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When Do Firms Shift Production Across States to Avoid Environmental Regulation?
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ABSTRACT

This paper takes a new approach to testing the impact of state environmental regulatory stringency on firms' location decisions, focusing on firms' allocation of production across states. We use Census data for the paper industry to measure the share of each firm's production in each state during 1967-2002. We use a conditional logit model, controlling for a variety of state characteristics that influence firm costs and revenues, and testing several measures of state environmental stringency. Firms allocate significantly smaller production shares to states with stricter regulations, but there is significant heterogeneity across firms in their sensitivity to regulatory stringency. Firms with low compliance rates are more sensitive than firms with high compliance rates, consistent with a model where compliance rates are driven by differences across firms in the costs of compliance, rather than in the benefits of compliance.

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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. Different states, facing different benefits and costs from environmental regulation, might be expected to choose different levels of stringency, imposing different abatement costs. In turn, firms might respond to differences in costs by shifting their operations, opening or expanding plants in less stringent states, and closing or reducing their operations in stricter states.

We examine the impact of regulatory stringency on firms' allocation of their production across different states, measured by the share of a firm's total production occurring in each state. This is (to our knowledge) the first examination of this topic. Existing studies of regulatory impact using plant-level data have tended to focus on discrete decisions: plant openings and closings. Bartik (1988), McConnell and Schwab (1990), and Levinson (1996) found relatively small or insignificant impacts, but more recent studies have found larger impacts. For example, Becker and Henderson (2000) found large reductions in the number of new plants opening in counties with stricter regulation, as did List, et. al. (2003). Furthermore, Gray (1997) found lower birth rates of new plants in states with stricter regulation, and Deily and Gray (1991) found that steel mills facing more stringent regulatory enforcement were more likely to close. Finally, Greenstone (2002) a paper much closer in spirit to the our paper, finds significant reductions in economic activity of polluting plants in higher-stringency counties, but doesn't consider the firm-level aspect of the decision.

In addition to being novel, examining shifts in production shares is quantitatively important. In our data, changes in production at existing plants account for two-thirds of the aggregate changes in firms' production shares over time, while plant openings and closings account for only about one-sixth each. It is not obvious whether differences in environmental regulation should affect production shares more than they affect plant openings and closings. On the one hand, shifting production among existing plants may be easier than opening or closing plants, making such shifts more sensitive to differences in regulation. On the other hand, many regulations, such as new source performance review, tend to be stricter for new plants and exempt existing ones due to grandfathering, possibly making existing plants less affected by differences in regulation than new plants.

We use eight years of plant-level Census year data (1967-2002) for the pulp and paper industry from the Census Bureau's Longitudinal Research Database. The data set includes 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. We also control for other state characteristics are included that could influence production allocation, such as factor prices and quality, industry concentration, and product demand.

We find a significant relationship between regulatory stringency and production allocation. States with stricter regulations have smaller production shares, even after controlling for a variety of other state characteristics. This impact is concentrated in firms with low levels of compliance with environmental regulations. If anything, firms with high compliance rates tend to prefer more stringent states, though this effect is relatively small. These results are consistent with a model where differences across firms in compliance rates are driven primarily by differences in compliance costs (e.g. economies of scale in compliance), rather than by differences in the benefits of compliance (e.g. maintaining the firm's reputation). Briefly, if firms choose low compliance rates because they see few benefits from complying, they would have no need to avoid high-stringency states. If, instead, low-compliance firms would like to comply, but don't because it is too costly, they would avoid high-stringency states - which is what we observe.

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

2. Model

State regulatory stringency may influence firms' decisions along many dimensions. The usual assumption is that production costs are higher in stricter states where 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, more stringent states may have more complex permit procedures, requiring firms to undertake lengthy negotiations whenever they wish to change their production process, 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]

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[1] Becker (2005) demonstrates the connection between regulatory stringency and pollution abatement costs. Other studies have measured regulation-induced increases in costs as decreases in 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, while Berman and Bui (2001), Boyd and McClelland (1999), and Gray and Shadbegian (2002,2003) examine manufacturing plants.

[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

In addition to the overall impact of regulatory stringency on firms' decisions, we are also interested in heterogeneity across firms in their decisions. For example, we observe variations in regulatory compliance across firms, with larger firms serving national markets having better environmental performance (being more often in compliance with regulations) than smaller firms serving local markets. Why might such differences occur?

