Environmental Regulations and Livestock Production Levels: What is the Direction of Causality?

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ABSTRACT

Fundamental to the assertion that environmental regulatory standards are strategically set by decentralized authorities and consequently firms respond to spatial differences in regulatory standards is the underline causal relationship. Establishing the cause-effect association between regulatory standard setting and industry response is essential to justify the existence of the pollution haven and the potential for a race to the bottom. In this paper using 25 years data of the livestock production intensities for hog, dairy and fed cattle sectors and environmental regulatory stringency measure from 1975 to 2000 for 48 contiguous states we explore whether the direction of causality as suggested by race to the bottom hypothesis is in fact supported by the empirical evidence and hence the potential for existence of pollution haven is real in the U.S. livestock production sector. The results in general support the existence of pollution havens and potential for a race to the bottom at the regional level. There were no convincing evidences supporting the reserve causality that the "industry driving policy" hypothesis. Across the different livestock types, dairy sector provided conclusive evidence that in the regions with substantial growth of dairy inventories, there are strong evidences for a race to the bottom.

Key words: Pollution Haven Hypothesis, Granger Causality Test, Livestock Production

Introduction

Location choices of livestock operation have been examined focusing on the variation of environmental regulatory stringency among states in the U.S. (Park, Seidl and Davies, Roe, Irwin, and Sharp; Metcalfe, 2001; Mo and Abdalla; Osei and Luxminarayan; Herath, Weersink and Carpentier). The inquiry of association between location choices and environmental regulations for livestock producers is a branch of a broader research thrust in the trade and environment literature involving pollution haven hypothesis (see for example, Bridsall and Wheeler, 1993; Jensen, 1996; Eskeland and Harrison, 1997; Neumayer, 2001; Millimet and List, 2004; Frankel and Rose, 2005). The pollution haven hypothesis asserts that polluting firms will locate in regions with the laxest environmental regulations in order to avoid the costs of abatement (Levinson, 1999; Millimet and List, 2004; Scott, 2004). Support of the hypothesis implies that regional differences in the stringency of environmental legislation will result in a race to the bottom for those laws in order to attract firms into an area (Bartick 1988; Levinson 1996; Becker and Henderson, 2000). For example, Fredriksson and Millimet (2002) suggest a strategic interaction exists between the stringency of environmental regulations of both contiguous and regional neighbors operating within a five year window.

Race to the bottom hypothesis suggests a proactive policy making where state policies have been put in place in anticipation of the favorable reaction from the large livestock operators in their location choices (Park, Seidl and Davies). 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). Fundamental to the assertion that regulatory standards are strategically set by decentralized authorities and consequently firms respond to spatial differences in regulatory standards is the underline causal relationship. Establishing the cause-effect association between regulatory standard setting and industry response is essential to justify the existence of the pollution haven and the potential for a race to the bottom. The direction of causality has significant policy implications for those concerned about the environmental impacts from CAFOs. If different levels of regulatory stringency significantly affect the dynamics of the spatial distribution of livestock production, then there is preliminary support for the pollution haven hypothesis. CAFOs may be moving to states with lenient environmental regulations and the potential race to the bottom implies a need for federal level environmental policy regulations. On the other hand, if livestock numbers determine environmental regulations, there will be no competition among states to attract capital and growth opportunities associated with livestock operations. Local regulations are thus appropriate to handle potential local issues with the livestock sector and federal regulation is unnecessary. Despite the significance of the implications for general environmental policies through active stake holder participation in shaping the regulatory outcome as suggested by capture theory, surprisingly the direction of causality issue is largely unexplored in the pollution haven literature in the livestock sector. The purpose of this study is to test the direction of causality between the stringency of environmental regulations facing animal operations and the intensity of livestock production for the US hog, dairy and fed-cattle sectors. In this paper we explore whether the direction of causality as suggested by race to the bottom hypothesis is in fact supported by the empirical evidence and hence the potential for existence of pollution haven is real in the U.S. livestock production sector. We have used 25 years data of the livestock production intensities for hog, dairy and fed cattle sectors and environmental regulatory stringency measure from 1975 to 2000 for 48 contiguous states. We tested the direction of causality using panel data specification of the Granger causality test for these two variables at the 8 Census regions. The paper contributes to the literature related to pollution haven hypothesis in livestock sector by testing not only the existence of causal relationship between livestock production intensities and environmental regulatory stringency but the direction of causality as well.

