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## The Effect of Environmental Regulation on Optimal Plant Size and Factor Shares

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CENTER FOR THE STUDY OF THE ECONOMY AND THE STATE  
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The Effect of Environmental Regulation  
On Optimal Plant Size and Factor Shares

by

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WORKING PAPER 025

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## INTRODUCTION

The regulation of environmental conditions by the federal government began in earnest in 1970. With the passage of the 1970 Clean Air Act, the federal government inaugurated a comprehensive program to improve air and then water quality by establishing minimum ambient standards, by promulgating new source performance standards and by limiting the deterioration of air quality in clean air areas. The principle justification for the federal government's role in the regulation of environmental conditions is to correct for interstate and regional externalities caused by the mobility of airborne emissions and water discharges.

The externality hypothesis has received widespread support by economists and others. This support may have been given prematurely since the effects of environmental regulation have yet to be comprehensively measured. While the stated goal of the legislation is the improvement of public health, experience with the governmental regulations suggests the stated goals and the actual effects are not always the same. A careful catalog of the actual effects of environmental regulation is an essential step if the underlying reasons for the legislation are to be understood.

There is reason to believe the externality hypothesis is incomplete and requires modification if some forms of environmental regulations are to be explained. Special interest groups have played an important and active role in shaping the legislation and the regulations. Testimony at Congressional hearings and votes cast on environmental bills reveal fundamental conflicts between developed and developing regions of the country, between urban areas and underdeveloped rural areas, between environmental and industry groups, and between low and high sulfur coal producers.<sup>1</sup> Less attention has been directed at the intra industry conflicts that are both a product and a cause of

environmental regulation. Environmental regulations can and are drawn to redistribute intra industry rents<sup>2</sup>. If the minimum optimal size of plant increases with compliance, then larger plants may benefit relative to smaller plants. On the other hand, smaller plants can benefit from regulations if larger plants are subject to more stringent regulation. It would be worth knowing whether environmental regulation has on balance benefitted or harmed small plants.<sup>3</sup> The twin objectives of this paper are to measure the effects of environmental regulation on the size distribution of plants and on the distribution of factor shares. Section I reviews the possible effects of environmental regulation on the costs of different size plants, the distribution of industry output by plant size and on the shares of output distributed to capital and labor. The methodology for testing for the effects of environmental regulation is presented in Section II. In Section III the economic characteristics of the twenty industries with highest per unit pollution abatement costs are compared with those of the twenty industries with the lowest per unit pollution abatement costs. Section IV focuses on a much larger sample of four digit industries and estimates the effect of environmental regulation on the number of plants in an industry, the mean size of plant and capital's share of output. In Section V a variant of the survivorship method is employed to determine if the size distribution of plants in the high pollution cost industries changed more under regulation than the size distribution of plants in the low pollution cost industries. The paper ends with a brief summary.

I. The Effect of Environmental Regulation on Plant Size and Factor Shares

Environmental regulation will change the size distribution of plants if compliance changes the optimal plant size or the range of optimal sizes.<sup>4</sup> Assume the long run industry supply curve is horizontal so no rents exist in long run equilibrium. If the long run average cost curve is flat over a range of output, small and large plants will coexist in the industry. Suppose there are some economies of scale in compliance and the minimum optimal plant size is larger under regulation. Mandated cost increases will raise the market share of large plants as small plants withdraw from the industry or expand and become larger. Regulation has caused the average size of plant to increase. In the long run, no rents will be earned by the plants that remain in the industry. Those plants remaining in the industry would earn rents if the regulations also imposed still higher per unit compliance costs on new plants and if demand increased subsequently.

In some industries small plants (firms) are numerous, politically important and obtain exemptions or are subject to less stringent enforcement.<sup>5</sup> If small plants are treated less harshly, regulation will increase the market share of small plants as large plants leave the industry or shrink in size.<sup>6</sup> Once again, the remaining plants in the industry will earn no rents unless the regulations impose still higher per unit compliance costs on new plants and if demand increases.