Differences in compliance between large and small firms could arise from differences in their costs of dealing with the complexity of environmental regulations. Larger firms can afford a corporate environmental staff supporting many plants. Smaller firms, relying on plant-level personnel with many other responsibilities, cannot keep up with frequent regulatory changes.[3] Larger firms may also have the political clout to intervene in the standards-setting process, making compliance easier.[4] These economies of scale in compliance should give larger firms an advantage, especially in states with stringent regulations (and more complex bureaucratic procedures to enforce those regulations), allowing them to choose higher compliance rates.

Differences across firms in compliance could also arise from differences in their benefits of compliance, attributable 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

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uncertainty in their permitting process.

[3] 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. These trends have been more pronounced in recent years, so should be less important for the period being studied here.

[4] Environmental officers at large corporations commonly serve on state environmental advisory boards, where they are in a position to influence the development of new regulations.

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 on there being 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 should face smaller benefits from compliance, leading them to choose lower levels of compliance effort.

Now consider the optimizing decision of a profit-maximizing firm choosing its production level Qs in each of a number of different states, as shown in Equation 1 below. R(Qs) and C(Qs) refer to the revenue function (net of transportation costs to consumers, possibly located in other states) and production cost function in state s. We assume that over the relevant range of output the revenue and cost functions have the usual shape – diminishing marginal revenue ($d^2R(Qs)/dQs^2<0$) and increasing marginal costs ($d^2C(Qs)/dQs^2>0$). We also assume that production of Q causes pollution and the firm is faced with a choice about how much of its pollution to abate, As ($0<=As<=1$), with resulting abatement costs PAC(As). We further assume increasing marginal abatement costs ($d^2PACs/dAs^2>0$). On the other hand, not abating pollution can also be costly, as the firm faces expected penalties Ps from state regulators, where Ps depends on both inspection frequency and the level of penalties for violations. Note that both abatement costs and penalties are measured proportional to output. The model allows for heterogeneity across firms in both costs of abatement α_c (e.g. economies of scale in abatement) and benefits from abatement α_b (e.g. "penalties" from customer backlash if the firm is found in violation).

(1) $\text{Max } \Pi = R(Qs) - C(Qs) - \alpha_c*PAC(As)*Qs - \alpha_b*Ps*(1-As)*Qs$

Qs, As

The profit-maximizing firm chooses both the optimal level of output (Qs^*) and the optimal level of abatement (As^*) in each state. The first-order condition for choosing Qs* is shown in Equation 2, where the usual equality between marginal revenue and marginal cost (R'=C') is complicated by an additional wedge, based on a combination of the cost of pollution abatement and the penalties from non-abatement. The first-order condition for choosing As* is shown in Equation 3, where the firm sets its marginal abatement cost equal to its expected penalties from not abating pollution, adjusted by the firm-specific factors α_c and α_b.

(2) $R'(Qs^*) = C'(Qs^*) + \alpha_c{*}PAC(As^*) + \alpha_b{*}Ps{*}(1-As^*)$

(3) $PAC'(As^*) = (\alpha_b / \alpha_c){*}Ps$

With constant or declining marginal costs of production and no transportation costs, a profit-maximizing firm should produce all its output in the lowest-cost state, taking into account pollution-related cost differences. Since we are analyzing data for firms that produced output in at least four different states, they must have either increasing marginal production costs or transportation costs, in order to have an interior solution to Equation 2 in multiple states. Firms will tend to produce less in those states with higher regulatory stringency: all else equal, higher Ps in a state encourages a greater abatement effort (As), both combining to create a larger wedge between marginal revenue and marginal cost. In the extreme, firms may choose to produce nothing in states with sufficiently high regulatory stringency.

We are also interested in differences across firms in their sensitivity to state regulatory stringency, dQs*/dPs. These differences could arise from differences in the firms' α_c or α_b. We don't observe α_c and α_b, but we do observe the firm's level of regulatory compliance, which we take as an indicator of its average abatement decisions. Suppose that differences in compliance across firms are driven by differences in their α_c. High-compliance firms would be those with lower α_c and a smaller wedge, and thus would be less sensitive to regulatory stringency. If, instead, differences across firms in compliance are driven by differences in their α_b, high-compliance firms would be those with higher α_b and a larger wedge, and thus would be more sensitive to regulatory stringency.