Direction of causality "chicken or egg"

Researchers acknowledge that livestock location choices are determined not only by regulatory stringency but also by input availability and prices, output prices, physical and climatic conditions, and management and technology access. However, perfection of the intensive livestock farming in a more controlled environment, better disease and feeding management systems and lower transportation costs have increasingly weaken the geographical comparative advantage of feed availability and climatic suitability in location choices (Abdalla, et al 1995). Therefore, institutional variables such as regulatory stringency, anti-corporate farming laws, affinity with contract farming and other sociopolitical characteristics of the constituent have been brought into explain the recent changes in the spatial dynamics of livestock operations in the U.S. (Roe et al; Drabenstott; Sumner and Wolf; Stretesky et al; Jackson-Smith and Buttel). If there is little regional comparative advantage from climatic conditions or other technological factors, the institutional variables are likely to play a bigger role especially in the proactive public policy making. For instance, if regional and st5ate 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. On the contrary, if pollution control costs are significant and vary across geographical locations due to reasons other than regulatory stringency such as industry agglomeration effects and availability and supply of inputs for pollution control services, some regions may have a comparative advantage of providing pollution control services (but not on the livestock production). Thus the implicit assumption of treating regulatory stringency equivalent to cost of pollution control as poised in the pollution haven hypothesis is untenable if such comparative advantage of pollution control exists (Neumayer, 2001). The validity of such alternative hypothesis of spatial dynamics of livestock operations has been largely unexplored in the literature.

The potential existence of pollution havens resulting from decentralized policy making was a partial impetus behind the creation of the US Environmental Protection Agency (EPA) in 1968 (House Report 1979) and the reason why the US Clean Air Act is implemented at the federal level (Revesz 1992). However, pollution control in the US is generally a combination of centralized standard-setting and state-level implementation and enforcement. 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 state authorities (Kraft and Vig; Lester; Levinson, 2000). Consequently, a state retains considerable flexibility in their environmental policy making. For example, Clean Air Act and Clean Water act grants considerable latitude in selecting methods of pollution control at the state level facilitating the free riding behavior (Holmes et al., 1993). Differences in environmental regulations at the state-level may explain the spatial differences in livestock numbers over time. Inventory has increased in non-traditional producing regions particularly for the hog sector. The increased concentration of animal feeding operations has been linked to the growth of nearby processing facilities (Abdalla et al., 1995). However, the changes may be a reflection of pollution havens arising.

While Metcalfe (2000) found environmental regulations to have an inconclusive effect on location decisions for the hog sector, Osei and Lakshiminarayan (1996) found higher environmental regulations deterred the decision to site dairies. Herath et al. (2005) also found that differences in the severity of environmental legislation affected inventory numbers for the dairy and hog sectors.

The pollution haven hypothesis assumes that lax (stringent) environmental laws cause an increase (a decrease) in the number of polluting firms to a region. However, thedirection of causality may be reversed or may be the change in environmental laws and change in number of polluting firms are determined simultaneously. Political economy theory suggests that the severity of environmental regulation is not exogenous but rather endogenously determined through the lobbying efforts of affected stakeholders (Pashigian, 1985). For example, regulations directed toward the livestock sector would not normally be considered until pollution problems attributable to animal operations arose. On one hand existing livestock farms would have the incentive to lobby government representatives to minimize the financial impact to their operations of any proposed legislation. On the other hand, these efforts may be countered by pressures from non-farm groups seeking to limit the growth of confined animal feeding operations (CAFOs). Either way, the environmental regulations facing the sector are determined by factors such as livestock production numbers rather than being exogenously determined and thereby altering inventory levels as suggested by the pollution haven hypothesis.