When the long run average cost curve is flat over a range of outputs, a mandated cost increase that reduces the market share of small plants implies regulation has increased the minimum optimal size of plant. A fall in the market share of small plants is not, however, sufficient to infer economies of scale in compliance. For example, suppose there are external economies so the industry supply curve has a positive slope. For simplicity, assume there are

just two types of plants in an industry, small and larger plants. Let  $Q = D(P)$  be the market demand curve where  $P$  is market price.  $L(P, \alpha)$  is the supply curve of all large plants in the industry where  $\alpha$  is a parameter that is determined by the regulatory authorities and shifts the supply curve. More stringent regulations reduce the quantity supplied by large firms (by raising each firm's average and marginal cost) and higher prices raise the quantity supplied by large plants so  $L_\alpha < 0$  and  $L_P > 0$ .  $S(P, \alpha)$  is the supply curve of all small plants in the industry.<sup>6</sup> In equilibrium

$$(1) \quad D(P) - L(P, \alpha) - S(P, \alpha) = 0$$

An increase in regulatory stringency raises marginal costs and raises the equilibrium price because the quantity supplied by both large and small plants decreases.

$$(2) \quad \frac{dP}{d\alpha} = \frac{P[L_\alpha + S_\alpha]}{D[\eta - k_L \eta_L - k_S \eta_S]} > 0$$

where  $\eta$  is the price elasticity,  $k_L$  is the share of industry output supplied by large plants,  $\eta_L$  is the supply elasticity of large plants' output,  $k_S$  is the share of industry output supplied by small plants and  $\eta_S$  is the supply elasticity of small plants' output. The change in the market share of small plants' output due to more stringent regulation is

$$(3) \quad \frac{d(k_S)}{d\alpha} = \left( \frac{Dk_S k_L}{\eta - k_L \eta_L - k_S \eta_S} \right) \left[ (-\eta + \eta_S) \left( \frac{L_\alpha}{L} \right) + (\eta - \eta_L) \left( \frac{S_\alpha}{S} \right) \right]$$

Because  $\eta - k_L \eta_L - k_S \eta_S < 0$ , the small plants' market share will rise (fall) only if the expression in the square brackets is negative (positive) which requires

$$(4) \quad \left[ \frac{\eta - \eta_S}{\eta - \eta_L} \right] > \left( \frac{\frac{S}{\alpha}}{\frac{L}{\alpha}} \right)$$

$S_{\alpha}/S$  and  $L_{\alpha}/L$  represents the percentage shifts in the small (and large) plants supply curve due to more stringent regulation. If the small plants supply curve shifts by a larger percentage because of regulation, then the right side of (4) is greater than one and the small plants' share must decline as long as  $\eta_L \geq \eta_S$ .

Suppose there are no economies of scale in compliance and regulation causes per unit costs to rise by the same absolute amount for both small and large plants. The small plants' supply will decline by a larger percentage as long as small plants' share of the market is less than 50 percent. If  $\eta_L \geq \eta_S$ , small plants, share falls even though there are no economies of scale in compliance. Therefore, a fall in the market share of small plants does not imply economies of scale in compliance. This would be a valid inference only if one knows the industry supply curve is flat. Distinguishing between constant versus economies of scale in compliance is a difficult task without knowing the elasticities of supply of large and small plants.

The market share of small plants will change for reasons other than changes in regulatory stringency. Increases in the size of market will reduce the small plants' share if  $\eta_L \geq \eta_S$ .<sup>7</sup> On the other hand, stable market shares during a period of industry growth would indicate the supply

elasticities do not differ. The interpretation of  $\alpha$  need not be limited to changes in regulation. Suppose  $\alpha$  represents the price of energy. A rise in the price of energy raises the cost of production for both large and small plants in an industry. Suppose larger plants use energy more intensively and a rise in the price of energy shifts the supply curve of large plants by a larger percentage amount, then the market share of small plants will rise if  $\eta_L \leq \eta_S$ . A rise in the price of energy will increase the small plants' share of the market if the large plants' supply curve shifts proportionally more and if the supply elasticity of large plants does not exceed the supply elasticity of small plants. This is an important point to keep in mind since environmental regulation and the rise in the price of energy occurred over the same time interval.

