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Working Paper Series

Working Paper # 02-02
January, 2002

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**Subject Area**: Costs of Pollution Control and Environmental Policy
**Key Words**: 1) Environmental Regulation; 2) State Regulatory Stringency ; 3) Production Allocation; 4) Compliance

Financial support from the National Science Foundation (SBR-9410059) and the Environmental Protection Agency (R826155) is gratefully acknowledged. We received helpful comments from Arik Levinson and participants at the 1997 Western Economic Association Meetings, the 1998 Allied Social Science Associations Meetings, the 1998 World Congress of Environmental and Natural Resource Economists, and seminars at Clark University and the University of Indiana. Capable research assistance was provided by Zahid Hafeez. The research in this paper was conducted while the authors were Census Bureau Research Associates at the Boston Research Data Center. Research results and conclusions expressed are those of the authors and do not necessarily indicate concurrence by the Bureau of the Census. This paper has been screened to ensure that no confidential data are revealed.

Abstract

This paper examines whether a firm's allocation of production across its plants responds to the environmental regulation faced by those plants, as measured by differences in stringency across states. We also test whether sensitivity to regulation differs based on differences across firms in compliance behavior and/or differences across states in industry importance and concentration. We use Census data for the paper and oil industries to measure the share of each state in each firm's production during the 1967-1992 period. We use several measures of state environmental stringency and test for interactions between regulatory stringency and three factors: the firm's overall compliance rate, a Herfindahl index of industry concentration in the state, and the industry's share in the state economy.

We find significant results for the paper industry: firms allocate smaller production shares to states with stricter regulations. This impact is concentrated among firms with low compliance rates, suggesting that low compliance rates are due to high compliance costs, not low compliance benefits. The interactions between stringency and industry characteristics are less often significant, but suggest that the paper industry is more affected by regulation where it is larger or more concentrated. Our results are weaker for the oil industry, reflecting either less opportunity to shift production across states or a greater impact of environmental regulation on paper mills.

## 1. Introduction

Environmental regulation in the U.S. has a decidedly federal nature, with state regulatory agencies responsible for much of the enforcement activity, along with some setting of standards. With different states facing different benefits and costs from environmental regulation, they might be expected to choose different levels of stringency, imposing different abatement costs. In turn, firms might respond to differences in production costs by shifting their operations, opening or expanding plants in less stringent states, and closing or reducing their operations in stricter states.

Studies of regulatory impact on production location use a variety of research strategies (Jaffe, et. al. (1995)). In studies using aggregate data, Duffy-Deno (1992) finds that SMSAs with high pollution abatement costs have slower-growing earnings and employment, while Kahn (1994) finds that non-attainment counties (facing stricter pollution controls) have slower employment growth. Most micro-level research in this area has focussed on the location of new plants, with mixed results. Bartik (1988) finds no impact on new manufacturing branch plants of Fortune 500 companies between 1972 and 1978. McConnell and Schwab (1990) find a small impact of ozone standards on the location of motor vehicle assembly plants between 1973 and 1982. Levinson (1996) finds little effect, with a small negative impact on branch plants of large firms in high-pollution manufacturing industries. Henderson (1996) finds an increase in the presence of highly-polluting industries in counties with less stringent regulation. Gray (1997) finds lower birth rates of new plants in states with stricter regulation, while Deily and Gray (1991) find that steel mills facing more stringent regulatory enforcement were more likely to close.

In this paper, we look at a firm's allocation of production across its plants in different states, measured by the share of its total production occurring in each state. A firm could change its production shares by opening a new plant, but it could also close one of its plants or vary production levels at its existing plants. As far as we know, this is the first work using firm-level production shares to measure regulatory impacts. It is not clear whether environmental regulation should have a larger impact on production shares than on new plant openings. On the one hand, shifting production among existing plants may be easier than opening new plants, which would lead to a larger impact on shares. On the other hand, regulations tend to be stricter for new plants and exempt existing ones due to grandfathering, which would lead to a smaller impact on shares.

We use plant-level data for the paper and oil industries from the Census Bureau's Longitudinal Research Database, with six Census years of data between 1967 and 1992. The data include firm identifiers, allowing us to calculate the share that each state represents in a firm's shipments. We also use information on each firm's compliance status from EPA regulatory databases to see whether more compliant firms are more or less sensitive to state regulatory differences. Other state characteristics are included that could influence production allocation, such as factor prices and quality, concentration, and product demand.

We find a significant relationship between regulatory stringency and production allocation for the paper industry. States with stricter regulations have smaller production shares, even after controlling for a variety of other state characteristics. This impact is concentrated on firms that are out of compliance. If anything, firms with high compliance rates seem to (slightly) prefer more stringent states. These results support a model where differences across firms in compliance are driven primarily by differences in compliance costs (economies of scale in compliance), rather than by differences in the benefits of compliance (maintaining the firm's reputation). If firms choose low compliance rates because they do not see any benefits from complying, they will not need to avoid high-stringency states. If they are trying to comply, but failing due to high compliance costs, they would want to avoid high-stringency states.

We find few significant interactions between regulatory stringency and industry characteristics within a state. We had expected that the paper industry would be able to avoid regulatory pressures in states where it had more political power, due to being especially large (relative to the state economy) or especially concentrated. This would make the overall state regulatory stringency measures less important, yielding a positive interaction term. Instead we find a more negative impact of regulatory stringency on production share in large and concentrated states, although this effect was generally not significant.

Our overall results are weaker for the oil industry in terms of statistical significance, although the impacts are similar in sign: negative impacts of state regulatory stringency on production shares, concentrated among low-compliance firms. Unlike the paper industry results, the oil industry results do show the expected result for industry concentration, namely reducing the impact of state regulatory stringency. The less significant overall results may reflect a more local market for oil, with less opportunity to shift production across states: data from the 1993 Commodity Flow Survey indicate that shipments from paper mills tend to travel much farther than shipments from oil refineries. Our weaker oil industry results could also reflect real differences in the impact of regulation across industries as found in previous studies. For example, Gray and Shadbegian (1995) find a smaller impact of regulation on the productivity of oil refineries than on the productivity of paper mills. In a similar study, Berman and Bui (2001a) find only a small impact of regulation on the productivity of oil refineries. Finally, Berman and Bui (2001b) find no significant impact of regulation on labor demand for oil refineries.