Econometric Specification

We test for Granger causality between two variables: environmental regulatory stringency index and livestock inventories for hog, dairy and fed-cattle using a panel data approach. The panel data approach permits the use of both cross-sectional and time series information to test the causality relationship between two variables. The substantial increase of number of observation raises the degrees of freedom thereby improves the efficiency of Granger causality test. The notion of Granger causality is based on a criterion of incremental forecasting value. Variable *X* is said to be "Granger cause" variable *Y* if *Y* can be better predicted from the past values of the *X* and *Y* variables together than the past values of *Y* alone (Granger, 1969). In assessing causality, social scientists often posit the exogeneity of certain variables on the basis of a priori reasoning. However, if these variables are not, in fact, exogenous, the conditions for identification will be misstated and parameter estimates will not be consistent. According to Sims (1972) a necessary condition for a variable to be exogenous to another variable is that the second variable fails to Granger cause first variable. In other words by testing for Granger causality, it is possible to refute claims of econometric exogeneity.

There are many ways that the Granger causality can be operationalized for the simplest bivariate case (see Freeman, 1983). This study tests for the direction of causality using a Granger causality test procedure modified by Hurlin and Vent (2001) to handle panel data and this method has been employed recently by Hoffman et al. (2005). First we test for the existence of causality. Consider a time-stationary VAR representation, adapted to a panel data context. Let *i* denotes the state and *t* denotes the time period of the panel data set where *i* goes from 1 to *N* (48 states) and *t* goes from 1 to *T* (1975 to

2000). Then if environmental stringency regulations Granger cause spatial variation in inventories;

$$INV_{i,t} = \sum_{k=1}^{p} \gamma^{(k)} INV_{i,t-k} + \sum_{k=1}^{p} \beta_i^{(k)} ESR_{i,t-k} + \delta_{i,t} \qquad (1)$$

where $INV_{i,t}$ is the level of inventory for the i^{th} state in the t^{th} year (inventory could be hog, dairy or fed-cattle in thousand heads), $ERS_{i,t}$ is the index of the environmental regulatory stringency for the i^{th} state in the t^{th} year and $\delta_{i,t}$ is the error term. The lag structure for the variable *INV* is characterized by $\gamma^{(k)}$ for the k^{th} lag and the lag structure for the *ERS* is characterized by $\beta^{(k)}$ for the k^{th} lag. On the other hand if environmental regulatory stringency has been caused by the level of livestock inventories the reverse causality has been explored based on following specification:

$$ERS_{i,t} = \sum_{k=1}^{p} \gamma^{(k)} ERS_{i,t-k} + \sum_{k=1}^{p} \beta_i^{(k)} INV_{i,t-k} + \delta_{i,t} \qquad (2)$$

The above two specifications were also estimated separately for the 8 Census regions. The breakdown of the 48 states across 8 regions is in Appendix II.

In the Granger causality testing first the null hypothesis of no causal relationship is tested as shown below.

$$H_0 : \beta^{(k)} = 0 \forall i \in [1, N], \forall k \in [1, p]$$
$$H_1 : \exists (i,k) / \beta^{(k)} \neq 0$$

If the null hypothesis is rejected, then there is evidence of a causal relationship between livestock inventories and environmental regulation. Second, given that the null hypothesis is rejected, Granger causality analysis is conducted to determine the direction of the causality. The test statistics can be computed by the following Wald test as proposed by Hurlin and Venet (2001).

$$F_{hnc} = \frac{(RRSS - URRSS)/(N_p)}{URSS_1[SN - N(1+p) - p]}$$

Where *SN* denotes the total number of observations, *RRSS* denotes the restricted residual sum of squares obtained under the null hypothesis and *URRSS* is the unrestricted residual sum of squares obtained from equation 1 and 2.