There are several reasons why environmental regulation might have changed the distribution of factor shares between labor and capital. First, compliance with environmental regulations and technology forcing regulations can favor more capital intensive methods for reducing or treating emissions. Second, mandated compliance costs cause short run losses. Third, new source performance standards and the policy of prevention of significant deterioration imposes larger per unit cost increases on new or enlarged plants. The supply curves of new plants, small or large, shift up. Therefore, prices must rise by a larger amount before these new plants will be constructed and existing plants will receive higher rents than otherwise if market demand increases. The first and third effect represent moderate to long term effects of environmental regulation and would raise capital's share of industry output (value added). If compliance with environmental regulation has had a major effect on industry output, then capital's share of value added should have increased under environmental regulation particularly in the industries most affected by the regulations.



## II. Methodology For Measuring The Effects of Regulation

Environmental regulation has had a very uneven impact upon manufacturing industries. A small number of industries have incurred relatively high per unit compliance cost while many industries have been barely affected. For example, gross annual pollution abatement costs have averaged about nine percent of industry value added in the primary copper industry. Other four digit industries in the paper, chemical, stone-clay-glass, petroleum and primary metals industries have incurred smaller but still sizeable per unit compliance costs.

The uneven industrial impact of environmental regulation has been exploited in formulating the tests. By selecting and then grouping industries with very high or with very low per unit compliance costs, a "high cost" and a "low cost" portfolio of industries can be formed. The difference between the mean per unit compliance cost of the two groups of industries will be large by design so the effects of compliance should be detectable, providing they exist. Changes in the size distribution of plants in each industry are studied from 1958 to 1972, the pre-regulation period, and then from 1972 to 1977, the regulatory period. This methodology will detect any systematic shifts in the size distribution for industries in each group prior to regulation and any change during regulation. The low cost group of industries is the control group. If there is a pervasive economy wide trend toward large or smaller plants, this trend will be detected through changes in the size distribution of plants in the "low cost" group. Effects due to environmental regulation will be detected by observing larger changes in either direction during the regulatory period in the "high cost" group of industries than in the "low cost" group compared to past changes.

The regulatory period is defined from 1972 to 1977 because Census data for plants are used. Real energy prices also rose during this period and caused independent changes in the size distribution of plants and the number of plants. In some industries larger plants appear to be both more energy and capital intensive. Unfortunately, the only relevant data are from a special study and are limited to companies, not plants. Table 1 shows larger companies produce more BTU's per employee and incur higher total energy costs relative to shipments or to value added. Table 2 shows energy costs relative to shipments for companies with less than or more than 250 employees by two digit industry. In 12 of the 20 industries, large companies have higher energy intensities. More importantly, the larger companies have appreciably high relative energy costs in the paper, chemicals, and primary metals industries. The petroleum industry, is another high pollution cost industry but larger companies have lower relative energy costs. In these three industries a rise in energy prices will induce a shift toward more labor intensive methods if capital and energy are complements. Since labor intensive methods of production are often employed in smaller plants, a rise in energy prices could lower the minimum optimal size of plant. One should not be surprised and indeed might expect the market share of small plants to rise because of the rise in energy prices. If the actual market share of small plants increases from 1972 to 1977, the regulatory period, it will be unclear whether the rise is due to less stringent environmental regulation of small plants or to the energy price rise. If the market share of small plants declines during the regulatory period, one can infer the decline was caused by compliance with environmental or other regulations since the rise in energy prices would have increased the small plants' share.