We can see this more simply by considering the extreme cases, where $\alpha_c=0$ or $\alpha_b=0$. If $\alpha_c=0$, then it is costless for the firm to abate, so it sets As*=1 and the wedge disappears. In this case, differences in Ps have no effect on high-compliance firms. On the other hand, if $\alpha_b=0$, then the firm sees no benefit from abatement, so it sets As*=0. Again the wedge disappears, but now it is low-compliance firms that are unaffected by differences in Ps. In our empirical work, we interact the firm's overall compliance rate with a measure of state regulatory stringency. Based on the argument above, a positive coefficient on the interaction term indicates that differences in the costs of pollution abatement are the more important source of firm heterogeneity: higher firm compliance reduces the negative impact of state stringency on production within the state. A negative coefficient indicates that differences in benefits are more important.

We use a conditional logit model for the analysis, examining the probability that a firm allocates a given unit of production to a given state, given the characteristics of that state and all the other available states to choose from:

$$(4)\quad \text{Prob}(\textit{firm i chooses state s}) = \frac{\exp(\beta * Z_s + \delta * P_s + \gamma * A_i * P_s)}{\prod_j \exp(\beta * Z_j + \delta * P_j + \gamma * A_i * P_j)}.$$

State characteristics Zs include the cost of labor and other inputs, along with factors that might influence marginal revenue, such as industry concentration and an index of product demand within the state. Following this model focuses our attention on the differences in regulation (and other explanatory variables) across states at a given time. A general increase in regulatory stringency across all states could leave the ratio in equation (2) unchanged, in which case it would be predicted not to influence the firm's allocation decision – every unit of production has to be allocated somewhere, and it's differences in P and Z across states which matter in the conditional logit model.

Firm characteristics cannot directly enter the model, since they would cancel out in the numerator and denominator of (2), but we interact our measures of regulatory stringency with the firm's compliance rate, to see whether low-compliance firms respond more or less to regulatory differences. We use the fraction of all of the firm's plants that are in compliance, based on all plant-year observations with compliance data, so each firm has one compliance rate, fixed over time. This is intended to capture differences across firms in their long-term compliance tendencies.[5] We consider two types of interactions, one using the continuous measure of compliance and the other using a spline in compliance to see how responsiveness changes as compliance rates change.

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[5] Comments on an earlier version suggested concerns about possible endogeneity of compliance. This seems less relevant in the conditional logit model, but we did test instrumenting for the firm compliance rate, modeling plant-level compliance for the firm's plants based on plant age and output, state regulatory enforcement, and state and year dummies, with essentially identical results (available from the authors).

The model doesn't allow us to differentiate shifts in production across existing plants from shifts due to plant openings and plant closings. We might expect shifting production among existing plants to be easier than opening new plants, since new plants are generally subject to more stringent regulations. However, air pollution regulations requiring stricter rules for new plants (New Source Performance Standards) can also require existing plants to be treated as new if they substantially expand their production process. This could make production shifts among existing plants more costly. In any event, our estimated effects are best thought of as averages across the different categories of changing production shares, weighted by their relative sizes.

To implement our model using a standard conditional logit routine, we treat each firm as making 100 decisions in each time period, allocating 100 'percentage points' of its production across the available states. The estimation routine interprets this as generating a huge sample size for the analysis, with correspondingly small standard errors and large t-statistics – but the impact is predictable, so we can adjust for it.[6] The key is to decide what the "true" sample size is, from which the appropriate adjustment factor can be calculated and applied. In our analyses we use the actual number of firm-state observations with positive production. This should be a conservative measure of sample size, since it excludes any states where the firm is not currently producing.

[6] For example, doubling the sample size (allocating 200 rather than 100 shares of production) would double the log-likelihood and reduce all standard errors by the square root of 2, but has no effect on the estimated coefficients.

3. Data

Our 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 concentrate on pulp and paper mills, which we have studied extensively, including an analysis of the impact of pollution abatement costs on productivity (Gray and Shadbegian (2002) and Shadbegian and Gray (2005)). The plant-level data includes a firm identifier, with which we link together all the paper mills owned by the same firm in each Census year from 1967-2002.

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 (SHTVS) for our analysis.[7] 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 at some point. 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 (corresponding to the 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.