Section 2 sketches the model we use in analyzing the firm's decision to allocate its production across states. Section 3 describes the data and econometric models used. Section 4 presents the results, with our conclusions and some thoughts for future research following in Section 5.

## 2. Model

Regulatory stringency may influence firms' decisions along many dimensions. The usual assumption is that production costs are higher in stricter states since firms are required to meet tougher emissions standards, install higher-capacity (more expensive) pollution control equipment, incur higher operating costs, and perform more frequent maintenance.[1] In addition to higher production costs, stringent states may have more complex permit procedures, requiring firms to undertake lengthy negotiations whenever they wish to change their production process,

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[1] A regulation-induced increase in costs could be measured as a decrease in productivity. Many studies have examined this, often finding significant impacts of regulation on productivity. Fare et al (1989), Gray (1987), and Barbera and McConnell (1986) use industry-level data. In plant-level work, Gollop and Roberts (1983) study electric utilities, and Berman and Bui (2001a), Boyd and McClelland (1999), and Gray and Shadbegian (1995) examine manufacturing.

and perhaps imposing uncertainty about whether the changes will be permitted at all. Since these permits are commonly required when opening a new plant, there could also be a direct impact of regulatory stringency on the expenses or time required to open a new plant.[2]

In the standard plant location model, firms are assumed to choose among a set of available sites. Sites differ in their production costs for a variety of reasons, including regulatory differences. Firms locate their plants in the site with the highest discounted profits. If regulatory stringency is a major factor in production costs, states with stricter regulation should see fewer new plants. Such a finding could reflect both the long-run influence of higher production costs and the short-run influence of a more complicated permit process on startup costs.

In this paper we are considering a broader range of firm decisions, including shifts in production across existing plants as well as plant openings and closings, with our dependent variable being the share of a firm's production taking place in each state. How important are shifts across existing plants compared with new plant openings? One way to measure this is to consider their relative contributions to the growth in firm shipments over time. In the paper industry, growth in existing plants accounts for half of the growth in firm shipments; in the oil industry it accounts for two-thirds.[3]

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2 The importance of permit uncertainty in the paper industry is discussed in Gray and Shadbegian (1998). We have no direct measures of permit difficulties, but conversations with industry people suggest that states which are stricter on our regulatory stringency measures are likely to have more delays and uncertainty in their permitting process.

3 Our data show plant-level production at five year intervals. A firm can expand its production over time by opening a new plant (OPEN), buying a plant from some other firm (BUY), or expanding production at an existing plant (GROW). We calculate the fraction of production growth accounted for by existing plants (owned by the same firm at the start and end of the interval) as GROW/(GROW+OPEN+BUY).

How does the sensitivity of production shares compare with the sensitivity of new plant openings? Shifting production across existing plants ought to be easier than opening a new plant, so we might expect production shares to be more sensitive than new plant openings. On the other hand, two factors could make production shares less sensitive than new plant openings. First, stricter states are likely to have a more complex permitting process, delaying and discouraging new plant openings.[4] Second, older plants are usually 'grandfathered' (not required to meet as stringent a standard as new plants). This weakening of standards at existing plants is likely to reduce differences in 'effective' regulatory stringency across states, reducing the firm's incentive to shift production.

Does it make sense to treat the market for an industry's product as a national one, able to be served by plants in many different states? The 1993 Commodity Flow Survey reports the distance travelled by shipments for particular industries. Based on this data, we see substantial differences between shipments from paper mills (SIC code 26) and oil refineries (SIC code 29). Paper shipments travelled an average of 238 miles, with 26 percent of shipments travelling further than 500 miles.[5] Oil shipments travelled an average of 79 miles, with only 4 percent

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Here GROW is the increase in real production at existing plants, while OPEN and BUY are the end-of-period production levels (since their contribution to the firm's shipments at the start of the period is zero). This ratio is .50 for paper firms and .65 for oil firms.

4 In some cases, a significant expansion of production at an existing plant could also trigger the need for a new permit. If so, this distinction between new plants and existing plants would be less relevant.

5 Calculations done by the author, using the publicly available 1993 Commodity Flow Survey on CD-ROM. The details of this analysis (aggregating data for specific state-industry cells on the average shipment distance and the frequency distribution of shipments for different categories of distances) are available from the author. The averaging is done based on each shipment's value.

travelling further than 500 miles. This indicates a more national market for paper, with more opportunities to shift production across states. Therefore, we would expect a larger impact of regulation on production shares for paper firms.

Consider the production allocation decision for a firm within a set of existing (and potential new) plants. The firm can change its production allocation by closing old plants, opening new plants, or shifting production among existing plants. We can think of the firm deciding the appropriate vector of inputs $X_{it}$ at each plant i and time t, attempting to maximize its profits under the influence of regulatory variables ($R_{it}$) and other factors ($Z_{it}$) that vary across plants. In our empirical implementation we work with firms shifting their production across states, so we think of 'i' as indexing firm-state observations:

$$Max \quad \pi(X_{it}, Z_{it}, R_{it}) = \sum_{it} \{P_{it} * Q(X_{it}, Z_{it}, R_{it}) - W_{it} * X_{it} - C(X_{it}, dX_{it}, Z_{it}, R_{it})\} \qquad (1)$$

We assume that the firm jointly maximizes its total profits, summed over all plants. We also assume the firm's summation over time is carried out with appropriate discounting, although this is omitted from equation (1) to avoid unnecessary complications. Note that regulatory costs are allowed to directly affect the plant's output (through Q), as well as affecting the costs of regulation, C. We include an adjustment cost ($dX_{it}$) as one of the determinants of the costs of regulation, C, because delays caused by the environmental permitting process mentioned earlier could make it especially difficult to expand production in a stringent state.

We expect that $dQ/dR<0$ and $dC/dR>0$, so that production costs are higher in stricter states. If each plant faces an upward sloping marginal cost curve, the higher costs in stricter states will lead the firm to reduce production there until marginal costs are equated across plants, assuming a national market for the firm's product and no significant transportation costs. If plants face constant marginal costs, the firm should close down its plants in stricter states and concentrate production in the least stringent state.

These results could be somewhat modified by general equilibrium effects, if the particular industry being studied is a large part of a given state's economy. Any reduction in labor demand by the industry due to regulation would tend to drive down its wages. If the stricter regulation leads to a cleaner environment within the state, wages could be further lowered as the improved environmental quality attracts more workers. The concentration of an industry's production in a few firms in a state might also affect the impact of regulatory stringency on the industry. Concentrated production means greater market power for producers, and possibly greater flexibility in adjusting market price (though if regulation raises costs for all producers in a state, even a competitive industry would wind up raising prices).