Table 1

ENERGY INTENSITY BY SIZE OF COMPANY, 1975

Size of Company Employment	British Therman Units Total Employees (Millions of BTU's)	Total Cost of Purchased <u>Electricity and Fuels</u> Value of Shipments	Total Cost of Purchased <u>Electricity and Fuels</u> Value of Shipments- Cost of Materials
	(1)	(2)	(3)
1 - 19	224	.015	.034
20 - 99	202	.014	.029
100 - 249	288	.016	.036
250 - 499	328	.017	.038
500 or more	917	.024	.059
TOTAL	696	.022	.052

Source: Unpublished tables supplied by Bureau of Census

Table 2

COST OF PURCHASED FUELS AND ELECTRIC ENERGY  
AS A PERCENTAGE OF VALUE OF SHIPMENTS, 1975

<u>Industry</u>	<u>Companies With Less Than 250 Employees</u>	<u>Companies With More Than 250 Employees</u>	<u>(1) (2)</u>
20. Food	1.07	1.08	.99
21. Tobacco	.86	.60	1.43
22. Textile	2.32	2.85	.81
23. Apparel	.61	.68	.90
24. Lumber	2.32	2.09	1.11
25. Furniture	.97	1.22	.80
26. Paper	1.94	5.65	.34
27. Printing	.92	.76	1.21
28. Chemicals	1.76	5.08	.35
29. Petroleum	2.71	2.45	1.11
30. Rubber	2.07	2.40	.86
31. Leather	1.13	.96	1.18
32. Stone, Clay & Glass	3.60	8.12	.44
33. Primary Metals	3.17	5.82	.54
34. Fabricated Metals	1.42	1.41	1.01
35. Machinery	1.05	.95	1.11
36. Electrical Machinery	1.01	1.12	.90
37. Transportation	.93	.88	1.06
38. Instruments	.75	.92	.82
39. Miscellaneous	.93	1.10	.85
	<hr/>	<hr/>	<hr/>
Manufacturing	1.47	2.40	.61

Source: Unpublished tables supplied by Bureau of Census

Because environmental regulations are often applied to industrial processes and are applicable to plants, the appropriate unit of analysis appears to be the plant and not the firm. For this reason, this study uses the plant size distribution data as reported in the Census of Manufacturers. Gross pollution abatement operating costs have been collected and published by the Bureau of Census at the four digit industry level since 1973. About 19,000 manufacturing plants are surveyed annually. Respondents report payments to governments for public sewage use, solid waste collection and disposal, depreciation, labor, equipment leasing and materials and supplies. Gross pollution abatement costs are reported by type of pollution but not by size of plant at the four digit industry level. Because pollution cost data are not available by size of plant, it is only possible to rank the four digit industries by relative pollution abatement operating costs. The weighted average of gross pollution abatement operating cost per thousand dollars of value added (hereafter PACVA) for 1974, 1975 and 1977 was calculated for each eligible four digit industry.<sup>8</sup> PACVA measures the importance of pollution abatement costs relative to industry value added.<sup>9,10</sup>

### III. High and Low Pollution Cost Industries

The twenty industries with the highest and the twenty industries with the lowest values of PACVA are listed in Table 3 along with the value of PACVA.<sup>11</sup> The high pollution abatement cost industries are often found in the paper, chemical, petroleum, stone, clay and glass and primary metals industries while the low pollution abatement cost industries are often in the printing and machinery industries. The average value of PACVA for the high cost group is more than seventy times the average value of PACVA for the low group. The average value of PACVA in a sample of 319 four digit industries

Table 3

INDUSTRIES WITH THE TWENTY HIGHEST AND TWENTY LOWEST RATIOS  
OF POLLUTION ABATEMENT COSTS TO VALUE ADDED (PACVA)

