LOCAL ENVIRONMENTAL REGULATION AND PLANT-LEVEL PRODUCTIVITY

By

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Abstract

This paper examines the impact of environmental regulation on the productivity of manufacturing plants in the United States. Establishment-level data from three Censuses of Manufactures are used to estimate 3-factor Cobb-Douglas production functions that include a measure of the stringency of environmental regulation faced by manufacturing plants. In contrast to previous studies, this paper examines effects on plants in all manufacturing industries, not just those in “dirty” industries. Further, this paper employs spatial-temporal variation in environmental compliance costs to identify effects, using a time-varying county-level index that is based on multiple years of establishment-level data from the Pollution Abatement Costs and Expenditures survey and the Annual Survey of Manufactures. Results suggest that, for the average manufacturing plant, there is no statistically significant effect on productivity of being in a county with higher environmental compliance costs. For the average plant, the main effect of environmental regulation may not be in the spatial and temporal dimensions.

Keywords: environmental regulation, productivity, U.S. manufacturing

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1. Introduction

This paper examines the impact of environmental regulation on the productivity of manufacturing plants in the United States. At the facility level, environmental regulation may affect productivity in at least two ways. First, compliance may require the diversion of inputs—capital, labor, materials, etc.—toward the production of (unmeasured) environmental quality. Second, regulation may necessitate changes in the production process, reducing efficiency (as traditionally defined). At a more aggregate level, environmental regulation may affect productivity by exempting existing plants from the most stringent standards. This can discourage entry of new, more efficient producers.

A number of studies have attempted to measure the effects of environmental regulation on aggregate productivity (i.e., at the national, sectoral, or industry level), particularly on the productivity slowdown of the 1970s (see Jaffe et al. 1995 for a review). Gray (1987) examines productivity growth in 450 manufacturing industries (4-digit SIC industries) between 1958 and 1978 and finds that, for the average manufacturing industry, about 12% of the 1970s productivity decline is attributable to environmental regulation—an estimate that does not achieve statistical significance. Barbera and McConnell (1986) focus on four particularly polluting (and regulated) manufacturing sectors (2- to 3-digit SIC industries) between 1960 and 1980 and find that pollution abatement requirements reduced both average labor productivity growth and capital productivity growth in the chemical and primary metal sectors, but not in paper. It further appears that environmental regulation is responsible for a large portion of the productivity slowdown after 1973. In another study, analyzing these same manufacturing sectors, the same authors find that environmental regulations reduced the productivity growth rate between 9% and 55%, accounting for 10% to 30% of the 1970s productivity decline (Barbera and McConnell
A more limited number of studies have examined facility-level productivity, as I do here. For example, Gollop and Roberts (1983) find that electric utilities subject to greater restrictions on their sulfur dioxide emissions had lower productivity growth rates. Gray and Shadbegian (1995) find that $1 of additional expenditure on pollution abatement reduced facility output by more than $1 – upwards of $3.28 for plants in the steel industry. In a more recent study, these same authors find that pollution abatement expenditure reduced productivity by 9.3% in “integrated” paper mills (i.e., ones that also produce pulp) and only 0.9% in non-integrated mills (Gray and Shadbegian 2003). In their study of integrated paper mills, Boyd and McClelland (1999) find a nearly identical reduction in productivity due to environmental constraints. Meanwhile, Shadbegian and Gray (2005) find few statistically significant effects (positive or negative) of pollution abatement expenditures (capital, labor, or materials) on the productivity of paper mills, petroleum refineries, and steel plants.

In contrast to these other studies that also use facility-level data, I examine effects on plants in all manufacturing industries, not just those in “dirty” industries, such as electric utilities, steel, petroleum refining, and paper. Here, I employ establishment-level data from three Censuses of Manufactures (CMs) to estimate 3-factor Cobb-Douglas production functions. While these previous studies use a facility-specific measure of regulatory stringency, I employ spatial-temporal variation in environmental compliance costs, in the form of a newly developed county-level index that reveals extra-normal environmental compliance costs, generally due to above- or below-normal environmental regulation and enforcement faced by manufacturers at the county level. This index is based on establishment-level data from multiple years of the Pollution Abatement Costs and Expenditures (PACE) survey and the Annual Survey of Manufactures
Results suggest that, for the average manufacturing plant, there is no statistically significant effect on productivity of being in a county with higher environmental compliance costs. The paper proceeds as follows. Section 2 discusses the time-varying county-level index of environmental compliance costs, and Section 3 discusses the data and empirical specification used in the productivity analyses. Section 4 presents results, and Section 5 offers some concluding remarks.