We could explain the same effects through the political process. When the industry is a large part of the state's economy it should have more political power and hence be more able to negotiate exemptions from otherwise strict state regulations. A more concentrated industry should have fewer free rider problems in mobilizing political effort. Therefore, for both political and economic reasons, we would expect to find that larger and more concentrated industries are less affected by state regulatory stringency.

We model the quantity of output produced by the firm in a given state as depending on both regulatory and other differences across states, including the possibility of interactions between regulation and industry characteristics (size and concentration) within the state:

(2) $Q_{it} = Q(Z_{it}, R_{it}, Z_{it}*R_{it})$.

A final issue to consider is the impact of differences across firms in their compliance behavior. Differences in compliance behavior have been observed in other settings, with larger firms serving national markets tending to be in compliance more often than smaller firms serving local markets. If we think of firms as choosing their compliance level to maximize profits (benefits-costs), then the optimal compliance level arises when the marginal benefits from additional compliance are just equal to the marginal costs. Different levels of compliance across firms could therefore be connected either to differences in benefits or differences in costs, related to the size or scope of the firm. We now consider differences in the implications for firm behavior arising from the cost and benefit explanations.

First, consider the cost explanation. Differences between large and small firms in the marginal costs of regulatory compliance are likely, given the complexity of environmental regulations. Larger firms can afford a corporate environmental staff supporting many plants. Smaller firms, relying on plant-level personnel with too many other responsibilities, cannot keep up with frequent regulatory changes.[6] Larger firms may also have the political clout to intervene in the standards-setting process, making compliance easier.[7] These economies of scale in

6 These differences may be growing smaller over time (though we do not test for that here). Down-sizing and cost-cutting pressures at large corporations have reduced the size of corporate staffs, and there has been greater use of outside consultants specializing in environmental issues, providing smaller firms with access to some scale economies.

7 Environmental officers at large corporations commonly serve on state environmental advisory boards,

compliance should give larger firms an advantage relative to smaller ones, especially in states with stringent regulations (and more complex bureaucratic procedures to enforce those regulations). Therefore, if small firms are less compliant because their compliance costs are greater, we would expect to see these non-compliant firms being more anxious to avoid stringent states, where their compliance costs would be especially great.

Now, consider the benefits explanation. Differences across firms in the benefits of compliance are attributed to the importance of reputation, both in terms of reputation with regulatory agencies and with customers. Failure to comply with regulations may result in lost sales, if customers value a 'green' image for the products they consume. Regulators may punish violators with stricter future enforcement at all plants owned by the firm (see Harrington (1988)). In both cases, the importance of reputation relies on non-compliant behavior being highly visible, and a large number of future interactions where the punishment can take place. Smaller firms have fewer other plants or future sales to be punished, and their violations are likely to be less newsworthy. Therefore smaller firms face smaller benefits from compliance, leading them to choose compliance less often.

Under the benefits explanation, the non-compliant firms do not care whether or not they comply, facing a relatively small reputation penalty. Therefore (in the limit, with no reputation penalty) they have no reason to avoid more stringent states. Note that this contrasts with the costs explanation, where non-compliant firms would be more likely to avoid more stringent states. To test for this difference between the 'benefits' and 'costs' explanations, we need to add

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where they are in a position to influence the outcome of the process.

information on the firm's compliance decision (COMP) to equation (2). Finally, we put the equation in 'production share' terms, dividing the firm's production in each state ($Q_{it}$) by total firm production nationwide in the year ($Q_t$), getting:

(3) $Q_{it}/Q_t = Q(Z_{it}, R_{it}, Z_{it}*R_{it}, COMP, COMP*R_{it})$.

For reasons stated above we expect a negative coefficient on $R_{it}$. If the 'cost' explanation for compliance is important we should see a positive coefficient on the interaction of $R_{it}$ and COMP, with more compliant firms less sensitive to stringency differences.

In our model, a firm is assumed to allocate its production across those states in which it ever does business during the period we observe. This reflects a compromise, driven by the observation that most firms operate in a limited number of states, with minor changes in the set of active states over time for a particular firm. If we included all 48 (continental) states in the allocation decision each year, our estimation process would be complicated by many zero values, including a large number of states where the firm might have no inclination to locate. On the other hand, if we only included the states of current operation in the share calculation, we would be neglecting the possibility of expansion into those states where expansion is most likely (judging by the fact that the firm operated in that state in some other year).

Our specification induces one more complication into the analysis. Since different firms operate in different numbers of states, their average production shares will differ in magnitude. A firm operating in 10 states would have an average share of .1; a firm operating in 25 states would have an average share of .04. We include in the regression the 'expected average share' for the firm, which is the reciprocal of the number of states the firm operated in. This variable should get a coefficient of around 1.0, and is likely to be quite powerful, capturing as it does a key difference across firms when we calculate their production shares. In some specifications we instead include firm dummies, capturing any fixed firm-specific differences in production allocation.

## 3. Data

The basic plant-level data on production comes from the Longitudinal Research Database (LRD) maintained at the Center for Economic Studies of the Census Bureau (see McGuckin and Pascoe (1988) for a detailed description). We use information from the Census of Manufactures, done every five years since 1967 on all manufacturing plants in the country (around 300,000 plants in each census). For this paper, we do two separate analyses: one for pulp and paper mills, and the other for oil refineries. We studied these industries earlier, looking at the connection between pollution abatement costs and productivity (Gray and Shadbegian (1995)).[8] The plant-level data includes a firm identifier, allowing us to link together all the firms in that industry owned by the same firm in each Census year.

We add up the total value of shipments from each plant owned by the firm and calculate the share of a firm's production arising in each state, which forms the dependent variable

[8] In our productivity work we also analyzed the steel industry. Unfortunately, there are relatively few steel firms which operate in multiple states, so we were not able to analyze steel here.

(SHTVS) for our analysis.[9] As noted earlier, we use a fixed set of states for each firm, including those states in which the firm produces at any point during the 1967-1992 period. In order to focus on those firms which are in a position to allocate production across states, we limit our sample to those firms which produced in at least four different states. This would give us a 'balanced' panel, if all firms were in business throughout the period. A few of our firms are out of existence at some point (birth or death of the entire firm). We drop those firm-year observations since their production shares cannot be defined in that year, but keep them in the sample for the other years. As discussed above, the average SHTVS value differs substantially across firms, inversely related to the number of states the firm is operating in. We include SCALE (the inverse of the number of states in which the firm operates) to control for these differences.