<u>Twenty Highest</u>		<u>Twenty Lowest</u>	
<u>Industry</u>	<u>SIC</u>	<u>Industry</u>	<u>SIC</u>
1. Primary Copper	3331	1. Lace Goods	2292
2. Primary Zinc	3333	2. Periodicals	2721
3. Petroleum Refining	2911	3. Miscellaneous Publishing	2741
4. Electrometalurgical Products	3313	4. Typesetting	2791
5. Inorganic Pigment	2816	5. Book Publishing	2731
6. Primary Lead	3332	6. Special Dies, Tools & Jigs	3544
7. Pulp Mills	2611	7. Industrial Patterns	3565
8. Lime	3274	8. Newspapers	2711
9. Phosphatic Fertilizers	2874	9. Jewelry, Precious Metals	3911
10. Explosives	2892	10. Hoists, Cranes and Monorails	3536
11. Carbon Black	2895	11. Industrial Furnaces & Ovens	3567
12. Hydraulic Cement	3241	12. Set-up Paperboard Boxes	2652
13. Paper Board Mills	2631	13. Blankbooks & Looseleaf Binders	2782
14. Cyclic Crudes & Intermediates	2865	14. Jewelers' Materials & Lapidary	3915
15. Paper Mills excl. Building Paper	2621	15. Women's Handbags & Purses	3171
16. Minerals, Ground or Treated	3295	16. Signs & Advertising Displays	3993
17. Primary Aluminum	3334	17. Luggage	3161
18. Blast Furnaces & Steel Mills	3312	18. Conveyers & Conveying Equipment	3535
19. Mineral Wool	3296	19. Fabricated Structural Metal	3441
20. Wet Corn Milling	2046	20. Fabricated Pipe & Fittings	3498

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SUMMARY

	<u>High Cost</u>	<u>Low Cost</u>	<u>319 Manufacturing Industries</u>
1a) Average	4.67	.06	.74
b) Standard Deviation	1.49	.03	1.19

Source: U.S. Bureau of Census, Census of Manufacturing, various issues  
U.S. Bureau of Census, Annual Survey, various issues  
U.S. Bureau of Census, Pollution Abatement Costs & Expenditures, Industrial Reports, MA-200, 1974-1978

was .74%. This large sample includes all four digit industries after miscellaneous industries and industries with abnormally large changes in the number of plants between 1972 and 1977 due to Census reclassification of plants among industries were excluded.

Table 4 presents some descriptive statistics for the two groups and for the sample of 319 manufacturing industries. The high cost group has fewer but larger establishments (rows 1 and 3). These industries are more capital intensive (row 4), as measured by 1 minus the ratio of payrolls to value added, more fuel intensive (row 6), as measured by the ratio of fuels purchased to value added, and use electricity more intensively (row 5), as measured by the ratio of purchased electricity to value added. To summarize, industries with relatively high pollution abatement costs have fewer and larger plants and are high energy and capital users compared to the representative manufacturing industry. Table 4 shows the two groups of twenty industries experienced some unusual changes between 1972 and 1977. In the high cost group the number of plants declined (row 7) even though mean industry value added grew more rapidly (row 9) (84.6%) than in manufacturing (59.8%) and in the low cost group (64.1%). Consequently, the mean percent change in plant size (row 8) - value added per plant - rose more in the high cost group (105.9) than in manufacturing (51.3) or in the low cost group (75.1). These are puzzling changes. Normally, one would expect industries with larger percentage increases in value added to experience correspondingly larger percentage increases in the number of plants. Other factors must have been operating to reduce the mean number of plants per industry in the high cost group of industries.

Table 4

MEANS AND STANDARD DEVIATIONS FOR HIGH,  
LOW AND ALL INDUSTRIES  
(STANDARD DEVIATIONS IN BRACKETS)

Variable	Twenty Industries With Highest Values of PACVA	All Industries (N=319)	Twenty Industries With Lowest Values of PACVA
1. Number of Establishments 1977	154 (153)	754 (1,635)	1,934 (2,342)
2. Industry Value Added, 1977 (\$ Millions)	2,542 (4,406)	1,396 (2,060)	1,536 (2,174)
3. Value Added per Establishment 1977 (\$ Millions)	16.67 (15.28)	4.95 (8.80)	.93 (.57)
4. Total Payroll to Value Added, 1977	.338 (.117)	.427 (.106)	.478 (.103)
5. Purchased Electricity to Value Added, 1977	.102 (.111)	.029 (.043)	.010 (.004)
6. Fuels Consumed to Value Added, 1977	.176 (.129)	.036 (.062)	.007 (.011)
7. Percent Change in Number of Establishments, 1972-1977	-5.9 (23.8)	7.5 (19.9)	13.6 (19.6)
8. Percent Change in Value Added Per Establishment, 1972-1977	105.9 (75.1)	51.3 (41.6)	44.7 (16.7)
9. Percent Change in Industry Value Added, 1972-1977	84.6 (57.2)	59.8 (42.6)	64.1 (32.6)
10. Percent Change in Payroll to Value Added, 1972-1977	-12.2 (18.1)	-6.9 (11.2)	-9.4 (7.9)



