Census Bureau) for census years and interpolated for other years
Business Climate		
Population Density	Resident population/total state land area	Population from above and state land area from Netstate.com website.
Unemployment rate	Percent of workforce unemployed	Bureau of Labor Statistics (http://data.bls.gov/labjava/outside.jsp?survey=la).
Farmland-animal ratio	Farmland area (000 acres)/number of animal units as EPA definition	Animal inventories from NASS website
Resident Population	State resident population	
Family income	Median income of 4 member family ($)	US Census Bureau (http://www.census.gov/hhes/income/4person.html).
Natural Endowment		
Precipitation	Mean annual precipitation (mm)	Economic Research Service 1992-1994 (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. Regression results of factors affecting number of large livestock operations among state

	Hogs	***elasticity***	**Dairy**	***elasticity***	**Fed-Cattle**	***elasticity***
Regulatory Stringency						
Relative regulatory stringency	**-39.86**	**0.17**	3.37		2.91	
	(0.008)		(0.491)		(0.317)	
Relative Prices						
Output-corn price ratio	-2.65		-0.93		0.69	
	(0.413)		(0.794)		(0.166)	
Energy price	15.04		-5.41		0.882	
	(0.353)		(0.297)		(0.831)	
Farm labor wage	**172.42**	**2.72**	**63.32**	**1.22**	1.01	
	(0.001)		**(0.001)**		(0.876)	
Farmland price	**0.61**	**1.75**	0.001		0.294	
	(0.001)		(0.959)		(0.637)	
Property tax	19.24		-15.98		17.07	
	(0.790)		(0.606)		(0.830)	
Livestock Infrastructure						
Processing capacity	**0.0212**	**0.35**	**0.00025**	**0.35**	**-2.457**	**-0.39**
	(0.017)		**(0.000)**		**(0.017)**	
Agriculture's economic importance	543.70		-85.34		**-604.10**	**-0.12**
	(0.391)		(0.909)		**(0.075)**	
Rural population share	**-172.99**	**-21.7**	**26.28**	**3.40**	-2.70	
	(0.000)		**(0.010)**		(0.817)	
Business Climate						
Population density	-5.54		-0.376		-1.27	
	(0.705)		(0.781)		(0.687)	
Unemployment rate	-12.17		5.87		7.724	
	(0.524)		(0.427)		(0.109)	
Relative farm land availability	**-4.81**	**-0.329**	-159.52		-315.11	
	(0.022)		(0.497)		(0.192)	
Family income	-0.006		**3.23**	**1.56**	0.001	
	(0.429)		**(0.001)**		(0.549)	
Total population	-0.16		-0.027		0.013	
	(0.519)		(0.107)		(0.390)	
Natural Endowment						
Temperature	-0.08		0.024		-1.68	
	(0.968)		(0.977)		(0.459)	
Precipitation	0.620		0.700		-0.04	
	(0.741)		(0.261)		(0.942)	
R-Square (within)	0.52		0.34		0.28	
Model F value	9.17		5.79		1.31	
	(0.000)		(0.000)		(0.22)	
Number of observation	171		219		82	

p-value in parentheses