The Role of Environmental Regulation on Concentrations of U.S. Livestock Sectors

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Abstract

The industrialization of U.S. beef, dairy, hog, and poultry sectors has received considerable attention. There have been regional shifts in the geographical location of livestock inventories and livestock farms. This paper examines the trends in geographical concentrations of livestock sectors in the U.S., and determines whether the environmental regulations have impacted the geographical concentrations. It uses an entropy-based geographical concentration measure to determine the extent of concentrations of beef, dairy, hog, and poultry inventories and farms. The results show that livestock productions on a national level and within states are becoming more geographically concentrated. The geographical concentration of livestock sectors is negatively related to the stringency of state environmental regulations.

1. Introduction

The industrialization of U.S. livestock sectors (e.g., beef cattle, dairy, hog, and poultry) has received considerable attention in the literature. Much of this attention has focused on the negative impacts of livestock production on the environment because animal waste generated in livestock feedlots has grown enormously, contributing significantly to air and water pollution. Livestock feedlots contribute to about 13 percent of the impairments in rivers nationwide, which is higher than that from the industrial sources (Environmental Protection Agency). Substantial public scrutiny has fallen upon the livestock sectors because of the increased public concerns about environmental quality degradation. Much public discussions about the adverse environmental impacts of livestock sectors have recently resulted in increased local, state, and federal environmental regulations. For example, in December 2002, the Environmental Protection Agency signed the new rule for Concentrated Animal Feeding Operations (CAFOs) that identifies potential revisions to the existing permit provisions and effluent guidelines for CAFOs.

Social, economic, and environmental factors have shaped the transition of the livestock productions (especially hog sector) from small, geographically dispersed operations, to fewer, larger, more concentrated into relatively few states. There have been regional shifts in the geographical location of livestock inventories and livestock farms. Many states and production regions have lost in terms of the national share of livestock inventories and farms, while several other regions have increased their share. For example, traditional dairy production regions such as the Corn Belt, Lake and Northeast States have lost in terms of the national share of cow inventories and milk productions to the Pacific, Mountain, and Southern States during the 1980s and 1990s (Blayney; Program on Agricultural Technology Studies). Similar changes have also

been observed in the spatial reorganization of hog production, with the traditional Corn Belt states losing in terms of national share of hog production to the Southeastern, Great Planes and Mountain states during the 1980s and 1990s (Roe, Irwin, and Sharp; Hubbell and Welsh).

The main concern from an environmental perspective is the concentrations of livestock inventories and farms within geographic areas. Geographic concentrations coupled with the increased inventories of the livestock production may lead to increased environmental and social problems. To alleviate some of these environmental problems, federal involvement in the environmental regulations of the livestock sectors has been slowly increasing, which aims at harmonizing state environmental regulations of the livestock sectors. This is important because geographic variations in environmental regulations can induce a migration of industries across state or county boundaries to places where compliance costs are lower. Therefore, it is significant to examine how the current variability in state environmental regulations has impacted the geographical concentration of the livestock industry.

The purpose of this paper is to examine the trends in geographical concentrations of the livestock inventories and number of farms in the U.S. It uses an entropy-based measure of concentrations to examine whether geographic concentration is occurring both on a national level and within particular states. The paper also aims at determining whether the environmental regulations have impacted the geographic concentrations of livestock production. It uses a spatial econometric model to analyze whether the entropy-based concentration measure in a state is related to the stringency of environmental regulations of that state. We also explore the policy implications of the results from the analyses.

There has been little attention given to the evaluations of the structural changes and geographical shifts in livestock inventories and farms in U.S. livestock sectors. Most of the

previous studies have examined either the changing structure of the hog industry and state environmental regulations (i.e., Hubbell and Welsh; Metcalfe; and Roe, Irwin, and Sharp) or the factors affecting livestock and dairy inventories (Osei and Lakshminarayan; Rahelizatovo and Gillespie; Thurow and Holt; Isik). However, these studies examined the factors affecting the livestock inventory levels of a specific sector (i.e., hog or dairy) for a given census year. Most of these studies also did not focus on the trend in geographical location of production and livestock farms over time and how they differ across different sectors.