There is another interesting difference between the high and low cost groups. The high cost group of industries experienced a larger mean percentage drop in the ratio of payrolls to value added (row 10) (-12.2) than did the low cost group (-9.4) or the large sample of industries (-6.9). So, capital's share of value added rose more in the high pollution abatement cost industries during the regulatory period.

#### IV. Changes in the Number of Plants, Value Added Per Plant and Labor Share of Value Added

These unusual changes may have been caused by environmental regulation, occupational and safety regulation (another important regulatory program), the energy price rise or other factors. The full sample of 319 industries is used to identify the causes of the change from 1972 to 1977 in the a) log of the number of plants; b) log of plant value added; and c) log of payrolls to value added (factor share). The independent variables measure the effects of the change in energy costs, change in the absolute size of market and compliance with two important regulatory programs, environmental regulation and occupational safety. The definitions of the dependent and independent variables are presented in Table 5.

Regression results in Table 6 indicate environmental regulation did cause a fall in labor's share of value added and the number of plants in an industry as well as an increase in average plant size. In contrast, the effects of the OSHA variables are weaker and less often significant.<sup>12</sup> Environmental regulation appears to have had larger and more systematic effects on the size structure of plants and the distribution of factor shares than the regulation of occupational safety.<sup>13</sup> The effects of a rise in relative energy costs are opposite to the effects of compliance with

Table 5

DEFINITION OF VARIABLES

Dependent Variables

- 1)  $DLN_7$  = Difference between the log of the number of plants in 1977 and 1972.
- 2)  $DLS_7$  = Difference between the log of value added per establishment in 1977 and 1972.
- 3)  $DLL_7$  = Difference between the log of wages payments divided by value added in 1977 and 1972. (This variable is also used as an independent variable in some regressions.)

Independent Variables

A. Change in Absolute Size of Market:

- 1)  $DLVA_7$  = Difference between the log of industry value added in 1977 and 1972.

B. Government Regulation:

1) Environmental Regulation:

- a)  $LPACVA_7$  = Log of gross pollution abatement annual costs to industry value added (selected years from 1973 to 1978).

2) Occupational Health and Safety Regulation:

- a)  $LPENVA_7$  = Log of average annual penalties for all violations per dollar of industry value added, 1973-1977.
- b)  $LPENPT_7$  = Log of average annual penalties for all violations per plant, 1973-1977.
- c)  $LAVIN_7$  = Log of average annual number of inspections per plant, 1973-1977.

C. Change in Relative Energy Costs:

- 1)  $DLEN_7$  = Difference between the log of cost of purchased electricity and fuels consumed divided by industry value added in 1977 and 1972.

Table 6

CHANGES IN LABORS' SHARE OF VALUE ADDED,  
NUMBER OF PLANTS AND PLANT SIZE (N = 319)  
(1972-1977)

Independent Variable	Dependent Variable					
	Change in Labor Share DLL <sub>7</sub>		Change in Establishments DLN <sub>7</sub>		Change in Plant Size DLS <sub>7</sub>	
1. Constant	-.362 (9.8)	-.349 (9.6)	-.372 (5.4)	-.297 (4.3)	.888 (10.8)	.509 (6.2)
2. Change in Market Size; DLVA <sub>7</sub>			.336 (8.3)	.425 (9.3)		
3. Environmental Regulation; LPACVA <sub>7</sub>	-.023 (4.2)	-.026 (4.8)	-.045 (5.0)	-.038 (4.2)	.068 (5.6)	.040 (3.6)
4. OSHA Regulation; LPENVA <sub>7</sub>	.0081 (2.9)	.0060 (2.4)	.0015 (.3)	.0016 (.4)	.0032 (.6)	.0098 (1.9)
5. OSHA Regulation; LAVIN <sub>7</sub>	-.011 (1.8)					
6. Change in Energy Costs; DLEN <sub>7</sub>	.283 (11.4)	.279 (11.3)	.053 (1.2)	-.028 (.6)	-.305 (5.4)	-.011 (.2)
7. Change in Labor Share; DLL <sub>7</sub>				.412 (3.9)		-1.086 (9.6)
8. R <sup>2</sup> (adjusted)	.287	.282	.224	.256	.123	.320
9. Standard Deviation of Residuals	.101	.101	.170	.166	.231	.203