As described above, firms' decisions about whether or not to comply with regulations may provide some information about their sensitivity to regulatory costs. We use plant-level air pollution compliance data for 1979-1989 taken from the EPA's Compliance Data System, where compliance is defined as not being 'in violation' for any pollutant at any point during the year. All of the available plant-years of compliance data were linked together by firm, and the 'firm compliance average' was calculated as the fraction of all observations in compliance.[10] We use a single compliance measure for each firm (not a time-varying one) because the compliance data is

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[9] We could calculate plant-level production shares, but all of our explanatory variables are state-specific, so we use state-level shares instead.

[10] The CDS information was originally compiled for our productivity analyses, so the compliance variable is only available for firms which had at least one plant in our productivity sample.

not consistently available before the 1980s. Using a single compliance measure is appropriate as long as differences in compliance behavior depend primarily on long-run differences between firms, rather than transitory fluctuations.

Aside from the firm compliance variable and firm and year dummies, all of the explanatory variables in our model are state-specific. These range from state-level regulatory variables to input cost and other factors expected to influence the production decision. In earlier plant-location analyses (Gray (1997)) the issue of endogeneity of these explanatory variables arose, and was addressed in part by lagging the explanatory variables by five years. Thus 1977 explanatory variables are assumed to influence the birth rate of new plants between 1977 and 1982. We use a similar procedure here, so that 1977 explanatory variables are used to explain production shares in 1982. This may be less appropriate here, since allocating production among existing plants may take much less time than deciding to open a new plant.

The state-level regulatory data comes from a variety of sources. One problem with our regulatory measures is that they tend not to be available before the 1980s, and often have no time-series variation available at all. Our principle index of regulatory stringency does have some time-series variation: support for environmental legislation in Congress. The League of Conservation Voters calculates a scorecard for each member of Congress on environmental issues, with data available back to the early 1970s. We use the average score for the state's House of Representative members (VOTE) in our analysis.[11]

[11] The earliest year available in the League of Conservation Voters data is 1970. We calculated comparable measures for the 1960s, using congressional voting data on environment-related legislation in those years. Of course the environmental bills being considered in the 1960s were fewer and less costly

The Census Bureau's Pollution Abatement Costs and Expenditures (PACE) survey reports the dollars spent for pollution abatement by manufacturing firms, giving totals for all industries in each state and for all plants nationwide in each industry. We divide annual pollution abatement operating costs by total manufacturing shipments to measure pollution abatement intensity (for each state and each industry). We then calculate a predicted abatement intensity for each state, multiplying each industry's abatement intensity by its share in total state employment (from the Census of Manufactures). The residual abatement intensity (actual minus predicted), is used in the regressions (PAOCADJ). The survey was first done in 1973, and the 1973 values are used for all years of data before 1973. This is equivalent to assuming that the relative rankings of the states were unchanged before 1973 and allowing the year dummies in the regressions to control for the expected (but unmeasured) tendency towards lower expenditures before 1973.

The Green Index publication (Hall and Kerr 1991) contains one-time rankings of all the states on a large number of environmental-related variables. A measure of regulatory stringency is the ‘Green Policies’ (ENVPOLICY) index, designed to measure the stringency of state environmental regulations based on a set of 77 specific indicators, such as the presence of state laws on specific topics such as recycling. A measure of environmental problems in each state is the 'Green Conditions' (DIRTY) index, which indicates the state's combined ranking on over 100 measures of the quality of the state's environment, including air and water pollution

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than those voted on in later years, but the votes should reflect similar differences in state preferences for regulation.

information.[12] CONVMEMB (taken from the same source) is the number of members of three conservation groups (Sierra Club, Greenpeace, and National Wildlife Federation) per 1000 in the state population, indicating support for environmental issues among the state's electorate. REGSPEND is the dollars per capita spent on the state's programs for environmental and natural resources in 1988 (Council of State Governments (1991)).

A direct measure of enforcement activity for air pollution regulation is taken from the EPA's Compliance Data System. This database reports all air pollution inspections, identifying the affected plant by industry and location. The total number of inspections of manufacturing plants between 1984 and 1987, divided by the number of manufacturing plants in 1982, was calculated for each state (AIRINSP). Greater enforcement activity is expected to put more pressure on plants in the state to come into compliance with air pollution regulations, raising costs and reducing profitability. In Deily and Gray (1991) a similar measure of enforcement was found to increase the probability that a steel plant would close.

One final regulatory variable (NONATTAIN) measures the state's attainment status for key pollutants. We select a single pollutant for each industry (particulates for paper and ozone for oil), and calculated the fraction of the counties in the state that are not in attainment.[13] A high value should be associated with more regulation, as dirtier air calls for more restrictions on plant expansion or new plant construction.

[12] The original rankings were designed so that low scores reflected stricter regulation and a cleaner environment. Since all other stringency measures use higher values to indicate stricter regulation, we multiplied the Green Policies index by -1 to improve comparability.

[13] We would like to thank Michael Greenstone for providing this attainment data.

We also create a few variables measuring the characteristics of the industry in each state. DEMAND is a state-specific demand index for the industry's product in the state. We use data on employment for each one-digit industry in the state, and combine it with data from the 1982 input-output tables on how much oil or paper each one-digit industry consumes (per employee). To capture 'final demand' for oil or paper by consumers, we use the state's total income and calculated final demand per dollar of total state income. Adding up the industry and consumer demand for oil or paper gives an indicator of total demand in the state. It only captures shifts in within-state demand; to the extent that the market is national or regional in scope, this local demand index may be less important.

HERF is the Herfindahl index for plants in the state, measuring how concentrated the production of oil or paper is in the state. We identify all plants in the industry in each Census year, add up their individual shipments, and calculate a share of each plant in the total shipments. Finally, we square each plant's share and sum them. A number close to one indicates highly concentrated production, while numbers near zero indicate little concentration. To the extent that a more concentrated industry has more market power, it could raise price in response to stricter regulations, so may be less sensitive to regulatory pressures. Of course, an ideal measure of such concentration would be firm-level, rather than plant-level, and might include plants in nearby states that supplied the same market.