In this study, we analyze the trends in geographical location of beef cattle, dairy, hog, and poultry sectors and compare their trends across U.S. counties and states. This paper makes contributions to the literature by showing that the extent to which the concentrations of the livestock sectors have increased over time. Using the county-level time series data between 1975 and 1998, the paper shows that livestock productions on a national level and within states are becoming more geographically concentrated. The concentrations of livestock production and farms are found to be highest in the poultry and hog inventories. However, the rates of increases in the concentrations of dairy and beef cattle over time have been relatively high. This indicates that like hog and poultry sectors, the dairy and beef cattle sectors have become increasingly concentrated. The concentrations of state-level livestock inventories are found to be negatively related to the stringency of state-level environmental regulations. The results from this paper have important policy implications for public policies affecting the location and development of the livestock sectors.

2. Empirical Model

We first develop a geographical concentration measure to determine the extent of geographical concentration occurring in U.S. livestock sectors. We employ the Shannon diversity

index, which is a commonly used measure of industrial concentration. The Shannon diversity index is represented as (Horowitz; Batten):

$$H(b) = -\sum_{i=1}^{N} b_i \ln b_i \quad (1)$$

where b_i is the i*th* firm's share of production. In the case where geographic concentration is to be measured, b_i represents the i*th* region's share of production (or firms). Higher values of $H(b)$ indicate more entropy, or dispersion, and lower values indicate more concentration. The diversity index is bounded such that $0 \leq H(b) \leq \ln N$.

A more useful measure for examining geographic concentration is the relative entropy measure. The relative entropy measure is an index of concentration measuring how dispersed the livestock production is relative to the maximum level of dispersion. The Shannon's evenness index (SEI) can be calculated by dividing $H(b)$ by $H^{Max} = \ln N$ as:

$$SEI = \frac{H(b)}{\ln N}. \quad (2)$$

The Shannon's evenness index given (1) assumes a value between 0 and 1, with 1 being complete evenness. This is an index of concentration measuring how dispersed production (or the number of farms) is relative to the maximum level of dispersion. Thus, if there is complete concentration in one region, $H(b)$ will equal 0 and if there is complete dispersion $H(b)$ will equal 1. If livestock productions or livestock farms are becoming more geographically concentrated, the values of $H(b)$ should be tending to zero.

Spatial Concentration and Environmental Regulation

We also examine whether the spatial concentration of livestock production in a state is related to the level of environmental regulation stringency of that state. We run the following

spatial lag model to determine whether there is a spatial structure in concentrations of livestock inventories (Anselin; Anselin and Bera):

$$SEI = rW(SEI) + bZ + u \tag{3}$$

where SEI is the within-states evenness index of livestock inventories, r is the scalar spatial lag coefficient that accounts for the impacts of the concentrations of neighboring states, W is the spatial weight matrix, Z is the stringency of environmental regulation, b is the parameter to be estimated, and u is the vector of normally distributed error term with mean zero and variance s^2.

There are various ways to define the spatial weight matrix (W). In this study, adjacency criteria is used to assign the weights in the spatial weight matrix as: w_{ij}. According to the adjacency criteria, the element of the spatial weight matrix w_{ij} is one if state i is adjacent to state j, and zero otherwise. Estimation of (3) for each livestock sector will reveal whether there is a spatial pattern in concentrations of livestock sectors and whether the environmental regulation stringency affects the concentration levels.

3. Data

Trends in geographical concentrations of livestock sectors are examined using the county-level time series data between 1975 and 1998 for the beef cattle, dairy, hog, and poultry inventories and U.S. Census of Agriculture data. The data was obtained from the USDA-NASS data base. The 1982, 1987, 1992, and 1997 Census of Agriculture data are also used to examine the trends in the livestock farm concentrations in the U.S. (U.S. Department of Agriculture, 1994, 1999). We also determine the overall concentrations of livestock productions by

converting the inventory levels of beef cattle, dairy, hog, and poultry to animal units (AU) in each county[1].

We generate an environmental stringency index for each state using the 1998 National Survey of Animal Confinement Policies. The survey was administered by the Animal Confinement Policy National Task Force in 1998, and contains information from 48 states in the U.S. about their policies and implementations regarding the environmental regulations of the livestock industry. A proxy variable is constructed to represent the general stringency of the state environmental regulations and the cost of satisfying the regulatory requirements using this survey information. The environmental stringency index is constructed as an unweighted sum of the affirmative responses to the twenty-nine regulatory stringency survey questions. For example, the survey questions include whether there are requirements on the minimum set-back distance or confinement facility construction permits and approval of confined livestock facility locations. Other questions involve whether public notices or hearings about livestock facility construction are required, or whether regulatory staff is required to make site visits. The survey also has information about whether there is local enforcement. The constructed index varies between 1 and 21, with 1 representing the lowest environmental stringency and 21 representing the highest environmental stringency. It is expected to be positively correlated with the amount of farm operator resources needed to satisfy the regulatory requirements and therefore positively correlated with the compliance costs associated with state environmental regulations.