2. A Time-varying County-level Index of Environmental Compliance Costs

In this paper, I use spatial and temporal variation in environmental compliance costs to examine the effects of environmental regulation on productivity. This variation is measured by a county-level index of the sort introduced and discussed in Becker (2011). In particular, I employ the establishment-level data from the PACE surveys of 1980-1982, 1984-1986, and 1988-1994, which includes data on total pollution abatement operating costs (PAOC).¹ PAOC includes salaries & wages, parts & materials, fuel & electricity, capital depreciation, contract work, equipment leasing, and other operating costs associated with a plant’s abatement of its air and water pollution as well as its solid waste in that calendar year. To this I merge data on these establishments from the ASM or CM, including employment, value of shipments, four-digit SIC industry, county, and plant vintage (as measured by an establishment’s first appearance in the Census of Manufactures). After restricting the sample to cases that had linkable PACE and ASM/CM records in a given year, and after eliminating inactive establishments, plants in Alaska

¹ These survey data, as well as those from the Annual Survey of Manufactures and the Census of Manufactures, are confidential, collected and protected under Title 13 of the U.S. Code. Restricted access to these data can be arranged through the U.S. Census Bureau’s Center for Economic Studies. See http://www.census.gov/ces/ for details.
and Hawaii, and those with missing or incomplete data on critical items, there are 188,326 establishment-years of observations for estimating the county-level index.

The basis for my index is an establishment’s PAOC intensity — that is, its pollution abatement operating costs per unit of economic activity – namely, its value of shipments (VS).

My county-level index of environmental compliance costs is the vector of \( \phi_m \) parameters from the following regression equation:

\[
\ln\left(\frac{PAOC_{i,j,mt}}{VS_{i,j,mt}}\right) = \alpha + \beta \cdot \ln\left(\text{median}\left(\frac{PAOC_{j,mt}}{VS_{j,mt}}\right)\right) + \sum_{k \in K} \gamma_k \cdot V_k + \sum_{m \in M \cap P} \left(\phi_m \cdot C_m\right) + \varepsilon_i
\]

where observation \( i \) is an establishment in industry \( n' \), year \( t' \), size quartile \( q' \), and \( j \) also indexes establishments in the sample. \( K \) is the set of possible first CM appearances \{1963, 1967, 1972, 1977, 1982, 1987, 1992, 1997\}, \( k \) indexes those possibilities, and \( V_k \) is one in a series of plant vintage indicators, less one omitted possibility (1963). \( M \) is the set of U.S. counties, \( P \) is the set of time periods used in estimation, \( m \) indexes those county-periods, and \( C_m \) is one in a series of county-period indicator variables, less one omitted category. In contrast to Becker (2011), where I estimate a county index for the entire time period, here I assume and employ three separate time periods: 1980-84, 1985-89, and 1990-94. As will become clearer in the next section, this creates index values that align with each of the three CMs used in the productivity estimation (namely, 1982, 1987, and 1992). Finally, the parameter \( \alpha \) is the estimated constant, representing the omitted group (establishments in Washington DC in the period 1980-84 that were in existence as early as the 1963 CM), and \( \varepsilon_i \) is an error term.

Since the value of the dependent variable is bounded from below for a significant number of observations, the parameters of equation (1) are estimated via a Tobit specification.\(^2\)

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\(^2\) Establishments are asked to report their expenditures in *thousands* of dollars. Therefore, with rounding, a response of zero reflects expenditures of less than $500. The `censreg` (censored normal regression) command in Stata is a
Furthermore, $\beta$ is restricted to be equal to one, forcing the notion that an establishment is *expected* to have PAOC intensity equivalent to the estimate for its industry-year-size class — in this case, the median. Deviations from this are, in part, explained by differences between counties, as measured by the estimated $\phi_m$ parameters — the county-level index. This index reveals any extra-normal environmental compliance costs, due to above- or below-normal environmental regulation and enforcement faced by manufacturers at the county level. The index also includes potential geographic differences in prices related to pollution abatement, such as the salaries of environmental workers, cost of low-sulfur coal, price of electricity, fees for solid waste hauling and disposal, and so forth. In the remainder of the paper, I will notate the index value of county $c$ in period $p$ as $ECCINDEX_{cp}$.