Data

Environmental stringency regulation index has been developed by Herath et al. (2005) and the index provides the panel data on the regulatory stringency for 48 contiguous U.S. states from 1975 to 2000 and state level livestock inventories were taken from the NASS website of the USDA for the same period. In total, 1200 observations were available for the analysis. The stationarity of the two variables should be tested in order to avoid improper causal effect attributable to the serial correlation. Augmented Dickey-Fuller test was used to test for the unit roots of panel values of inventories (hog, dairy and fed-cattle) and panel values of environmental regulatory stringency. The levels of two variables found to have no unit roots thus found to be stationary.

Results of the Granger Causality Test

The causality test results for the entire 48 states along with different lag structures are reported in Table 1. The *F* statistics for the Wald test with the significant levels 95% or greater have been reported with a star. In the second column for the lag values, first value indicates number of lags for the dependent variable and second value indicates numbers of lags for the independent variable. First nine rows of the Table 1 report whether environmental regulatory stringency Granger cause livestock inventory levels while the second nine rows report whether livestock inventory levels Granger cause environmental regulatory stringency. The direction of causality could be either way at the national level and results are inconclusive and no appreciable differences were found across type of livestock operations. Across the lag structures, significant *F* values for rejecting null hypothesis of no causal relationship is equally likely for the both directions. These results are not surprising since that it is unlikely to have homogeneous causal relationship between environmental regulatory stringency and livestock inventory level at national level. Heterogeneity among the states is abound especially due to the sociopolitical traits of the population and their reactions to environmental nuisances and the lobbying power for influencing environmental regulatory outcomes. The state level heterogeneity could be controlled to some extent by grouping the states in to more comparable classes. In order to address the potential heterogeneity of the states, we have estimated the above models separately for the 8 Census regions and detailed results are reported in Appendix 2 and summary results are in Table 2.

Albeit the direction of causality is ambiguous at the region levels too, some interesting patterns are emerging from the results reported in Table2. Only a very few regions provided the evidence for the reverse causality (inventory level Granger causing environmental regulatory stringency). Hog sector seems to be the most likeliest to have such a reverse causal relationship given that the general revulsion for the mega hog farms among most stakeholders. However, we have not found any evidence for such a reverse causal association between hog inventories and environmental regulatory stringency at any of the 8 census regions. Therefore the empirical evidence for "industry driving policy" hypothesis is weak in the hog sector. Populated regions such as New England (in dairy) and Far west (in fed-cattle) seems to provide evidence for the existence of reverse causality (inventory level Granger causing environmental regulatory stringency). However, we cannot comment about these regional characteristics steadfastly since New England and Far West seems to have opposite causal relationship in Hog and Fed-cattle sectors. However, in general, evidence for pollution haven hypothesis is found in many of the regions. Environmental regulatory stringency Granger cause hog inventories in New England, Great Plains and Far West, dairy inventories in Mid east Great Lakes, South West, Rocky Mountains, and Fed-cattle inventories in New England and South west. There are two potential explanations for the evidence for pollution haven hypothesis in these regions. New England, Mid East and Far west regions are likely to have stringent environmental regulatory regimes mainly due to population density and the prominence of non-agricultural industrial growth in the industrialization of U.S. economy. Thus stringent regulatory regimes are likely to be in place to combat the pollution generated from such industrial activities and polluting firms with livestock production seem to face similar stringent measures in such regions. In contrary, Southwest and Rocky Mountains have been noted as the "new home" for livestock operators especially during the recent past. Especially, states such as Oklahoma, Colorado, Utah, and Idaho have experienced substantial growth in livestock inventories. Among such states, it is likely that entering large livestock operators searching for the states with less stringent regulatory regimes in such regions. For instance dairy inventories have been increased in Mideast by 1413%, in Great Lake by 2171%, in Southwest by 594%, and in Rocky Mountain by 557% from 1975 to 2000. It is plausible that such substantial increase in livestock inventories are responding to regulatory stringencies strategically by searching for pollution havens among the states. Leniently regulated states in these regions are likely to house a disproportionately larger share of expanding livestock inventories hence providing the evidence for pollution haven hypothesis. A similar observation is reported for the fed-cattle inventory growth in Southwest (85%). A precautionary remark is due given the nature of the mixed results. Many of the regions also reported situations of causality in both directions, yet these results are across different livestock types. While there are reasons to believe that across different livestock species environmental regulatory stringency likely to play a different role, in general across all the livestock types the results are more incline to be supportive for pollution haven hypothesis and potential for the race to the bottom.