In what ways do firms shift production in our data? Changes in production shares at

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

continuing plants accounted for 68 percent of all share changes, while plant openings accounted for 17 percent and closings for 15 percent. Thus changes in production shares at existing plants are about four times as important as plant openings or closings in terms of moving production activity across plants in different states.

Does it make sense to treat the market as being served by plants in many different states? The 1993 Commodity Flow Survey reports the distance traveled by shipments for particular industries. Based on these data, paper shipments traveled an average of 238 miles, with 26 percent of shipments traveling further than 500 miles.[8] This indicates a somewhat national market for paper, with opportunities to shift production across states, but not a market in which firms are concentrating all their production in one or a few states.

As noted earlier, 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.[9] We use a single compliance measure for each firm (not a time-varying one) because the compliance data is not consistently available before the 1980s. Using a single compliance measure is appropriate as long as differences in compliance primarily reflect long-run differences between firms, rather

8 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.

9 We originally compiled the CDS information for our productivity analyses, so the compliance variable is only available for firms which had at least one plant in our productivity sample.

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.

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.[10]

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

[10] 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 the 1960s. Of course the environmental bills being considered in the 1960s were fewer and less costly than those in later years, but the votes should reflect similar differences in state preferences for regulation.

abatement intensity (for each state and each industry). We then calculate the 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 information.[11] 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)).

[11] 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.

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 air pollutant that is particularly relevant for the paper industry (particulates), and calculate the fraction of the counties in the state that are not in attainment.[12] A high value should be associated with more regulation, as dirtier air calls for more restrictions on plant expansion or new plant construction.

We also create a few variables measuring the characteristics of the industry in each state. DEMAND is a state-specific demand index for paper 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 paper each one-digit industry consumes (per employee). To capture 'final demand' for 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 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.

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[12] We would like to thank Randy Becker for providing this attainment data.

HERF is the Herfindahl index for plants in the state, measuring how concentrated the production of 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 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. 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 ENERGYPRI (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. In our data, the average paper firm is operating in about 15 states, resulting in an average of about 6-7 percent of the firm's production occurring in each state (or alternatively a probability of about 6-7 percent that any given unit of the firm's production occurs in that state). We have about 40 firms in our sample and 7 years of data, resulting in a sample size of 3574 firm-state observations with non-zero production. Most firms have relatively high compliance rates, averaging around 70 percent of their plants in compliance.

Table 2 presents the basic models, using the conditional logit model described earlier. The model explains 10-15 percent of the variation in production allocation across our firm-state observations, once state characteristics or state dummies are included in the model. Consider model 3, which includes state characteristics but not state dummies. 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. ENERGYPRI and WAGE have the expected significant negative impact on production shares: states with higher energy prices and a higher wages are allocated lower production shares. COLLEDUC has the expected positive effect on production shares, though it is only marginally significant. On the other hand, several variables have unexpected effects, and some of them are significant in model 3, such as LANDPRICE, TAXGSP, and ELECDEM. Not surprisingly, including state dummy variables in model 4 raises the overall explanatory power of the model, but reduces the significance of most of the state characteristics. In fact, DIRTY and AREA drop out of the model when the state dummies are included, since they are purely cross-sectional variables.

The main focus of this study is on state regulatory stringency, as measured by VOTE, and its interaction with firm compliance rates. The VOTE variable is consistently negative and significant, while the interaction between compliance and stringency (COMP*VOTE) is consistently positive and significant. This indicates that firms with low compliance rates tend to avoid states with stricter regulation, but that the effect is smaller for firms with higher compliance rates. In fact, at a high enough compliance rate, the marginal effect of more stringency is positive. The 'crossover' compliance rate varies from 56-74 percent in the models with state dummies to 97 percent in the models with state characteristics, but not state dummies. The average compliance rate in our sample, 70 percent, is near the crossover point of 74, so the marginal impact of stringency on a typical firm's production allocation is likely to be small. Still, the results indicate that low-compliance firms are more likely to avoid high-stringency states, which is consistent with compliance decisions being driven by differences in compliance costs across firms (economies of scale in compliance), rather than differences in benefits (maintaining firm reputation).