environmental regulation. Increases in relative energy costs, raise labor's share of value added, probably reduced mean plant size and did not have a pronounced effect on the number of plants in the industry.<sup>14</sup>

Are the effects attributed to environmental regulation really are due to the effects of other left out variables? If the effects attributed to PACVA are due to other left out variables, then similar results should be obtained if the regressions are repeated for a period before regulation. If the effects are really due to compliance with environmental regulation, then the coefficient of the regulatory variable will not be significantly different from zero in the regression for the pre regulatory period or will differ between the pre regulatory period and the regulatory period. For 1972-1977, let the regression equation for any one of the dependent variables be

$$(5) \quad Y_7 = \alpha_0 + \alpha_1 X_7 + \alpha_3 LPACVA_7 + \eta_7$$

where  $X_7$  is a vector of independent variables other than  $LPACVA_7$  and  $\eta_7$  is a disturbance term. The same regression will be run for the 1963-1967, the pre regulatory period, where the dependent and all the independent variables except the regulatory variables are measured from 1963 to 1967. The regulatory variables take on the values measured during the nineteen seventies.

$$(6) \quad Y_6 = \beta_0 + \beta_1 X_6 + \beta_3 LPACVA_7 + u_6$$

The first difference of this equation is

$$(7) \quad Y_7 - Y_6 = Y_0 + \alpha_1 X_7 - \beta_1 X_6 + (\alpha_3 - \beta_3) \text{LPACVA}_7 + \eta_7 - u_6$$

or

$$(8) \quad Y_7 - Y_6 = Y_0 + \gamma_1 (X_7 - X_6) + (\alpha_3 - \beta_3) \text{LPACVA}_7 + \eta_7 - u_6$$

where  $\gamma_1 = \alpha_1 - \beta_1$  assuming  $\alpha_1 = \beta_1$ .

If  $\text{LPACVA}_7$  is capturing the effects of regulation, then  $\beta_3$  will be close to zero and the coefficient of  $\text{LPACVA}_7$  in the difference regression (equation 8) will equal the coefficient of  $\text{LPACVA}_7$  in the level regression (equation 5). If  $\text{LPACVA}_7$  is measuring the effects of other left out variables, then  $\alpha_3$  and  $\beta_3$  measure the effects of the left out variables and  $\alpha_3$  will equal  $\beta_3$ . The estimated coefficient of  $\text{LPACVA}_7$  (in equation 8) will not be significantly different from zero.

A sample of 220 industries with uniform industry definitions between 1962 and 1977 was selected for study. Regression results for the difference equation (equation 8) are presented in Table 7. The regression coefficients for  $\text{LPACVA}_7$  are all statistically significant and different from zero. These results indicate  $\text{LPACVA}_7$  had a different effect on each dependent variable during the regulatory period than during the pre regulatory period. The estimated coefficients suggest  $\text{LPACVA}_7$  had an insignificant effect on  $\text{DLL}_6$  or on  $\text{DLN}_6$  and a small but significant effect on  $\text{DLS}_6$ .