Conclusions

This paper estimated the Granger causality test for livestock inventories (hog, dairy and fed-cattle sectors), and environmental regulatory stringency in the United States for the period of 1975 to 2000 using 48 contiguous states. The results in general support the existence of pollution havens and potential for a race to the bottom at the regional level.

There were no convincing evidences supporting the reserve causality that the “industry driving policy” hypothesis. Across the different livestock types, dairy sector provided conclusive evidence that in the regions with substantial growth of dairy inventories there are strong evidence for a race to the bottom.

Table 1. Granger causality for environment regulatory stringency and livestock inventories at the national level (for 48 states)

Direction of Causality	Lags	Hog	Dairy	Cattle
ESR→INVT	2-2	2.23	0.56	2.06
	2-3	3.86*	8.27*	44.97*
	2-4	24.65*	9.55*	54.65*
	3-2	2.49	0.68	1.50
	3-3	1.72	1.51	1.01
	3-4	21.28*	4.39*	20.76*
	4-2	2.39	0.52	1.65
	4-3	1.63	1.75	1.17
	4-4	1.47	1.71	1.00
INVT→ESR	2-2	1.81	0.56	1.93
	2-3	9.76*	8.50*	9.43*
	2-4	19.54*	18.42*	18.97*
	3-2	1.67	0.36	1.99
	3-3	1.78	0.49	1.46
	3-4	13.84*	12.56*	13.14*
	4-2	0.83	0.19	1.65
	4-3	1.07	0.28	1.22
	4-4	1.39	0.25	0.92

Table 2. Granger causality for environment regulatory stringency and livestock inventories at the regional level (for 8 Census Regiona)

Animal Type	No causality	ESR→INVT	INVT→ESR	Both directions
Hog	Mideast, Southwest, Rocky mountain	New England, Great plains, Far West	No evidence	Great Lakes, Southeast
Dairy		Mideast, Great Lakes, South West, Rocky Mountain	New England	Great Plains, Southeast, Far West
Cattle	Rocky Mountain	New England, South West,	Far West	Mideast, Great Lakes, Great Plains,

Appendix 1.Regional Inventories of Hogs, Dairy and Fed Cattle in US, 2000 (‘000s))

Region	State
New England	Connecticut
	Maine
	Massachusetts
	New Hampshire
	Rhode Island
	Vermont
Mideast	Delaware
	Maryland
	New Jersey
	New York
	Pennsylvania
Great Lakes	Illinois
	Indiana
	Michigan
	Ohio
	Wisconsin
Great Plains	Iowa
	Kansas
	Minnesota
	Missouri
	Nebraska
	North Dakota
	South Dakota
Southeast	Arkansas
	Alabama
	Florida
	Georgia
	Kentucky
	Louisiana
	Mississippi
	North Carolina
	South Carolina
	Tennessee
	Virginia
	West Virginia
Southwest	Arizona
	New Mexico
	Oklahoma
	Texas
Rocky Mountains	Colorado
	Idaho
	Montana
	Utah
	Wyoming
Far West	California
	Washington
	Nevada
	Oregon

Source: USDA, NASS

Appendix II. Regional level Granger Causality test

(results that are not appearing here are not significant at 5% level)