4. Results

Concentration of Livestock Inventories

Table 1 presents the Shannon's evenness index for the livestock inventories in the U.S. between 1975 and 1998. The estimated indices show the extent to which the between-counties

[1] Animal unit for each county is calculated as: AU=1*Beef Cattle+1.4*Dairy Cattle+0.4*Hog+0.001*Poultry.

evenness index for the nondairy cattle, dairy, hog, poultry, and animal unit changes over time. The calculated animal unit measure represents the total livestock inventories in a common unit and reveals the intensity of the overall livestock productions of U.S. counties. The estimated indices of beef, dairy, hog, and poultry inventories tend to decrease over time, indicating the evidence of increasing geographical concentration for all the sectors (Figure 1). Overall, there have been significant increases in the concentration of these livestock inventories over time. The concentration is found to be highest in the poultry and hog sectors. The between-county evenness index of the hog sector decreased from 0.94 in 1975 to 0.73 in 1998, while the evenness index of poultry decreased from 0.67 in 1975 to 0.45 in 1998. The dairy and cattle inventories have also increasingly become concentrated in recent years. The between-county evenness index of the non-dairy cattle decreased from 0.94 in 1975 to 0.45 in 1998, while that of the dairy sector declined from 0.84 in 1975 to 0.47 in 1998. The evenness index for the animal unit measure shows that the entire livestock industry has increasingly become concentrated in a few counties over time. The evenness index of the animal unit decreased from 0.94 in 1975 to 0.45 in 1998, indicating increasing concentrations of livestock inventories.

Table 1 also shows the between-states evenness index for the livestock inventories in the U.S. between 1975 and 1998. We find similar trends in the concentrations of livestock inventories to a few states and increasing concentrations of production over time. Additionally, we calculate the within-states evenness index for the livestock inventories and present the average within-states evenness index in Table 1. These results provide similar trends in the changes of the concentrations of livestock inventories. For example, the average within evenness index of the dairy sector decreased from 0.83 in 1975 to 0.43 in 1998. These results also confirm

the findings that increasing concentrations of the livestock inventories have occurred among U.S. counties.

Table 2 presents the trend in changes for the within-state evenness index of livestock inventories for the top-10 producing states for the nondairy cattle, dairy, hog, and poultry sectors. Most top-producing states have experienced increasing concentrations of production within states. For example, the evenness index of the non-dairy cattle inventories for Texas decreased from 0.96 in 1975 to 0.46 in 1998. For the dairy inventories the evenness index of California decreased from 0.70 in 1975 to 0.64 in 1998. The hog evenness indices of Iowa, North Carolina and South Dakota have decreased much faster than Illinois, Indiana and Nebraska. The poultry evenness index of Pennsylvania decreased from 0.65 in 1975 to 0.36 in 1998. These results indicate that there are relatively small numbers of counties that are increasingly accommodating large livestock inventories in top-producing states.

Concentration of Farms vs. Livestock Inventories

We also analyze the extent to which livestock farms are concentrated in the U.S. and compare the evenness index of livestock farms with that of livestock inventories using the U.S. Census of Agriculture data. Table 3 presents the evenness index of livestock inventories and number of livestock farms in the U.S. In general, we found that livestock farms are more concentrated than the livestock inventories for all the livestock sectors. The increasing trends in the concentrations of livestock inventories and farms have continued over time. For example, the county-level evenness indices of the number of livestock farms in 1982 are 0.95, 0.88, 0.84, and 0.81 for the non-dairy cattle, dairy, hog and poultry, respectively. The corresponding figures for 1997 are 0.93, 0.86, 0.92, and 0.79, respectively. On the other hand, the county-level evenness indices of the livestock inventories for the non-dairy cattle, dairy, hog and poultry sectors have

decreased from 0.93, 0.80, 0.83, and 0.58 in 1982 to 0.45, 0.50, 0.73, and 0.45 in 1997, respectively. Similar trends are also observed for the indices of between-states and average of within-sates for all the livestock sectors.