CLOUT is oil or paper industry shipments from plants in the state, divided by the total gross state product. A large industry might be expected to have more political power, and thus to be able to gain exemptions from regulatory pressures. On the other hand, a large industry is likely to be a larger contributor to the total pollution problem in the state, and may be a more visible target for stricter regulatory pressures. We will be focussing on interactions between CLOUT and the regulatory measures (CLOUT should get a positive coefficient, reflecting whatever characteristics make the state a desirable location).

In addition to the regulatory variables, a number of other variables are used to control for differences across states that might influence production allocation. These variables were used in earlier work focussing on plant location, Gray (1997), and were designed to capture a wide range of the other factors affecting the location decision. The earlier work found them to be generally significant as a group, although only a subset would be individually significant in any given regression. Factor price measures include ENERGY (dollars per million BTU, from the Energy Information Administration), LANDPRICE (value per acre of agricultural land and buildings, from the City and County Databook), and WAGE (average hourly wage in manufacturing, taken from the Statistical Abstract). All dollar values are converted to real 1982 values using the GDP deflator. Labor market indicators include UNION (percent of non-agricultural workforce unionized, from Bureau of Labor Statistics), UNEMP (civilian unemployment rate), and INCOME (income per capita). Labor quality is measured by the fraction of the over-25 population with college degrees (COLLEDUC). Tax differences are measured by state and local taxes, divided by gross state product (TAXGSP). ELECDEM is the percentage of votes for Democratic candidates in the U.S. House of Representatives for the state. Population density (POPDEN) controls for differences in the size of the local product market and possibly also for ‘agglomeration effects’ (the tendency to locate where existing businesses are already located). AREA provides a physical measure of the extent of the available market in the state.

## 4. Results

Table 1 presents the means and standard deviations for each variable used in the analysis, separately for the paper and oil industry samples. We have many more firm-state observations for the paper industry – there are more paper firms with data, but most of the difference is that paper firms tend to operate facilities in more states. In our data, the average paper firm is operating in 15 states while the average oil firm operates in fewer than 6 states, resulting in larger SHTVS values for oil firms.

Since most of the explanatory variables are state-specific, there is relatively little difference in the mean values of the explanatory variables between the two industry samples. Most firms in both industries have relatively high compliance rates, averaging around 70 percent of their plants in compliance, with some variation across firms. The industry-state variables (DEMAND, HERF, and CLOUT) differ somewhat: the oil industry is a bit less concentrated (more plants producing in those states with some production), and is more important to the average state's economy.

Table 2 presents the basic models for the paper industry data, using SHTVS as the dependent variable. We note that the SCALE variable (reflecting differences across firms in the number of states used to calculate production shares) enters with the expected coefficient of about one. The model explains 20-30 percent of the variation in SHTVS across our firm-state observations (with SCALE contributing a fairly large part of the total). There are sizable increases in R-squared when we add a broad set of state-specific variables, and then a set of state dummies: each set adds about 5 percent to the total explanatory power, going from 20% (model 2) to 25% (model 3) to 30% (model 5). The DEMAND index, as expected, shows that higher state demand for the industry's product is associated with greater production in the state; CLOUT is also positive. ENERGY and DIRTY enter significantly, both with negative signs as expected: higher energy prices and a dirtier environment are associated with lower production shares.[14] INCOME is also negative, reflecting the higher demand for a clean environment in wealthier states. COLLEDUC is positive, as is ELECDEM. Note that a few of the variables drop out when the firm and state dummy variables are included, since SCALE and COMP have no within-firm variation, and DIRTY and AREA have no within-state variation.

The variables on which we focus are firm compliance and state regulatory stringency, as measured by COMP and VOTE, and their interaction. Once the interaction term is included (in models 2-6), the VOTE variable has a negative coefficient, while COMP*VOTE is positive. This indicates that firms with higher compliance rates are less likely to avoid states with stricter regulation. Using the coefficients from model 6, a one standard deviation change in VOTE would be predicted to reduce a non-compliant (COMP=0) firm's share of production in a state by 2.68 percentage points.[15] This is over one-third of the mean production share.

The interaction between compliance and stringency is consistently positive and

[14] One possible explanation for the DIRTY impact is that states with more serious air and water pollution problems are forced to adopt more stringent regulations.

significant. In fact, at a high enough compliance rate, the marginal effect of more stringency is positive. The 'crossover' compliance rate varies from 47 percent (models 3 and 4) to 80 percent (models 5 and 6). The average compliance rate in our sample, 70 percent, is near this crossover point, so the marginal impact of stringency on a typical firm's production allocation is likely to be small. Still, the interaction results indicate that low-compliance firms are more likely to avoid high-stringency states.

The interactions between VOTE and the industry characteristics within the state, CLOUT and HERF, did not show the expected positive effects. The HERF*VOTE interaction is negative and marginally significant. The CLOUT*VOTE interaction is also negative, though not significant. This indicates that large and concentrated industries are more, not less, sensitive to state regulatory stringency, perhaps reflecting the political dangers of being a visible target for regulation. These interaction effects may also be capturing long-run differences across states, since they disappear when state dummies are included.

Table 3 examines six other measures of state regulatory stringency, along with their interactions with firm compliance. Because these measures (except PAOCADJ and NONATTAIN) have no within-state variation, we cannot include state fixed-effects in these models. We do include the full set of state-specific control variables, which have similar coefficients (not shown here) to those found in Table 2. We find most of the other stringency measures give results similar to VOTE, with a negative coefficient on the regulatory variable and a positive interaction with firm compliance. Similar coefficients are obtained when firm

[15] This is -0.137 (VOTE coefficient) * 19.6 (one standard deviation change in VOTE).

dummies are added to the equation, and when VOTE and COMP*VOTE are added.[16]

Tables 4 and 5 present the same analysis, applied to the oil industry data, with much weaker results. In Table 4, neither COMP, VOTE, nor their interaction are significant. We do see some significant coefficients on other variables: HERF*VOTE and COMP*HERF*VOTE are both significant, but with signs reversed from the paper industry. More concentrated production is associated with a positive impact of regulatory stringency, which is reversed for high-compliance firms (the crossover points occur around 60 or 70 percent firm compliance). In Table 5 we see that some of the other regulatory variables give stronger results than VOTE, with both ENVPOLICY and CONVMEMB having significant coefficients. For all regulatory measures except REGSPEND the pattern of signs is similar to that found in the paper industry: negative on the regulatory variable and positive on its interaction with COMP.[17]

## 5. Conclusions

We examine the decision faced by a firm trying to allocate its production across plants in several states, based in part on the regulatory stringency in those states. We are able to measure these decisions between 1967 and 1992, at five year intervals, using the Census Bureau's Longitudinal Research Database. We focus on paper and oil firms, as they face relatively stringent environmental regulation and were studied in our prior research.