Several previous studies also use PAOC intensity to measure geographic differences in the stringency of environmental regulations. Like this paper’s index, some of these previous indexes also take care to control for industry (e.g., Bartik 1988; Levinson 1996, 2001; Gray 1997), recognizing that some industries are inherently pollution intensive. Levinson (1996) goes further still, by also controlling for establishment size and a dichotomous measure of establishment age. The major innovation of $ECCINDEX_{cp}$ over the prior indexes that also use PACE data is that it is county-level. Using this index, Becker (2011) demonstrates that there can be significant spatial variation in environmental compliance costs within a state. At least 34% of counties (containing 21% of U.S. manufacturing employment) are found to have environmental compliance costs that are statistically different from their states’. Becker (2011) lists and maps some of these counties.

That $ECCINDEX$ is county-level prevents natural comparisons with other regulatory...
indexes. Nevertheless, the index is positively and significantly correlated with a number of state-level indexes produced by environmental organizations, including a +0.48 correlation with the state ranking based on the League of Conservation Voters (LCV) “scorecard” on each member of Congress.\(^4\) The states with highest index values tend to be in the northeast.\(^5\) The states with the lowest index values tend to be Great Plains states.

\(ECCINDEX\) is also found to be positively correlated with certain county characteristics, including population (and population density), manufacturing employment, per capita income, and dichotomous indicators of non-attainment of the Clean Air Act’s national ambient air quality standards (NAAQS) for each the six “criteria” air pollutants. Since these county characteristics are also significantly correlated with each other, a simple OLS regression is used to examine their independent impacts. Results suggest that, all else being equal, county population has a negative effect on \(ECCINDEX\), manufacturing employment has a positive effect, NAAQS non-attainment has a positive effect, and (mostly in specifications with state fixed effects) county per capita income has a positive effect.\(^6\) It is worth noting that \(ECCINDEX\)’s correlation with the county NAAQS non-attainment statuses, while positive, is relatively small (+0.12). This is perhaps not unexpected since the index here captures expenditures on the abatement of air pollutants beside the six criteria pollutants, as well as the abatement of water pollution and solid

\(^4\) Here, I create a state-level index by taking a weighted average of the county-level indexes in the state, where the weight is the county’s share of the state’s manufacturing employment. The Spearman rank correlation between this state-level index (based on \(ECCINDEX\)) and the states’ ranking according to the LCV’s National Environmental Scorecard for years 1977-1994 (as constructed by Levinson 2001) is +0.4783. The \(ECCINDEX\)-based state-level index is also significantly correlated with the state-level FREE index (+0.29), the Levinson 1996 index (+0.28), and the Hall-Kerr Green Index (+0.27), as republished in Levinson (2001).

\(^5\) Again using the state-level index that is a weighted average of the county-level indexes in the state, the top ten is dominated by New England and Mid-Atlantic states. Interestingly, the top 20 contains all 17 of the contiguous states east of (and including) Illinois and Michigan, and north of (and including) Kentucky, West Virginia, and Maryland.

\(^6\) Results depend somewhat on the exact specification – e.g., which of two formulations for \(ECCINDEX\) is employed, whether or not observations are weighted by a county’s manufacturing employment, whether or not state effects are include, and so forth. Here I report the most frequently occurring results.
Analyses on county-level indexes of the separate components of ECCINDEX suggest that the spatial variation in environmental compliance costs is greatest for air and water, and that ECCINDEX is most closely correlated with the index for solid waste. In terms of cost categories, ECCINDEX is found to be most closely correlated with the cost indexes for materials/supplies/fuel/electricity and for salaries/wages, both of which vary less than other components of costs.

To provide a sense of the cost differentials that are implied by ECCINDEX, I consider the difference between the 75th and 25th percentiles of its value. On average, all else being equal, plants located in the county with the higher index value would have pollution abatement operating costs that are about 198% higher. According to data published by the U.S. Census Bureau, in 1992, there were approximately 370,900 manufacturing establishments, and they had approximately $17.5 billion in PAOC, for an average of about $47,000 per manufacturing establishment. A 198% difference is roughly $93,000, which, for the average manufacturing plant in 1992, was about 1.15% of its annual shipments (revenue) and 2.42% of its value added. Considering where manufacturing activity actually takes place, by weighting each county by its total manufacturing employment, all else equal, plants in the county at the 75th percentile would have pollution abatement operating costs that are about 65% higher than those for plants in the county at the 25th percentile — a difference of about $30,500 for the average manufacturing

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7 During the period 1980-1994, the share of PAOC devoted to air, water, and solid waste was 33%, 38%, and 29%, respectively. Becker (2004) has also shown that certain populations can impact the pollution abatement expenditure of local manufacturers, over and above any “formal” regulatory requirements arising from county NAAQS non-attainment and from other state and federal regulation.