Concentration of Livestock Inventories and Environmental Regulation

We now focus on whether there is a relationship between the evenness index and environmental regulation stringency. Table 4 presents the estimated spatial lag model that determines whether the environmental regulation stringency of a state has an impact on the within-states evenness index of the nondairy cattle, dairy, hog, poultry, and animal unit. We found that the spatial lag coefficient is positive and statistically significant for all the livestock sectors except the poultry sector. Thus, the evenness indices of livestock inventories are correlated across U.S. states, indicating that the concentrations of livestock sectors are spatially correlated across U.S. These results also confirm the spatial structure and increasing concentrations of the livestock sectors in the U.S.

The spatial lag model presented in Table 4 also indicates that the environmental regulation stringency is positively related to the evenness index for all the livestock inventories. This indicates that an increase in the environmental regulation stringency of a state increases the concentration of livestock production in that state. However, it is statistically significant only for the non-dairy cattle and animal unit. The estimated elasticities for the environmental regulation stringency are found to be relatively low. The elasticities range from 0.03 for poultry to 0.53 for animal unit.

5. Conclusions

This paper examines the trends in geographical concentrations of the non-dairy cattle, dairy, hog, and poultry inventories and farms. It also analyzes the role of the environmental

regulation stringency on determining the extent of these geographic concentrations. The paper uses an entropy based measure of concentrations. It also analyzes whether the concentration in a state is related to the stringency of environmental regulations of that state by developing a spatial econometrics model.

The results from this paper show that livestock productions on a national level and within states are becoming more geographically concentrated. Geographical concentration appears to be occurring both in the livestock farms and livestock inventories at the state and county level. Large increases in the concentrations of the livestock production have occurred in key production regions. These concentrations of production are also accompanied by increases in the inventories in some states. The concentrations are found to be highest in poultry and hog inventories. However, the rates of increases in the concentrations for the dairy and beef cattle inventories over time have been relatively high. Overall, the concentrations of these sectors are found to be approaching to those of the poultry and hog inventories. The concentrations of the livestock inventories are found to be more pronounced between states than on the national level. The concentrations are also found to be negatively related to the stringency of environmental regulations. These results suggest that several key states are vulnerable to environmental problems, and the environmental regulations of livestock sectors play a role in the geographical concentrations of the livestock sectors.

The spatial concentration and production patterns of the livestock sectors have important implications for the future development of the livestock sectors. Understanding the possible trends and shifts in the concentrations of livestock inventories and farms would improve our ability to formulate public policies affecting the development of the livestock sectors as well as to effectively respond to the environmental problems of farm concentrations. The results also

have implications for policies that can harmonize federal manure management standards for animal feeding operations across U.S. states.

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Figure 1. Shannon Evenness Index of Livestock Inventories in U.S. Counties