[16] Results available from authors upon request.

[17] We also performed our analyses in growth rate form. The results were disappointing, with virtually none of the 'interesting' variables showing significant impacts. This may reflect the limited information available on within-state variation in regulation over time (most of our regulatory variables are cross-sectional in nature). These results are available upon request.

We find a significant relationship between our regulatory variables and production allocation within the paper industry. States with stricter regulations have smaller production shares, even after controlling for a variety of other state characteristics. Interacting firm compliance and state stringency, we find that the impact of stringency is concentrated on low-compliance firms. In fact, in all specifications firms with high compliance rates appear to be slightly more likely to produce in more stringent states. The crossover points (where state stringency has no impact on production location), occur between 50 and 80 percent compliance rates, relatively close to the actual compliance rates of about 70 percent in our data. We also tested for interactions with industry characteristics and found surprising (though not generally significant results), with a larger impact of regulatory stringency when the industry is larger or more concentrated within a state.

Our result that high-compliance firms are less concerned with regulatory stringency is consistent with compliance decisions being driven by differences in compliance <u>costs</u> across firms (economies of scale in compliance), rather than differences in <u>benefits</u> (maintaining firm reputation). If firms choose low compliance rates because they do not see any benefits from complying, they will not need to avoid high-stringency states (since they will not be complying anyway). If they are trying to comply, but failing due to high compliance costs, they would want to avoid high-stringency states.

Our results for the oil industry are consistent with the paper industry results, with smaller production shares in high-stringency states and this effect concentrated in low-compliance firms. However, the effects are less often statistically significant. This may reflect a more local market for oil, with less opportunity to shift production across states. Data from the 1993 Commodity Flow Survey indicate that paper mills tend to ship their products much farther than oil refineries. Our weaker oil industry results could also be explained by earlier findings that environmental regulation has had only a small (or no) impact on the oil industry [see Berman and Bui (2001a, 2001b) and Gray and Shadbegian (1995)]. We anticipate further work in this area, looking in more detail at changes in allocation over time and developing a model of a firm's compliance behavior in order to better understand how regulation affects production allocation decisions.

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TABLE 1
Descriptive Statistics

| Variable | PAPER Mean | (Std. Dev.) | OIL Mean | (Std. Dev.) |
|---|---|---|---|---|
| | (3019 obs) | | (628 obs) | |
| **Dependent Variables** | | | | |
| SHTVS | 6.459 | (13.870) | 17.675 | (24.640) |
| shipments from firm's plants in state, divided by total firm shipments (*100) | | | | |
| **Firm characteristics** | | | | |
| SCALE | 6.460 | (6.460) | 17.675 | (8.677) |
| 1/(# states where firm has plants) = expected SHTVS | | | | |
| COMP | 0.703 | (0.199) | 0.683 | (0.103) |
| firm compliance (% plants complying with air pollution regs in mid-1980s) | | | | |
| **State regulatory stringency** | | | | |
| VOTE | 46.504 | (19.599) | 40.430 | (19.911) |
| Pro-environment Congressional voting (League of Conservation Voters) | | | | |
| PAOCADJ | 0.248 | (1.327) | 0.236 | (1.478) |
| pollution abatement costs in state (adjusted for industry mix) | | | | |
| ENVPOLICY | -1.969 | (0.659) | -2.261 | (0.678) |
| Green Policies index from Hall and Kerr (1991); bigger negative=less strict | | | | |
| AIRINSP | 0.047 | (0.061) | 0.062 | (0.091) |
| state air pollution inspection rate (inspections/plants) in mid-1980s | | | | |
| NONATTAIN | 9.955 | (10.944) | 10.888 | (23.170) |
| attainment status for state's counties <particulates for paper; ozone for oil> | | | | |
| CONVMEMB | 8.377 | (3.307) | 7.508 | (3.119) |
| membership in 3 conservation groups, late 1980s, per 1000 population | | | | |
| REGSPEND | 24.574 | (13.507) | 36.494 | (49.504) |
| state government environmental spending per capita, 1988 | | | | |
| **Industry characteristics within state** | | | | |
| DEMAND | 2.764 | (0.608) | 8.323 | (1.221) |
| demand index (for industry's product) in state, based on industry mix | | | | |
| HERF | 0.313 | (0.262) | 0.260 | (0.237) |
| herfindahl index for industry in state, based on plant-level shipments | | | | |
| CLOUT | 0.193 | (0.375) | 1.328 | (1.446) |
| Industry shipments/Gross State Product | | | | |

TABLE 1 (cont.)
State Control Variables

| | | | | |
|---|---|---|---|---|
| WAGE<br>1982$ average manufacturing wage | 6.615 | (1.701) | 6.918 | (1.682) |
| ENERGY<br>1982$ per million BTU (*1000) | 0.187 | (0.149) | 0.153 | (0.129) |
| LANDPRICE<br>1982$ (1000) value per acre | 0.671 | (0.644) | 0.569 | (0.653) |
| UNION<br>Non-farm unionization rate | 24.075 | (10.114) | 22.034 | (9.391) |
| UNEMP<br>Civilian unemployment rate | 5.797 | (2.545) | 5.706 | (2.419) |
| COLLEDUC<br>Percent college graduates in population | 12.132 | (4.751) | 12.859 | (4.640) |
| TAXGSP<br>Total state and local taxes, as percent of gross state product | 8.232 | (1.470) | 7.885 | (1.245) |
| ELECDEM<br>Fraction voting for Democratic Congressional candidates | 0.454 | (0.194) | 0.428 | (0.204) |
| INCOME<br>1982$ (1000) Income per capita | 6.745 | (4.317) | 6.886 | (4.393) |
| POPDEN<br>(1000) population per square mile | 0.193 | (0.227) | 0.135 | (0.202) |
| AREA<br>land area in million square miles | 0.059 | (0.049) | 0.095 | (0.075) |
| DIRTY<br>Green Conditions index from Hall and Kerr (1991) | 4.658 | (0.620) | 4.867 | (0.611) |

