Analysis of the Effects of Environmental Regulation on Pulp and Paper

Industry Structure

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Abstract

This paper investigates the impact of environmental regulations on market structure using a Markov analysis to quantify relationships among macroeconomic variables, environmental regulation expenditures and firm size distribution in the pulp and paper. Results show that environmental regulation affects the probabilities of capacity moving from one company size category to another and of staying in the same category.

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During the past decades many natural resources-based industries have undergone tremendous adjustments as a consequence of environmental regulations and controls. Most of these regulations are a direct result of the Clean Air and Clean Water Acts that were initiated in the early and mid 1970s and subsequent amendments. While ostensively designed to control externalities and increase social welfare, environmental regulations may have indirect effects on market structure resulting from changes in firm behavior as agents adjust to legal mandates. Raising environmental standards may raise plant investment costs, creating potential barriers to entry or fostering mergers and acquisitions because small companies do not have the resources to comply with more stringent regulations.

To date, most economic studies of regulatory controls in natural resource markets follow the Pigouvian approach of selecting policy instruments that maximize social welfare. Cropper and Oates review this literature. In general, these studies have investigated the effects of taxes, subsidies, standards, and other regulatory instruments on quantities and prices, while assuming perfect competition and exogenous market structure. However, the assumption of perfect competition may be faulty since many polluting industries are characterized by regionally or nationally concentrated manufacturing sectors. Concentration may augment firms' market power, expanding their ability to pass on cost increases associated with environmental controls (Farber and Martin). More importantly, concentration may enhance firms' abilities to use environmental controls to restrict output supply and input demands, thereby increasing their market power. In this situation, regulatory controls designed to solve pollution problems in markets may change

each firm's ability to exert market power, and alter market structure. When policies endogenously alter market structure, standard welfare analyses are no longer appropriate since they presuppose a constant market structure.

One natural resource-based industry experiencing high levels of regulation is the U.S. pulp and paper industry. This industry faces stringent environmental restrictions on both water and air emissions. Pulp and paper ranks third after the primary metals and chemical industries in terms of freshwater withdrawal, and ranks fifth among major industries in its contribution to water pollution. Since 1976, many mills have built secondary biological waste treatment plants, and now an estimated 99% of the pulp and paper plants in the U.S. have secondary treatment or its equivalent (Springer). On the air pollution side, the pulp and paper industry is heavily regulated in particulate matter, oxides of sulfur, sulfur compounds and chlorine compounds.

The objective of this paper is to investigate the effects of environmental regulations on market structure in the pulp and paper industry. A nonstationary Markov chain analysis is used to investigate the linkages among environmental expenditures, macroeconomic variables and the size distribution of firms. If environmental policies are important in determining industry structure, assuming the relationship of production capacity to market structure is fixed, the atheoretical nature of this analytical technique will reveal that without the bias inherent in structural analyses.

Arkansas, Louisiana, and Texas are chosen for this analysis. In 1988, these states accounted for 17.9% of the total capacity of pulpwood, and 15.1% of the total U.S. paper and paperboard capacity. Additionally, plant-specific capacity data are available for these states for the period

1973-1992. This region provides a good test case because a considerable number of mergers and acquisitions of firms occurred during the analytical period.

The Markov Model

Following Burton, a stationary Markov chain model is postulated:

(1)
$$y_t = P y_{t-1}$$

where y_t is a vector of production capacity share held by groups of companies (categorized by capacity share) in the economy at time t and P is a transition probability matrix. The production capacities share vector is formed of elements y_i, representing model states. In this case, the state is the proportion of total production capacity or capacity share of companies in group i. Transition probability matrix P is composed of transition probabilities $\{p_{jk}\}$, where p_{jk} is the probability of capacity moving from state j to state k during period t. In a stationary Markov model, the probabilities remain constant across time t.

A source state permits new capacity to enter the system (Adelman and Haynes; Duncan and Lin). In this case, increases in total regional plant capacity must come from a source state. Movement into a source state from inside the system is forbidden. A sink state (Duncan and Lin) is also required to capture decreases in plant capacities or plant closures. Movement out of the sink state is prohibited.