In Table 3 we examine the interaction between the regulatory measures and the firm's compliance rate using a less constrained approach, creating dummies for firms with compliance rates exceeding 70 percent and 85 percent, which correspond very roughly to the median and 75th percentile of the firm compliance distribution.[13] For those models that incorporate state characteristics, we find that the impact of regulatory stringency on production allocation, as measured by VOTE, is negative and significant for those firms with less-than-average compliance rates (below 70 percent). For firms with intermediate compliance rates (between 70 and 85 percent), the impact of regulatory stringency is smaller, but still negative, while those firms with very high compliance rates (over 85 percent) tend to show a positive impact of regulatory stringency of production allocation.

Table 4 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 (model 3). In the upper panel, 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 (only ENVPOL has the unexpected positive sign on the regulatory variable). Those measures for which both terms are significant (PAOCADJ, NONPM, and CONVMEMB) have cross-over points for their

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[13] Due to Census confidentiality restrictions, we cannot report the exact values that correspond to a single observation in the dataset, such as the median value.

compliance rates roughly similar to those found for VOTE, ranging from 54 percent for PAOCADJ to 97 percent for CONVMEMB.

The results in the lower panel of Table 4 show the interactions of these 6 regulatory measures with dummies indicating firm compliance rates greater than 70 or 85 percent. The impacts here are less consistent than those for VOTE in Table 3, but for those regulatory measures with consistently significant effects in the upper panel, we see that firms with below-average compliance are more sensitive to regulation than high-compliance firms. Also, the highest-compliance firms have consistently positive effects – allocating relatively more production to those states with more stringent regulation.

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 2002, at five year intervals, using the Census Bureau's Longitudinal Research Database. We focus on paper firms, which face relatively stringent environmental regulation and have many firms with operations in multiple states.

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, 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.

Our result that high-compliance firms are less likely to avoid more stringent states seems consistent with compliance decisions being driven by differences in compliance costs across firms (economies of scale in compliance), rather than differences in benefits (maintaining firm reputation). If firms are choosing low compliance rates because they do not see any benefits from complying, they would not need to avoid high-stringency states (since they are not planning to comply anyway). If the low-compliance firms are trying to comply, but failing due to high compliance costs, they would want to avoid high-stringency states – consistent with our results.

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
(3574 obs)

Variable	Mean (Std. Dev.)
	Dependent Variable
SHTVS	6.355 (14.004)
shipments from firm's plants in state, divided by total firm shipments (*100)	
	Firm characteristics
COMP	0.707 (0.197)
firm compliance (% firm’s plants in compliance with air pollution regulations, 1979-1989)	
	State regulatory stringency
VOTE	46.136 (19.683)
pro-environment Congressional voting (League of Conservation Voters)	
PAOCADJ	0.364 (1.253)
pollution abatement costs in state (adjusted for industry mix)	
ENVPOL	-1.982 (0.660)
Green Policies index from Hall and Kerr (1991); bigger negative=less strict	
AIRINSP	0.048 (0.061)
state air pollution inspection rate (inspections/plants), 1979-1989	
NONATTAIN	9.146 (10.620)
percent of state's counties in non-attainment for particulate concentrations	
CONVMEMB	8.366 (3.321)
membership in 3 conservation groups, late 1980s, per 1000 population	
REGSPEND	24.599 (13.504)
state government environmental spending per capita, 1988	
	Industry characteristics within state
DEMAND	2.765 (0.592)
demand index for paper in state, based on industry mix	
HERF	0.305 (0.260)
herfindahl index for paper industry in state, based on plant-level shipments	
CLOUT	0.172 (0.353)
paper industry shipments/Gross State Product	

TABLE 1 (cont.)

State Control Variables

WAGE 7.464 (2.601)
1982$ average manufacturing wage

ENERGYPRI 0.287 (0.280)
1982$ per million BTU (*1000)

LANDPRICE 0.797 (0.807)
1982$ (1000) value per acre

UNION 22.604 (10.218)
non-farm unionization rate

UNEMP 5.855 (2.428)
civilian unemployment rate

COLLEDUC 13.643 (5.865)
percent college graduates in population

TAXGSP 8.248 (1.443)
total state and local taxes, as percent of gross state product

ELECDEM 0.465 (0.184)
fraction voting for Democratic Congressional candidates

INCOME 8.935 (6.616)
1982$ (1000) Income per capita

POPDEN 0.195 (0.229)
(1000) population per square mile

AREA 0.059 (0.049)
land area in million square miles

DIRTY 4.658 (0.621)
Green Conditions index from Hall and Kerr (1991)