8 These analyses are complicated by the fact that the PACE survey altered the categorization of costs during this period, such that labor and depreciation are the only two categories with completely consistent definitions.

9 There is uncertainty surrounding this difference, since index values toward the extremes tend to be less precisely estimated (i.e., tend to have higher standard errors, are based on fewer underlying observations). The precision of the index values is considered later in the paper.

10 In actuality, the aggregate PAOC figure is for establishments with 20 or more employees, of which there were approximately 119,000 in 1992. Establishments with fewer than 20 employees tend to be in less-polluting industries and therefore have relatively small pollution abatement expenditure.
plant in 1992, or about 0.38% of its annual revenue and 0.79% of its value added. This of course hides significant industry heterogeneity. For example, the average pulp mill (SIC 2611) had roughly $6.5 million of PAOC in 1992 – or about 138 times more than the average manufacturing plant. Moreover, a 65% difference was about 3.5% of the annual revenue for the average plant in this industry and 7.4% of its value added.

3. Productivity Data and Empirical Specification

Data to estimate plant-level productivity come from the CMs of 1982, 1987, and 1992, which include data on establishment employment, value of output, capital assets, material usage, location, industry, age, ownership, and so forth. After eliminating establishments that exhibited signs of inactivity (i.e., had a zero value for one or more critical items), whose data were largely imputed, and/or that were located in counties with no index, I am left with nearly 568,000 plant-years of observations.

To examine the effect of environmental compliance costs on manufacturers’ productivity, I estimate some traditional Cobb-Douglas production functions. In particular, I estimate 3-factor Cobb-Douglas labor productivity regressions, one of which includes:

\[
\log(rVS_{it} / EMP_{it}) = \lambda_0 + \lambda_1 \cdot ECCINDEX_{ct} + \lambda_2 \cdot \log(COUNTYMFG_{ct}) + \lambda_3 \cdot \log(EMP_{it}) + \lambda_4 \cdot \log(CAPITAL_{it} / EMP_{it}) + \lambda_5 \cdot \log(rMAT_{it} / EMP_{it}) + \lambda_6 \cdot \log(NPWE_{it} / EMP_{it}) + \lambda_7 \cdot MULTI_{it} + \sum \lambda_a \cdot AGE_{ait} + \sum \lambda_c \cdot YEAR_{ct} + \sum \lambda_n \cdot SIC_{nit} + \sum \lambda_c \cdot COUNTY_{ci} + e_{it}
\]

(2)

where, for plant \(i\) at time \(t\) in county \(c\), \(rVS\) is output (the real value of shipments), \(EMP\) is the total number of employees, \(ECCINDEX\) is the time-varying county-level index of environmental compliance costs (as defined in the previous section), \(COUNTYMFG\) is time-varying county-level manufacturing employment, \(CAPITAL\) is the book value of capital assets, \(rMAT\) is the real
value of material inputs, \( NPWEMP \) is the number of non-production workers (and
\( NPWEMP/EMP \) measures the proportion of the workforce that was not engaged in production –
a commonly used measure of “skill” mix), \( MULTI \) is a dummy variable indicating a plant
belonged to a multi-establishment firm, \( AGE \) is a series of five categorical variables to designate
the plant’s age/vintage (less one omitted category), \( YEAR \) is a set of year dummies, \( SIC \) is a set
of dummy variables indicating the plant’s four-digit SIC industry, and \( COUNTY \) is a set of
dummy variables indicating the plant’s county. Industry-specific deflators, to create constant-
dollar values for both value of shipments (\( VS \)) and value of material inputs (\( MAT \)), come from
the NBER-CES Manufacturing Industry Database.\(^{11}\)

Note that equation (2) controls for time-invariant location effects. This can be important if
there are such fixed effects (observed or unobserved) that are correlated with both manufacturing
plant productivity and the variable of interest, \( ECCINDEX \). Indeed, \( ECCINDEX \) is found to have
a statistically significant (positive) correlation with county characteristics such as total
population, industrial concentration in manufacturing, and being in a metropolitan area, which
may have impacts on plant productivity. The equation also controls for time-varying county
manufacturing employment, \( COUNTYMFG \), which measures changing “economies of
agglomeration” as manufacturing activity increases or declines in a county. Such a measure also
proxies for any observable and unobservable characteristics of a county that vary over time,
contribute to productivity, and lead manufacturers to increase or decrease their activity there. In
other words, if some county characteristic changes, and if it has an effect on manufacturers’
productivity, it would also presumably affect the level of manufacturing activity in the county,
which \( COUNTYMFG \) measures.\(^{12}\)