Region	Direction of Causality	Lag Structure	Hog	Dairy	Cattle
New England	ESR→INVT	2-3	5.37*	1.03	2.99*
	ESR→INVT	2-4	13.21***	1.13	2.91*
	ESR→INVT	3-4	11.11***	1.06	2.04
	INVT→ESR	2-3	1.62	3.01*	2.00
	INVT→ESR	2-4	1.64	3.00*	2.09
Mideast	ESR→INVT	2-2	0.08	1.89	4.87*
	ESR→INVT	2-3	0.51	4.50*	6.93*
	ESR→INVT	2-4	0.88	3.95*	5.79*
	ESR→INVT	3-2	0.02	1.89	4.93*
	ESR→INVT	3-3	0.02	1.72	4.23*
	ESR→INVT	3-4	1.71	1.88	3.80*
	ESR→INVT	4-2	0.02	1.80	3.92*
	ESR→INVT	4-3	0.02	1.74	3.60*
	ESR→INVT	4-4	0.12	1.52	2.86*
	INVT→ESR	2-2	0.51	0.59	4.17*
	INVT→ESR	2-3	0.53	2.49	5.26*
	INVT→ESR	2-4	1.33	2.41	4.31*
	INVT→ESR	3-2	0.44	0.55	4.04*
Great Lakes	ESR→INVT	2-2	0.47	1.54	6.30***
	ESR→INVT	2-3	4.60*	4.07*	9.93*
	ESR→INVT	2-4	9.16***	8.43***	7.39***
	ESR→INVT	3-2	0.70	1.06	7.30***
	ESR→INVT	3-3	0.47	0.74	9.88***
	ESR→INVT	3-4	5.58*	5.42*	7.78***
	ESR→INVT	4-2	1.58	0.52	4.85**
	ESR→INVT	4-3	1.05	0.48	7.67***
	ESR→INVT	4-4	0.85	0.37	6.12***
	INVT→ESR	2-2	0.71	0.45	4.79**
	INVT→ESR	2-3	6.91***	2.15	7.99***
	INVT→ESR	2-4	5.37**	2.03	6.58***
	INVT→ESR	3-2	0.67	0.33	7.22***
	INVT→ESR	3-3	5.08**	0.52	7.63***
	INVT→ESR	3-4	4.06**	0.88	6.53***
	INVT→ESR	4-2	0.30	0.17	6.39***
	INVT→ESR	4-3	6.51***	0.33	6.39***
	INVT→ESR	4-4	5.13**	0.25	5.05**
Great Plains	ESR→INVT	2-4	7.31***	2.89*	7.76***
	ESR→INVT	3-4	6.42*	1.98	6.43***

	INVT→ESR	2-3	0.68	2.96*	1.95
	INVT→ESR	2-4	0.93	10.87*	8.00*
	INVT→ESR	3-4	0.49	9.63*	6.65*
	INVT→ESR	4-4	0.03	2.68*	0.61
Southeast	ESR→INVT	2-2	0.19	3.28*	0.78
	ESR→INVT	2-3	1.69	34.14*	2.01
	ESR→INVT	2-4	6.56***	54.76***	7.84***
	ESR→INVT	3-4	5.76**	24.59***	6.92***
	INVT→ESR	2-3	4.84**	2.31	2.67*
	INVT→ESR	2-4	8.86***	8.32**	7.94***
	INVT→ESR	3-3	3.14*	0.79	1.17
	INVT→ESR	3-4	7.53***	7.28***	7.10***
	INVT→ESR	4-3	3.00*	0.69	1.16
	INVT→ESR	4-4	4.10**	0.91	0.87
Southwest	ESR→INVT	2-3	1.58	9.55*	2.13
	ESR→INVT	2-4	1.83	13.18*	3.20
	ESR→INVT	3-4	1.19	6.00***	2.69*
	ESR→INVT	4-3	0.81	3.61*	1.42
	ESR→INVT	4-4	0.88	4.16*	1.91
Rocky Mountain	ESR→INVT	2-3	0.43	5.79*	0.68
	ESR→INVT	2-4	1.94	4.51*	0.93
Far West	ESR→INVT	2-3	2.31	6.90*	0.99
	ESR→INVT	2-4	3.06*	7.62***	1.17
	INVT→ESR	2-3	1.65	3.42*	3.46*
	INVT→ESR	2-4	1.58	2.69*	2.51
	INVT→ESR	3-2	2.51	3.61*	2.59
	INVT→ESR	3-3	2.52	2.94*	2.45

- Significant at 5% significant level.

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