Interactions

| | | | | |
|---|---|---|---|---|
| COMP*VOTE | 32.759 | (17.189) | 27.353 | (13.644) |
| COMP*PAOCADJ | 0.176 | (0.981) | 0.167 | (1.019) |
| COMP*ENVPOLICY | -1.384 | (0.614) | -1.555 | (0.561) |
| COMP*AIRINSP | 0.033 | (0.047) | 0.042 | (0.062) |
| HERF*VOTE | 12.706 | (12.705) | 11.581 | (14.795) |
| COMP*HERF*VOTE | 8.857 | (9.335) | 7.828 | (9.787) |
| CLOUT*VOTE | 10.087 | (26.743) | 44.121 | (40.863) |
| COMP*CLOUT*VOTE | 708.53 | (3.307) | 2969.8 | (2762.9) |

TABLE 2
Paper Industry Analysis
Basic Production Share (SHTVS) Models
(N=3019)

| Model : | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| COMP | 0.003 | $-7.330^{***}$ | $-6.836^{**}$ | | $-7.249^{***}$ | |
| | (1.018) | (2.900) | (2.819) | | (2.765) | |
| VOTE | 0.010 | $-0.098^{**}$ | -0.070 | -0.074 | $-0.128^{**}$ | $-0.137^{**}$ |
| | (0.012) | (0.042) | (0.053) | (0.053) | (0.065) | (0.066) |
| COMP*VOTE | | $0.155^{***}$ | $0.147^{**}$ | $0.157^{**}$ | $0.159^{**}$ | $0.171^{**}$ |
| | | (0.061) | (0.066) | (0.068) | (0.065) | (0.068) |
| HERF | | | -0.540 | -0.389 | -2.485 | -2.624 |
| | | | (1.982) | (1.974) | (2.929) | (2.958) |
| HERF*VOTE | | | $-0.106^{**}$ | $-0.099^{*}$ | 0.022 | 0.035 |
| | | | (0.055) | (0.053) | (0.071) | (0.070) |
| COMP*HERF*VOTE | | | 0.022 | 0.001 | 0.046 | 0.030 |
| | | | (0.074) | (0.071) | (0.073) | (0.070) |
| CLOUT | | | $10.620^{***}$ | $11.271^{***}$ | -2.452 | -2.564 |
| | | | (3.564) | (3.621) | (4.405) | (4.443) |
| CLOUT*VOTE | | | -0.093 | -0.101 | 0.069 | 0.072 |
| | | | (0.084) | (0.085) | (0.125) | (0.127) |
| COMP*CLOUT*VOTE | | | -0.027 | -0.026 | -0.052 | -0.055 |
| | | | (0.069) | (0.070) | (0.062) | (0.063) |
| DEMAND | | | $0.977^{**}$ | $1.009^{**}$ | $3.307^{**}$ | $3.236^{**}$ |
| | | | (0.426) | (0.435) | (1.398) | (1.390) |
| WAGE | | | 0.155 | 0.185 | -0.212 | -0.180 |
| | | | (0.408) | (0.402) | (1.013) | (1.012) |
| ENERGY | | | $-22.789^{***}$ | $-23.378^{***}$ | -1.940 | -1.840 |
| | | | (6.237) | (6.267) | (8.914) | (8.900) |
| LANDPRICE | | | 0.736 | 0.739 | 1.031 | 1.024 |
| | | | (0.854) | (0.837) | (1.090) | (1.076) |
| UNION | | | 0.009 | 0.010 | 0.091 | 0.089 |
| | | | (0.044) | (0.044) | (0.078) | (0.078) |
| UNEMP | | | $-0.383^{*}$ | $-0.394^{*}$ | -0.147 | -0.147 |
| | | | (0.214) | (0.216) | (0.262) | (0.262) |
| COLLEDUC | | | $0.491^{***}$ | $0.488^{***}$ | 0.341 | 0.339 |
| | | | (0.189) | (0.189) | (0.328) | (0.335) |
| TAXGSP | | | 0.021 | 0.028 | 0.080 | 0.068 |
| | | | (0.302) | (0.301) | (0.460) | (0.461) |

TABLE 2 (cont.)
Paper Industry Analysis
Basic Production Share (SHTVS) Models
(N=3019)

| Model : | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| ELECDEM | | | 6.614*** | 6.553*** | 1.585 | 1.600 |
| | | | (2.568) | (2.555) | (2.970) | (2.924) |
| INCOME | | | -1.350*** | -1.405*** | -1.188** | -1.186** |
| | | | (0.413) | (0.416) | (0.506) | (0.514) |
| POPDEN | | | -0.040 | 0.044 | 20.003 | 19.112 |
| | | | (1.769) | (1.824) | (19.880) | (19.790) |
| AREA | | | 3.410 | 4.075 | | |
| | | | (5.259) | (5.167) | | |
| DIRTY | | | -1.525** | -1.615*** | | |
| | | | (0.629) | (0.610) | | |
| SCALE | 0.997*** | 0.992*** | 0.959*** | | 0.937*** | |
| | (0.065) | (0.065) | (0.064) | | (0.060) | |
| FIRM | | | | X | | X |
| STATE | | | | | X | X |
| RSQUARE | 0.217 | 0.219 | 0.254 | 0.256 | 0.307 | 0.311 |

NOTES:
All regressions also include year dummies.
(Standard Errors) adjusted for autocorrelation and heteroskedasticity
*** = Significant at the 1% level
** = Significant at the 5% level
* = Significant at the 10% level

TABLE 3
Paper Industry Analysis
Production Share (SHTVS) Models Using
Alternative Regulatory Measures
(N=3019)

| Regulatory Variable | COMP Coeff. | Reg. Coeff. | COMP*Reg. Coeff. | R-square |
|---|---|---|---|---|
| VOTE | -6.836** | -0.070 | 0.147** | 0.254 |
| | (2.879) | (0.053) | (0.066) | |
| PAOCADJ | -0.996 | -0.434 | 1.778* | 0.258 |
| | (1.561) | (0.673) | (0.939) | |
| ENVPOLICY | 6.546* | -2.265* | 3.850** | 0.254 |
| | (3.846) | (1.247) | (1.579) | |
| AIRINSP | -0.723 | -28.240*** | 0.760 | 0.262 |
| | (1.615) | (8.507) | (10.640) | |
| NONATTAIN | -0.759 | 0.031 | -0.004 | 0.253 |
| | (1.845) | (0.069) | (0.104) | |
| CONVMEMB | -8.822*** | -0.916*** | 0.969*** | 0.255 |
| | (2.751) | (0.308) | (0.331) | |
| REGSPEND | -8.054*** | -0.127** | 0.292*** | 0.258 |
| | (2.511) | (0.064) | (0.092) | |