The stationary Markov model is subject to three restrictions (Lee, Judge and Zellner). First, the elements of the state (production capacity share) vector must sum to one, $\sum_{i=1}^{I} y_i = 1$, where I is the total number of states, including the source and sink states. Second, the elements in each

column of the transition probability matrix must sum to one $\sum\limits_{j=1}^{J} p_{jk} = 1$ for each k. This ensures

that capacity represented in the model at time t-1 is also in the model at time t. Lastly, the

transition probabilities must stay within the probability bounds of zero and one, $0 \leq p_{jk} \leq 1$ for

each k.

Given these restrictions, the stationary Markov model for I states is as follows:

(2)
$$
\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_{I-1} \\ y_I \end{bmatrix}_t
=
\begin{bmatrix}
p_{1,1} & p_{2,1} & \cdots & p_{I-1,1} & 0 \\
p_{1,2} & p_{2,2} & \cdots & p_{I-1,2} & 0 \\
\vdots & \vdots & \cdots & \vdots & 0 \\
0 & 0 & \cdots & p_{I-1,I-1} & 0 \\
p_{1,I} & p_{2,I} & \cdots & 0 & 1
\end{bmatrix}
\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_{I-1} \\ y_I \end{bmatrix}_{t-1}
$$

where $p_{j,k}$ is the probability of moving out of state j into state k. The last column consists of those

probabilities of moving out of the sink state, which are set to zero, except for the last element.

This element is one by the restriction that column elements sum to one. The I-1 row elements are

the transition probabilities of moving into the source state, which are set to zero, except for the

probability of remaining in the source state. Lastly, no movement is permitted from the source

state directly to the sink state, thus the element in the last row is set to zero.

Data

Data used for this analysis are plant capacities for the 32 pulp and paper companies in the states of

Arkansas, Louisiana and Texas for the years 1973 to 1992. Aggregating across plant level data,

total capacity by company in this region is calculated. Pulp capacity data include all types of pulp

processes in the region. Similarly, paper production capacity covers production processes for

paper in this region. Pulp capacity data are from the USDA-Forest Service-Southern Experiment Station. Paper production capacities are from Post's-Lockwood directory.

For the analysis, firms are grouped into one of three capacity size categories: large, medium, and fringe. Companies with more than two thousand tons per day of capacity are included in the large category. Three companies meet this criterion. Companies with production capacities ranging between one thousand and two thousand tons per day comprise the second group. Six companies are in this group. Companies with less than one thousand tons per day are included in the third category. There are twenty-three small or fringe companies.

The source state for the Markov analysis is regional increase in production capacity. Increases in production capacity for pulp and for paper are calculated from changes in total production capacity for each product. The additional regional production capacity in period t+1 is the increment in the production capacity in period t and is in the source state in period t. Total production capacity for each product, pulpwood and paper, is differenced and a positive net change assigned to the respective source state. There are periods when total production capacity for each product declines in the region. Losses in regional production capacity are put into the respective sink states in period t+1. The Markov model has a large number of estimated parameters, and it is necessary to combine categories to reduce the number. Thus, the source state is added to the fringe capacity category to create a combined fringe-source state category.

The production capacity share vectors are created for pulp and for paper by dividing each category by the sum across all categories, including source and sink states. Each element then represents a production capacity share and the four elements sum to one for each time period. The production capacity share vector is $y_t = \begin{bmatrix} y_{large} & y_{medium} & y_{fringe+source} & y_{sink} \end{bmatrix}$.

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Estimation of the Stationary Model

Estimating equations for the transition probability matrix P are obtained using the methods developed in Burton. Estimation is performed using TSP 4.3 (Hall, Cummins and Schnake) and results for pulp and paper are as follows:

$$
(3) \qquad \text{Pulp} \qquad
\begin{bmatrix} y_l \\ y_m \\ y_f \\ y_s \end{bmatrix}_t
=
\begin{bmatrix}
.7005 & .3846 & .0669 & 0 \\
(7.23) & (3.26) & (1.16) & \\
& & & \\
.2233 & .6153 & .0583 & 0 \\
(1.63) & (3.68) & (.71) & \\
& & & \\
.0761 & .0000 & .8693 & 0 \\
(.42) & (.00) & (7.98) & \\
& & & \\
.0000 & .0000 & .0000 & 1 \\
(.00) & (.00) & (.00) &
\end{bmatrix}
\begin{bmatrix} y_l \\ y_m \\ y_f \\ y_s \end{bmatrix}_{t-1}
$$