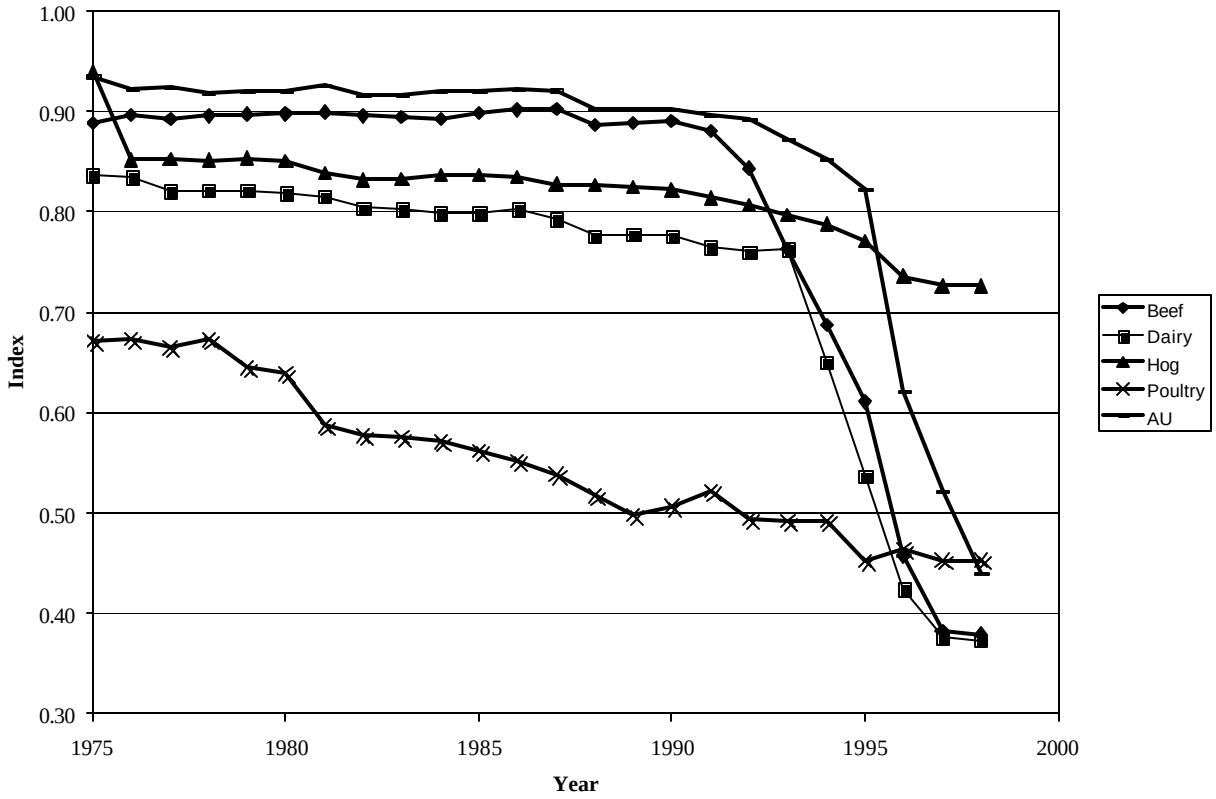

Table 1. Evenness Index of Livestock Inventories in the U.S.

	Non-Dairy Cattle	Dairy	Hog	Poultry	Animal Unit
Between-Counties					
1975	0.94	0.84	0.94	0.67	0.94
1980	0.93	0.82	0.85	0.64	0.92
1985	0.93	0.80	0.84	0.56	0.92
1990	0.92	0.78	0.82	0.51	0.90
1995	0.60	0.54	0.77	0.45	0.82
1998	0.45	0.47	0.73	0.45	0.44
Between-States					
1975	0.83	0.76	0.83	0.54	0.81
1980	0.84	0.76	0.68	0.55	0.79
1985	0.84	0.76	0.67	0.46	0.80
1990	0.87	0.76	0.69	0.40	0.84
1995	0.53	0.53	0.64	0.37	0.57
1998	0.52	0.52	0.54	0.37	0.57
Average of Within-States					
1975	0.93	0.83	0.93	0.71	0.93
1980	0.92	0.78	0.84	0.62	0.88
1985	0.92	0.75	0.81	0.52	0.88
1990	0.91	0.70	0.79	0.50	0.86
1995	0.58	0.44	0.76	0.37	0.63
1998	0.59	0.43	0.71	0.37	0.63

Table 2. Within-State Evenness Index of Livestock Inventories for the Top-10 Producing States