NOTES:
All regressions include all of the state-level control variables from model 3 in Table 2.
(Standard Errors) adjusted for autocorrelation and heteroskedasticity
*** = Significant at the 1% level
** = Significant at the 5% level
* = Significant at the 10% level

TABLE 4
Oil Industry Analysis
Basic Production Share (SHTVS) Models
(N=628)

| Model : | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| COMP | 0.219 | -1.489 | 9.427 | | 12.443 | |
| | (13.610) | (26.760) | (25.800) | | (28.370) | |
| VOTE | 0.008 | -0.022 | -0.166 | 0.010 | -0.636 | -0.423 |
| | (0.050) | (0.441) | (0.567) | (0.572) | (0.573) | (0.531) |
| COMP*VOTE | | 0.044 | 0.470 | 0.194 | 0.851 | 0.515 |
| | | (0.647) | (0.816) | (0.829) | (0.822) | (0.769) |
| HERF | | | 9.587 | 2.333 | -0.022 | -1.361 |
| | | | (13.800) | (14.440) | (14.100) | (12.940) |
| HERF*VOTE | | | 1.396$^{**}$ | 1.578$^{***}$ | 1.460$^{**}$ | 1.603$^{**}$ |
| | | | (0.737) | (0.720) | (0.841) | (0.813) |
| COMP*HERF*VOTE | | | -2.419$^{**}$ | -2.568$^{***}$ | -2.013$^{**}$ | -2.225$^{**}$ |
| | | | (1.144) | (1.132) | (1.202) | (1.158) |
| CLOUT | | | 1.851 | 2.362 | -0.035 | 0.183 |
| | | | (1.708) | (1.668) | (1.805) | (1.776) |
| CLOUT*VOTE | | | -0.089 | -0.099 | 0.093 | 0.138 |
| | | | (0.219) | (0.222) | (0.235) | (0.222) |
| COMP*CLOUT*VOTE | | | 0.085 | 0.113 | -0.111 | -0.180 |
| | | | (0.331) | (0.334) | (0.355) | (0.336) |
| DEMAND | | | 1.489 | 1.591 | 1.548 | 1.450 |
| | | | (1.362) | (1.412) | (1.834) | (1.867) |
| WAGE | | | -0.679 | -0.682 | 2.007 | 2.280 |
| | | | (2.005) | (2.065) | (3.042) | (2.907) |
| ENERGY | | | 34.113 | 27.287 | 21.127 | 16.769 |
| | | | (26.200) | (27.580) | (28.130) | (27.150) |
| LANDPRICE | | | 4.530$^{*}$ | 4.069$^{*}$ | 3.577 | 3.119 |
| | | | (2.927) | (2.820) | (3.088) | (2.982) |
| UNION | | | 0.468$^{***}$ | 0.662$^{***}$ | -0.132 | -0.147 |
| | | | (0.171) | (0.184) | (0.243) | (0.240) |
| UNEMP | | | -1.154$^{*}$ | -0.983 | 0.364 | -0.108 |
| | | | (0.722) | (0.782) | (0.780) | (0.765) |
| COLLEDUC | | | 0.457 | 0.472 | 1.336 | 1.737 |
| | | | (0.718) | (0.797) | (1.592) | (1.579) |
| TAXGSP | | | -1.051 | -0.797 | -2.555$^{**}$ | -2.218$^{*}$ |
| | | | (1.326) | (1.296) | (1.365) | (1.320) |

TABLE 4 (cont.)
Oil Industry Analysis
Basic Production Share (SHTVS) Models
(N=628)

| Model : | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| ELECDEM | | | -2.888 | 0.313 | -12.024 | -10.032 |
| | | | (8.932) | (8.617) | (9.932) | (9.339) |
| INCOME | | | -1.288 | -1.288 | 1.191 | 0.341 |
| | | | (1.667) | (1.775) | (1.789) | (1.767) |
| POPDEN | | | -3.024 | -1.309 | -58.475 | -48.537 |
| | | | (8.541) | (8.719) | (96.790) | (92.680) |
| AREA | | | 89.537*** | 95.071*** | | |
| | | | (25.480) | (24.880) | | |
| DIRTY | | | 7.400** | 9.427*** | | |
| | | | (3.390) | (3.536) | | |
| SCALE | 1.002*** | 1.003*** | 0.933*** | | 0.911*** | |
| | (0.177) | (0.177) | (0.161) | | (0.173) | |
| FIRM | | | | X | | X |
| STATE | | | | | X | X |
| RSQUARE | 0.124 | 0.124 | 0.265 | 0.290 | 0.343 | 0.412 |

NOTES:
All regressions also include year dummies.
(Standard Errors) adjusted for autocorrelation and heteroskedasticity
*** = Significant at the 1% level
** = Significant at the 5% level
* = Significant at the 10% level

TABLE 5
Oil Industry Analysis
Production Share (SHTVS) Models Using
Alternative Regulatory Measures
(N=628)

| Regulatory Variable | COMP Coeff. | Reg. Coeff. | COMP*Reg. Coeff. | R-square |
|---|---|---|---|---|
| VOTE | 9.427 | -0.166 | 0.470 | 0.265 |
| | (25.800) | (0.567) | (0.816) | |
| PAOCADJ | 18.994 | -5.908 | 7.972 | 0.265 |
| | (21.190) | (6.029) | (8.705) | |
| ENVPOLICY | 110.520** | -27.040** | 40.226** | 0.276 |
| | (47.990) | (12.470) | (17.540) | |
| AIRINSP | 16.028 | -88.630 | 125.480 | 0.264 |
| | (23.210) | (92.090) | (131.900) | |
| NONATTAIN | 14.416 | -0.282 | 0.586 | 0.268 |
| | (21.230) | (0.374) | (0.554) | |
| CONVMEMB | -40.810 | -6.259** | 8.241** | 0.274 |
| | (30.560) | (2.749) | (4.024) | |
| REGSPEND | 21.455 | 0.061 | -0.116 | 0.264 |
| | (22.180) | (0.301) | (0.423) | |

NOTES:
All regressions include all of the state-level control variables from model 3 in Table 4.
(Standard Errors) adjusted for autocorrelation and heteroskedasticity
** = Significant at the 5% level