$$
(4) \qquad \text{Paper} \qquad
\begin{bmatrix} y_l \\ y_m \\ y_f \\ y_s \end{bmatrix}_t
=
\begin{bmatrix}
.8790 & .1942 & .0000 & 0 \\
(9.28) & (2.23) & (0.00) & \\
& & & \\
.0000 & .8057 & .1613 & 0 \\
(0.00) & (5.04) & (1.11) & \\
& & & \\
.1209 & .0000 & .8363 & 0 \\
(.56) & (.00) & (4.66) & \\
& & & \\
.0000 & .0000 & .0022 & 1 \\
(.00) & (.00) & (.03) &
\end{bmatrix}
\begin{bmatrix} y_l \\ y_m \\ y_f \\ y_s \end{bmatrix}_{t-1}
$$

where values in parentheses are asymptotic t-statistics.

The general interpretation of these matrices is that, for the pulp case, large companies on average increased share of production capacity, over the period of estimation while medium-sized companies and small companies have decreased their shares. In the region, data show that there has been several company consolidations during this period. Large companies are buying small and medium companies, thereby increasing their production capacities (Mies, *et al.*). The paper sector displays similar behavior: large companies took over small and medium size plants.

Nonstationary Markov Model

If the Markov matrices are stationary, the transition probabilities have not changed over the period of analysis. If, however, the transition probabilities change over time, they could be parameterized by exogenous variables. The relative influence of environmental regulation on pulp and paper production capacity shares can then be compared with that of other exogenous variables. Hypothesis tests can be applied to determine the relative influence of exogenous variables on the transition probabilities. If national environmental policies are having an effect on industry structure, then these tests should indicate a statistically significant influence on transition probabilities involving movements of production capacities among the different categories in both the pulp and paper industries in this region.

To examine the stationarity of the Markov model, a test for structural change is performed for pulp and for paper. For a matrix to be nonstationary, only one element need be shown to be nonstationary. The data on production capacities are divided into three consecutive periods using multiplicative dummy variables, to test the hypothesis that the large-to-large transition probability is constant through time. The test statistics are 13.99 for pulp and 24.4 for paper versus a Chi-

squared tabled value of 12.59 with 6 degrees of freedom and 5% confidence level, and 18.55 for the 0.5% confidence level, respectively. Hence, the transition probability matrices for both pulp and paper are nonstationary, and the transition probabilities for both products can be parameterized.

Following the method used in Burton, the nonstationary Markov matrices are estimated assuming each off-diagonal transition probability is $p_{jk} = (a + b*MACRO + c*\%\triangle Environmental$ $Expenditures)^2$. Two macroeconomic variables are used: real AAA bond interest rate, and percentage change in GDP. The AAA bond rating represents a cost of capital for most of these pulp and paper companies. The change in GDP is a demand shifter for pulp and paper products. Information on industry expenditures due to environmental regulation is available for water, air, waste and total expenditures. The GDP variable and the AAA bond interest rate used are taken from the *Economic Report of the President,* and the environmental expenditures from *Pulp and Paper North American Factbook* (Mies, *et al.*). Several alternative sets of variables were considered. Each macro variable was considered with various environmental expenditure variables. The best model, among the ones that met the Markov model restrictions, was selected using the likelihood dominance criterion (Pollak and Wales). Model selection tests eliminated many variables considered, such as environmental expenditures on waste.

The final model for pulp uses a constant, percentage change in real GDP and percentage change in water regulation expenditures as exogenous variables to parameterize the transition probabilities. For pulp, changes in demand and in water input costs due to regulation are important determinants of production capacity retention and changes. For paper, the final model parameterizes transition probabilities with a constant, the real AAA bond interest rate and a

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percentage change in total expenditures associated with environmental regulation. Capacity

capital costs and regulations expenditures for water, air and waste are indeed important

determinants of capacity retention and changes.