\(^{11}\) The latest version of this database is available at http://www.nber.org/data/nbprod2005.html.
\(^{12}\) I have examined whether adding time-varying county-level population to specifications matters. It has no
An alternative to the above specification, which achieves similar goals, substitutes county fixed effects with plant fixed effects \((PLANT_i)\), as in:

\[
\log(rVS_{it} / EMP_{it}) = \lambda_0 + \lambda_1 \cdot ECCINDEX_{cP} + \lambda_2 \cdot \log(COUNTYMFG_{c}) + \lambda_3 \cdot \log(EMP_{it}) + \\
\lambda_4 \cdot \log(CAPITAL_{it} / EMP_{it}) + \lambda_5 \cdot \log(rMAT_{it} / EMP_{it}) + \\
\lambda_6 \cdot \log(NPWEEMP_{it} / EMP_{it}) + \lambda_7 \cdot MULTI_{it} + \sum \lambda_{it} \cdot AGE_{ait} + \\
\sum \lambda_9 \cdot YEAR_i + \sum \lambda_{10} \cdot PLANT_i + e_{it} \tag{3}
\]

In addition to removing location specific effects, this specification obviously also controls for any time-invariant plant characteristics that play a role in productivity, as well as a degree of self-selection of plants into counties that may have higher or lower environmental regulation. Another difference in these two specifications is in the cases that contribute to the identification of \(\lambda_1\). In (3), only plants that appear in at least two CMs help identify \(\lambda_1\), while in (2), a plant contributes to the identification of \(\lambda_1\) as long as its county appears in at least two CMs. Since plants change industries relatively infrequently, industry fixed effects are excluded from equation (3). In the next section, I present results from both of these specifications, and variations thereof.

4. Results

Table 1 presents results from county fixed effect models, a la equation (2), and Table 2 presents results from plant fixed effects models, a la equation (3). Column (1) in each table contains results from the simplest labor productivity equations, without \(ECCINDEX\) or the supplemental plant characteristics, while column (2) adds our variable of interest, \(ECCINDEX\), and column (3) adds three plant characteristics commonly thought to have potential impacts on statistically significant effect in most instances, adds little-to-no explanatory power, and never changes the sign or statistical significance of the models’ other coefficients and has little-to-no impact on their magnitudes. Most importantly, the inclusion of county population does not alter the coefficient of interest \((\lambda_1)\) or its interpretation. In most cases, the magnitude of this coefficient and its standard error are identical (to 4 decimal places). In the few cases where the magnitude of this coefficient changes, it is only by +0.0001 or +0.0002, and with no material effect on interpretation since the coefficient is statistically insignificant with or without the inclusion of population. Given these findings, I choose not to include county population in any of this paper’s specifications.
productivity ($NPWEMP/EMP$, $MULTI$, and $AGE$). Finally, column (4) of each table contains results from the (full) models specified in equations (2) and (3), respectively, which include time-varying county-level manufacturing employment ($COUNTYMFG$).

In none of the specifications of Table 1 or Table 2 does $ECCINDEX$ have a statistically significant effect on productivity. Table 3 evaluates the robustness of these results, employing several alternate samples. Sample 2 includes plants, previously excluded, whose data were largely imputed. Sample 3 eliminates establishments in the top and bottom 1% of $ECCINDEX$, to assess whether extreme cases are influencing results. Neither of these samples changes the basic conclusion, though in the latter case, the point estimates do change a fair amount, but are nonetheless statistically insignificant. Endogeneity may be a concern in these analyses, since plants in the productivity regressions may also be in the sample used to estimate $ECCINDEX$. Sample 4 treats this by excluding all plants that entered the estimation of (contemporaneous) $ECCINDEX$. The point estimates are a bit higher but statistically insignificant. Sample 4 is rather unforgiving – eliminating 13.3% of the sample (relative to Sample 1), including many “important” plants, as well as ones located in counties with extensive manufacturing activity, where a single plant has little likelihood of dominating the estimated $ECCINDEX$. Sample 5 instead eliminates plants that entered the estimation of $ECCINDEX$, but only if the plant contributed at least 20% of the underlying observations in that county-period. Again, $ECCINDEX$ has no statistically significant effect on productivity. Meanwhile, the coefficients on the models’ other variables are as one might expect.\textsuperscript{14}

\textsuperscript{13} Cutoffs of 10% and 5% were also chosen, yielding the same essential conclusion.