	1975	1980	1985	1990	1995	1998
Non-Dairy Cattle						
Texas	0.96	0.96	0.96	0.72	0.54	0.46
Missouri	0.97	0.97	0.97	0.97	0.73	0.54
Oklahoma	0.98	0.98	0.98	0.98	0.50	0.50
Nebraska	0.95	0.94	0.93	0.93	0.56	0.56
South Dakota	0.95	0.94	0.93	0.93	0.94	0.93
Kansas	0.98	0.98	0.98	0.98	0.60	0.57
Montana	0.96	0.96	0.96	0.96	0.64	0.64
Kentucky	0.93	0.93	0.93	0.93	0.69	0.69
Iowa	0.97	0.97	0.97	0.96	0.93	0.93
Tennessee	0.97	0.96	0.95	0.95	0.60	0.51
Dairy						
California	0.70	0.68	0.66	0.64	0.68	0.64
Wisconsin	0.90	0.89	0.90	0.90	0.61	0.57
New York	0.90	0.89	0.89	0.89	0.51	0.51
Pennsylvania	0.90	0.81	0.73	0.58	0.43	0.38
Minnesota	0.90	0.90	0.89	0.88	0.54	0.44
Texas	0.72	0.70	0.67	0.55	0.45	0.37
Michigan	0.89	0.89	0.88	0.88	0.58	0.59
Idaho	0.88	0.82	0.80	0.77	0.48	0.49
Ohio	0.92	0.88	0.87	0.85	0.47	0.44
Washington	0.84	0.75	0.71	0.70	0.64	0.59
Hog						
Iowa	0.97	0.97	0.97	0.92	0.87	0.85
North Carolina	0.94	0.83	0.79	0.71	0.64	0.64
Minnesota	0.95	0.90	0.90	0.89	0.88	0.84
Illinois	0.95	0.93	0.93	0.93	0.91	0.91
Indiana	0.98	0.94	0.94	0.92	0.92	0.89
Nebraska	0.96	0.91	0.90	0.89	0.89	0.88
Missouri	0.97	0.94	0.92	0.91	0.87	0.86
Ohio	0.97	0.90	0.88	0.89	0.90	0.84
South Dakota	0.98	0.93	0.89	0.84	0.80	0.76
Oklahoma	0.98	0.93	0.88	0.77	0.75	0.73
Poultry						
California	0.85	0.79	0.74	0.68	0.64	0.59
Pennsylvania	0.65	0.64	0.55	0.57	0.45	0.36
Arkansas	0.68	0.63	0.59	0.55	0.51	0.47
Ohio	0.74	0.73	0.70	0.66	0.63	0.60
Florida	0.80	0.71	0.63	0.57	0.51	0.46
North Carolina	0.75	0.68	0.62	0.56	0.50	0.45
Texas	0.78	0.70	0.62	0.55	0.49	0.44
Alabama	0.77	0.76	0.72	0.70	0.71	0.69
Missouri	0.81	0.76	0.71	0.66	0.61	0.57
Michigan	0.78	0.73	0.68	0.63	0.59	0.54

Note: State rankings are based on the livestock inventories from 1997 U.S. Census of Agriculture.

Table 3. Evenness Index of Livestock Inventories and Number of Farms in the U.S. (1997)

	U.S. Counties		Between-States		Average of Within-States	
	Farm	**Inventories**	**Farm**	**Inventories**	**Farm**	**Inventories**
1982 Census of Agriculture						
Non-Dairy Cattle	0.95	0.93	0.90	0.84	0.96	0.92
Dairy	0.88	0.80	0.83	0.77	0.88	0.76
Hog	0.94	0.83	0.86	0.65	0.94	0.83
Poultry	0.81	0.58	0.95	0.47	0.81	0.55
1987 Census of Agriculture						
Non-Dairy Cattle	0.94	0.93	0.90	0.85	0.96	0.92
Dairy	0.87	0.80	0.82	0.77	0.88	0.73
Hog	0.93	0.83	0.86	0.66	0.94	0.81
Poultry	0.80	0.58	0.95	0.43	0.80	0.49
1992 Census of Agriculture						
Non-Dairy Cattle	0.94	0.91	0.89	0.86	0.96	0.91
Dairy	0.87	0.76	0.82	0.75	0.87	0.71
Hog	0.93	0.81	0.85	0.68	0.93	0.79
Poultry	0.80	0.49	0.94	0.38	0.80	0.43
1997 Census of Agriculture						
Non-Dairy Cattle	0.93	0.45	0.88	0.53	0.96	0.58
Dairy	0.86	0.50	0.81	0.52	0.86	0.43
Hog	0.92	0.73	0.84	0.59	0.92	0.71
Poultry	0.79	0.45	0.93	0.37	0.79	0.37

Table 4. Impact of Environmental Regulation Stringency on Within-States Evenness Index (1998)

Coefficients (Standard Deviation)	**Non-Dairy Cattle**	**Dairy**	**Hog**	**Poultry**	**Animal Unit**
Intercept	-0.064 (0.136)	0.086 (0.110)	0.170 (0.144)	0.052 (0.059)	-0.056 (0.113)
?	0.434 (0.213)**	0.485 (0.272)*	0.500 (0.259)*	-0.325 (0.282)	0.813 (0.183)***
Environmental Stringency Index	0.023 (0.009)***	0.010 (0.007)	0.002 (0.012)	0.001 (0.004)	0.014 (0.008)*
R^2	0.45	0.34	0.31	0.17	0.64
Elasticity of Environmental Stringency Index	0.42	0.19	0.06	0.03	0.53

Note: ***, **, and * indicate that the parameter is significant at the 1%, 5%, and 10% levels, respectively.