It is informative to examine how the transition probability matrices have changed over time.

Equations (5) and (6) show pulp industry transition probability matrices for 1986 and 1991.

$$
(5) \quad 1983 \quad \text{Pulp} \quad
\begin{bmatrix} y_l \\ y_m \\ y_f \\ y_s \end{bmatrix}_t
=
\begin{bmatrix}
.8549 & .1579 & .0588 & 0 \\
(5.42) & (0.85) & (0.95) & \\
.1330 & .8187 & .0045 & 0 \\
(0.89) & (4.06) & (0.15) & \\
.01212 & .0233 & .9331 & 0 \\
(0.39) & (0.42) & (16.31) & \\
.0000 & .0000 & .0036 & 1 \\
(0.00) & (0.00) & (0.07) &
\end{bmatrix}
\begin{bmatrix} y_l \\ y_m \\ y_f \\ y_s \end{bmatrix}_{t-1}
$$

$$
(6) \quad 1991 \quad \text{Pulp} \quad
\begin{bmatrix} y_l \\ y_m \\ y_f \\ y_s \end{bmatrix}_t
=
\begin{bmatrix}
.6580 & .3537 & .1097 & 0 \\
(5.26) & (1.32) & (1.06) & \\
.0812 & .6382 & .1787 & 0 \\
(0.58) & (2.01) & (1.48) & \\
.2608 & .0080 & .7080 & 0 \\
(3.53) & (0.07) & (7.012) & \\
.0000 & .0000 & .0036 & 1 \\
(0.00) & (0.00) & (0.07) &
\end{bmatrix}
\begin{bmatrix} y_l \\ y_m \\ y_f \\ y_s \end{bmatrix}_{t-1}
$$

The pulp matrix for 1991 is considerably different from the 1983 matrix. The large-to-large

transition probability drops to 0.66. The transition probability of capacity moving into the large

category from the medium size class rose to .35. Increased movement of capacity among groups

may be partially explained by the amendments to the Safe Drinking Water Act in 1986, Clean

Water Act in 1987, Clean Air Act in 1989-1990, as well as the 1986 Superfund Law. These

environmental regulations represent a heavy load on small mills that need to comply with the

regulation or pay the fines for their violations. Similar results are apparent in the paper industry.

Hypothesis Tests of Transition Probability Parameterization

Hypothesis tests are used to determine if environmental regulation expenditures are significant

determinants of capacity transition probabilities. A likelihood ratio test rejects the null hypothesis

that the coefficients on water environmental expenditures are jointly zero. The test statistic is

42.02 versus Chi-squared tabled value of 18.55 at the 0.5% significance level for six degrees of

freedom. A similar result holds for the macro variable percentage change in real GDP. When the

coefficients on this variable are set to zero, the test statistic is 116.37, rejecting the null hypothesis

at the 0.5% level. The paper model displays similar results. The hypothesis that the coefficients

on total environmental expenditures are jointly zero is soundly rejected with a test statistic of

20.63. Also, the hypothesis that the coefficients associated the real interest rate are jointly zero is

rejected with a test of 37.03. Thus, results show that for pulp, both percentage change in real

GDP and percentage change in real water environmental expenditures affect the probability of

capacity changing ownership by a large, medium or fringe company. For paper, the model uses

real interest rate and percentage change in real total environmental expenditures as explanatory

variables and these variables are both statistically important explaining paper production capacity

movements.

Conclusions

This paper investigates the impact of environmental regulations on market structure using a Markov analysis to quantify relationships among macroeconomic variables, environmental regulation expenditures, and firm size distribution in the pulp and paper industries of Arkansas, Louisiana and Texas. A nonstationary Markov model is estimated that allows data to reveal important relationships without inducing bias through maintained hypotheses inherent in many structural models. Results show that environmental regulation affects the probabilities of capacity moving from one company size category to another and of staying in the same category. This result empirically confirms ideas in Markusen, *et al.,* and in Conrad that plant location and market structure are a function of environmental policy. The transition probabilities for pulp validates the argument by Misiolek and Elder; by Pashigan, and by Brannlund, Fare and Grosskopf that environmental regulation affects small firms negatively.

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