\textsuperscript{14} A labor productivity equation in the form of $(Q/L)=A\cdot L^{\alpha}\cdot K^{\beta}\cdot M^{\gamma}$ is derived from a standard Cobb-Douglas production function of the form $Q=A\cdot L^{\alpha}\cdot K^{\beta}\cdot M^{\gamma}$. The coefficient on log($EMP$), therefore, is $\alpha+\beta+\gamma-1$. Therefore, column 4 of Table 1\textsuperscript{2} shows output elasticities on labor, capital, and materials of 0.385, 0.162, and 0.446, [0.459, 0.097, and 0.346], respectively, with statistically significant decreasing returns to scale in both instances. Meanwhile, the skill measure and multi-establishment status are both found to have statistically
These results suggest that the average manufacturing plant does not have lower productivity in counties with higher environmental compliance costs. One possible issue with these specifications is that the effect of ECCINDEX is identified only by changes within a county, for counties or plants that appear more than once. If much of the variation in ECCINDEX is cross-sectional (i.e., across counties, rather than over time), and if there is measurement error in ECCINDEX (and the estimation of equation (1) does yield a standard error on each index value), then controlling for county or plant fixed effects may leave relatively little “true” variation in ECCINDEX, which may bias its coefficient toward zero. Indeed, I find that of the 2,059 counties with an ECCINDEX for both the period 1980-84 and 1990-94, only 206 experienced a statistically meaningful change between those two periods.15,16 With this in mind, I present results from two further exercises.

First, I re-estimate the models of Tables 1 and 2, using only those plants in counties with statistically meaningful changes in their ECCINDEX.17 The results are presented in Tables 4 and 5, respectively. In the county fixed effect models (Table 4), ECCINDEX has a statistically significant (negative) effect on productivity, until county-level manufacturing employment is added to the specification in column 4. In the plant fixed effect models (Table 5), ECCINDEX

15 In particular, I test whether the 90% confidence interval of the difference in the index values excludes zero. The formula allows some overlap of the confidence intervals of the two individual index values (Schenker and Gentleman 2001).
16 No major manufacturing counties are among these 206, and collectively they contain less than 3% of U.S. manufacturing employment. An alternate specification of ECCINDEX yields a similar result. Namely, specification #6 in Becker (2011) uses: (i) plant employment (EMP) in the denominator of PAOC intensity (and expected PAOC intensity), instead of value of shipments (VS), and (ii) the weighted mean in computing expected PAOC intensity, instead of median. With this index, I find that 256 counties – containing 4% of U.S. manufacturing employment – experienced a statistically meaningful change between those two periods.
17 In particular, for each county, I perform pairwise tests between the index values in 1982 & 1987, 1987 & 1992, and 1982 & 1992. If there are no statistically meaningful differences between any of the three pairs, the county and all of its plants are dropped from the sample. If only one statistically meaningful difference is found (e.g., between 1982 & 1992), then only observations in the remaining year are dropped (in this example, 1987). If two statistically meaningfully differences are found (e.g., between 1982 & 1992 and 1987 & 1992), all years and observations are retained.
has a statistically significant (negative) effect in all specifications. To help interpret the \( \lambda_i \) coefficient in column 4, I compute the effect on labor productivity for the plant experiencing the average [and median] change in ECCINDEX, among those plants contributing to the identification of this coefficient in these two regressions. In the county fixed effect regression, the average [median] plant experienced an increase in ECCINDEX between its first and last year of appearance that translates into a decrease in labor productivity of -0.08% [-0.40%], which for the average [median] plant here reflects a decrease in output per worker of $88 [$280] in 1987 dollars. In the plant fixed effect regression, the average [median] plant experienced a decrease in labor productivity of -0.09% [-0.32%], which for the average [median] plant in that sample reflects a decrease in output per worker of $101 [$229] in 1987 dollars.20

Second, I estimate versions of equation (2) that employ 179 BEA economic area fixed effects (Johnson and Kort 2004) instead of county fixed effects. This allows for some cross-sectional variation in ECCINDEX while still controlling for local unobservables to a certain degree. Results appear in Table 6. We see that the effect of ECCINDEX is not statistically significant, though it is nearly so (p=0.118) in column (4). To help interpret this particular point estimate, I compute the effect on labor productivity of moving from the 25th percentile of ECCINDEX in this sample to the 75th percentile, holding all other variables constant. The effect

\[ \text{ECCINDEX in this sample to the 75th percentile, holding all other variables constant.} \]

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18 The endogeneity issue discussed above may be more of a concern here, since the counties in this sample appear to have less manufacturing activity than average and therefore a particular plant may be more likely to dominate the estimated ECCINDEX. Re-estimating the models of Table 4 and 5, using a sample that – like Sample 5 above – eliminates plants that entered the estimation of ECCINDEX but only if the plant contributed at least 20% of the underlying observations in that county-period (N=14,993), yields negative coefficients on ECCINDEX that are 50% to 75% the magnitude of those in Tables 4 and 5, and that do not quite achieve statistical significance.