TABLE 2
Basic Production Share (SHTVS) Models
N=3574 (t-statistics)

Model:	**1**	**2**	**3**	**4**
VOTE	-0.564 (-1.88)	-1.498 (-3.92)	-2.734 (-7.97)	-2.274 (-5.55)
COMP*VOTE	2.198 (4.82)	2.698 (5.40)	2.823 (5.75)	3.087 (6.03)
DEMAND			0.805 (16.44)	0.712 (3.86)
HERF			-2.858 (-18.33)	-1.140 (-3.81)
CLOUT			0.199 (3.64)	-0.210 (-1.25)
WAGE			-0.089 (-2.82)	-0.071 (-1.16)
ENERGY			-2.311 (-8.54)	-0.940 (-2.28)
LANDPRICE			0.109 (1.96)	0.073 (0.90)
UNION			0.006 (1.63)	-0.001 (-0.11)
UNEMP			-0.021 (-1.37)	-0.030 (-1.39)
COLLEDUC			0.029 (1.87)	-0.038 (-1.38)
TAXGSP			0.189 (8.28)	0.147 (3.52)
ELECDEM			2.328 (10.62)	0.080 (0.29)
INCOME			0.015 (0.86)	0.007 (0.23)
POPDEN			-0.873 (-4.96)	-0.135 (-0.07)
AREA			3.179 (5.56)	
DIRTY			0.093 (1.64)	
STATE DUMMIES	NO	YES	NO	YES
Log-L	-92440	-79281	-84598	-78909
R^2	0.005	0.147	0.089	0.151

TABLE 3
Production Share (SHTVS) Models
Using Spline on Firm Compliance
N=3574 (t-statistics)

Model :	**1**	**2**	**3**	**4**
VOTE	0.427 (3.03)	-0.308 (-1.21)	-1.480 (-7.53)	-0.918 (-3.26)
COMP70*VOTE	0.196 (0.85)	0.301 (1.22)	0.329 (1.33)	0.405 (1.59)
COMP85*VOTE	0.956 (4.42)	1.127 (4.82)	1.131 (4.82)	1.193 (4.92)
STATE CHARS	NO	NO	YES	YES
STATE DUMMMIES	NO	YES	NO	YES
Log-L	-92388	-79216	-84541	-78850
R^2	0.006	0.147	0.090	0.151

NOTES:
These model numbers correspond to those in Table 2, including all of the state-level control variables in models 3 and 4.

TABLE 4
Production Share (SHTVS) Models Using
Alternative Regulatory Measures
N=3574 (t-statistics)

	PAOCADJ	ENVPOL	AIRINSP	NONPM	CONVMEMB	REGSPEND
RegVar	-0.141 (-2.52)	0.176 (1.79)	-13.334 (-6.86)	-2.459 (-8.24)	-0.099 (-4.37)	-1.165 (-0.22)
Comp*Reg	0.262 (3.73)	0.092 (0.84)	3.720 (1.53)	3.235 (8.89)	0.102 (4.15)	15.965 (2.48)
Log-L	-84807	-84846	-82552	-84557	-84845	-84790
R^2	0.087	0.087	0.111	0.090	0.087	0.087

	PAOCADJ	ENVPOL	AIRINSP	NONPM	CONVMEMB	REGSPEND
RegVar	-0.018 (-0.73)	0.244 (3.87)	-12.493 (-13.09)	-0.671 (-4.32)	-0.044 (-2.90)	5.438 (1.96)
Comp70*Reg	0.130 (3.91)	-0.109 (-1.92)	3.570 (3.13)	0.353 (2.05)	-0.005 (-0.39)	4.469 (1.38)
Comp85*Reg	-0.035 (-1.11)	0.217 (3.98)	-1.573 (-1.45)	1.180 (6.92)	0.067 (5.76)	7.050 (2.28)
Log-L	-84798	-84774	-82517	-84506	-84716	-84750
R^2	0.087	0.087	0.112	0.090	0.088	0.088

NOTES:
All regressions include all of the state-level control variables from model 3 in Table 2 (not state dummies, since most of the regulatory variables examined here are cross-sectional in nature).