19 I also estimate these regressions using the aforementioned alternative specification of ECCINDEX that uses EMP in the denominator of (expected) PAOC intensity, instead of VS, and uses weighted mean in computing expected PAOC intensity, instead of median. This ECCINDEX has no statistically significant effect in any of the regressions of Tables 4 or 5, or in the regressions of Tables 1, 2, and 6 for that matter.

20 Though unjustified, given the statistically insignificant results found elsewhere, extrapolating these particular results to the entire manufacturing sector, which had 17.7 million employees in 1987, yields estimates of lost output ranging from $1.6 to $5.0 billion in 1987 dollars, assuming $88 and $280 per worker, respectively. At this time, pollution abatement operating costs for the entire manufacturing sector was around $12 billion.
of such an increase in the index is a decrease in labor productivity of about -0.04%.

5. Conclusion

This paper has explored the impact of environmental regulation on the productivity of manufacturing plants in the United States. In contrast to previous studies that have also used establishment-level data, I examine effects on plants in all manufacturing industries, not just those in “dirty” industries. Further, I employ spatial and temporal variation in environmental compliance costs to identify effects.

The results here suggest that, for the average manufacturing plant, there is no statistically significant effect on productivity of being in a county with higher environmental compliance costs. In one instance of statistical significance (Table 5), the average [median] plant in the sample is found to have experienced a decrease in labor productivity of -0.09% [-0.32%] – a result that is not robust to concerns of endogeneity. As a point of comparison, the manufacturing sector as a whole expended about 0.43% to 0.60% of its value of shipments on pollution abatement operating costs during this period, according to published statistics. Applying published statistics, by industry and year, to the sample used in this paper, the average [median] plant expended about 0.27% [0.15%] of its value of shipments on PAOC. Using the establishment-level PACE data to compute median PAOC intensity within each industry-year-size class, as in equation (1), and applying those statistics to the sample used in this paper, the average [median] plant expended about 0.17% [0.03%] of its value of shipments on PAOC.21

21 Many industries have PAOC intensity many times these amounts. According to published statistics, in 1994, the industry that led the list was cellulosic manmade fibers, which expended 5.0% of its value of shipments on pollution abatement operating costs. Sixty-four four-digit SIC industries had PAOC intensity greater than 1.0%, and twenty-six had PAOC intensity greater than 2.0%, including pulp mills (4.1%) and other paper industries, various industrial organic chemicals industries (together, 2.6%), various industrial inorganic chemicals industries (together, 2.5%), various primary nonferrous metals industries (together, 2.4%), petroleum refining (2.2%), steel mills (2.2%), and so forth.
The results in this paper do not necessarily suggest that environmental regulation has little impact on productivity. Rather, it appears that whatever spatial and temporal variation exists (as embodied in this particular index) has little effect on productivity, at least for the average manufacturing plant. For plants in particularly polluting industries, spatial competition may still be a major issue (see Becker and Henderson 2000, Greenstone 2002, Becker 2005). For the average plant however, the main effect of environmental regulation may not be in the spatial and temporal dimensions. That is, the (negative) impact may be relatively uniform across space. The (non-)result here in this paper is also consistent with Gray (1987), which found no statistically significant effect of pollution abatement spending on the productivity of the average manufacturing industry, for the period leading up to that explored here in this study.

In future work, I hope to explore outcomes besides productivity. For example, with this index, one could begin to (re-)explore the effects of environmental regulation on industrial location, employment, investment (including foreign direct investment), industrial emissions, ambient pollution levels, and so forth, using U.S. counties as the laboratory, rather than – the more usual – states. This paper has shown that there may not be a sufficient number of observations in the PACE data to support the estimation of a time-varying county-level index. In particular, the precision of the resulting time-varying ECCINDEX simply is not great enough to discern many statistically meaningful changes over time in county-level environmental compliance costs, even if such changes were real. This is true even with the pooling of multiple years into a county-period index. This suggests that the index’s best use may be as a time-invariant index, as presented in Becker (2011).
References


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</table>

† The dependent variable is real value of shipments per employee. This variable, the three factors of production, and county-level manufacturing employment are in natural logs. Robust standard errors are reported, which allow for the potential correlation of within-plant observations (i.e., between repeated observations of the same plant). Statistical significance at the 10%, 5%, and 1% level are indicated by single, double, and triple asterisks, respectively.
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<td>-0.0004 (0.0007)</td>
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<td>+0.3463*** (0.0010)</td>
<td>+0.3462*** (0.0010)</td>
<td>+0.3462*** (0.0010)</td>
</tr>
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<td>+0.0175*** (0.0045)</td>
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<td>+0.0911*** (0.0012)</td>
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<td>+0.0233*** (0.0014)</td>
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<td>-0.0188*** (0.0022)</td>
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† The dependent variable is real value of shipments per employee. This variable, the three factors of production, and county-level manufacturing employment are in natural logs. Statistical significance at the 10%, 5%, and 1% level are indicated by single, double, and triple asterisks, respectively.
<table>
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<tr>
<td>2. Include plants whose data were largely imputed</td>
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<td>+0.0001</td>
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<tr>
<td>3. Exclude observations with most extreme values of ECCINDEX (top and bottom 1 percent)</td>
<td>+0.0023</td>
<td>-0.0018</td>
<td>556,397</td>
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<td>4. Exclude all plants that entered the estimation of contemporaneous ECCINDEX</td>
<td>+0.0003</td>
<td>+0.0003</td>
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<td>5. Exclude plants that entered the estimation of contemporaneous ECCINDEX, unless the plant contributed &lt;20% of observations</td>
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<td>-0.0003</td>
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</table>

† This table contains coefficients on county-level environmental compliance cost index (ECCINDEX) from empirical specifications identical to those in column (4) of Tables 1 and 2. Statistical significance at the 10%, 5%, and 1% level are indicated by single, double, and triple asterisks, respectively.
TABLE 4
Cobb-Douglas Labor Productivity Regressions with County Fixed Effects:
Sample Restricted to Counties with “Meaningful” Changes†

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<td>(0.0029)</td>
<td>(0.0033)</td>
<td>(0.0033)</td>
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<td>+0.1662***</td>
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<td>(0.0058)</td>
<td>(0.0057)</td>
<td>(0.0057)</td>
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<tr>
<td>Materials per employee</td>
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<td>(0.0240)</td>
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<td>(0.0089)</td>
</tr>
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† The dependent variable is real value of shipments per employee. This variable, the three factors of production, and county-level manufacturing employment are in natural logs. Robust standard errors are reported, which allow for the potential correlation of within-plant observations (i.e., between repeated observations of the same plant). Statistical significance at the 10%, 5%, and 1% level are indicated by single, double, and triple asterisks, respectively.
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<td>+0.3382***</td>
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<td>(0.0066)</td>
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</tbody>
</table>

† The dependent variable is real value of shipments per employee. This variable, the three factors of production, and county-level manufacturing employment are in natural logs. Statistical significance at the 10%, 5%, and 1% level are indicated by single, double, and triple asterisks, respectively.
# TABLE 6
Cobb-Douglas Labor Productivity Regressions with BEA Economic Area Fixed Effects†

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<td>Non-production workers per employee</td>
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<td>(0.0015)</td>
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</tr>
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<td>1987</td>
<td>+0.0574***</td>
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<td>+0.0575***</td>
<td>+0.0585***</td>
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<tr>
<td></td>
<td>(0.0012)</td>
<td>(0.0012)</td>
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<tr>
<td>1992</td>
<td>-0.0424***</td>
<td>-0.0424***</td>
<td>-0.0414***</td>
<td>-0.0384***</td>
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<td>(0.0013)</td>
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<tr>
<td>Plant age categories</td>
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</tr>
<tr>
<td>Four-digit SIC industry effects</td>
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<td>yes</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>BEA economic area effects</td>
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<tr>
<td>R-squared</td>
<td>0.7830</td>
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<td>0.7870</td>
<td>0.7875</td>
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<tr>
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<td>567,753</td>
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† The dependent variable is real value of shipments per employee. This variable, the three factors of production, and county-level manufacturing employment are in natural logs. Robust standard errors are reported, which allow for the potential correlation of within-plant observations (i.e., between repeated observations of the same plant). Statistical significance at the 10%, 5%, and 1% level are indicated by single, double, and triple asterisks, respectively.