Table 7

DIFFERENCE REGRESSIONS  
(N = 220)

Independent Variable	Dependable Variables					
	DLL <sub>7</sub> -DLL <sub>6</sub>		DLN <sub>7</sub> -DLN <sub>6</sub>		DLS <sub>7</sub> -DLS <sub>6</sub>	
1. Constant	-.315 (6.8)	-.336 (7.1)	-.228 (2.2)	-.333 (3.9)	.855 (8.4)	.593 (5.7)
2. DLVA <sub>7</sub> -DLVA <sub>6</sub>			.236 (4.3)	.251 (3.9)		
3. Environmental Regulation; LPACVA <sub>7</sub>	-.025 (3.4)	-.026 (3.6)	-.051 (4.1)	-.059 (5.0)	.108 (7.2)	.087 (6.0)
4. OSHA Regulation LPENVA <sub>7</sub>		.0078 (1.8)		-.009 (1.5)		
5. OSHA Regulation LPENPT <sub>7</sub>			-.029 (2.4)		.008 (.9)	.012 (1.6)
6. DLEN <sub>7</sub> -DLEN <sub>6</sub>	.268 (9.2)	.274 (9.4)	.028 (.6)	.017 (.3)	-.259 (4.3)	-.054 (.8)
7. DLL <sub>7</sub> -DLL <sub>6</sub>				.060 (.5)		-.763 (5.9)
8. R <sup>2</sup> (adjusted)	.278	.286	.173	.157	.230	.335
9. Standard Deviation of Residuals	.132	.131	.194	.196	.267	.248

The OSHA regulatory variables perform somewhat better in the difference regressions but the coefficient estimates at times are at the borderline of significance. The other major surprise is the insignificant effect of  $DLL_7 - DLL_6$  on  $DLN_7 - DLN_6$ .

The results of the difference regressions reinforce the conclusions reached earlier. Compliance with environmental regulation has raised capital's share of output, reduced the number of establishments per industry and raised the average plant size. The results suggest that the environmental regulation program is not a benign and insignificant one but has reduced the number of plants and raised plant size and raised capital's share of output.

#### V. Changes in the Size Distribution of Establishments

The twenty industries in the high cost and low cost groups and with consistent industry definitions from 1958 to 1977 were studied more closely. The purpose of this smaller scale investigation was to determine if larger changes in the size distribution were experienced during the regulatory period in the high cost industries than in the low cost industries.

The Census employment size distribution for plants for each of the 40 industries was tabulated for each Census year from 1958 to 1977. A useful way of summarizing the changes in these distributions during the pre regulatory and regulatory periods is to compute the percentage change in the coefficient of variation (standard deviation divided by the mean) from 1958 to 1972 and from 1972 to 1977. In each relevant Census year, the ratio of the standard deviation of plant size to the mean plant employment size was calculated for each industry. The percentage change in this ratio was computed for each industry from 1958 to 1972 and from 1972 to 1977. Then, a grand mean of these percentage changes was calculated for each group and for each period and is

shown in Table 8. The mean value of the coefficients of variation decreased in the high group during the regulatory period after increasing during the 1958-1972 period. The low cost group experienced the opposite change. To test for significant differences between the two groups during the pre regulatory and regulatory periods, the percent change in the coefficient of variation from 1958 (1972) to 1972 (1977) for the  $i$ th industry ( $CCV_{it}$ ) was regressed on two dummy variables  $R_{it}$  is a dummy variable equal to one if the industry is a high pollution abatement cost industry and the period is 1972-1977.  $T_{it}$  equals one during the regulatory period and zero otherwise. The coefficient  $R_{it}$  measures the difference between the mean percent change between the high and the low cost groups during the regulatory period. The coefficient of  $T_{it}$  measures any general effect that raised or lowered the percent change in the coefficients of variations of all industries during the regulatory period. The regression equation has the form

$$(9) \quad CCV_{it} = \alpha_0 + \alpha_1 D_{it} + \alpha_2 T_{it} + \eta_{it} \quad \begin{array}{l} i = 1, \dots, 40; \\ t = 1958-1972 \text{ or} \\ \quad 1972-1977 \end{array}$$

Regression results are presented in Table 9. There is considerable randomness in  $CCV_{it}$  so the estimated coefficients are sometimes lacking in precision. Still, the percent change in the coefficient of variation in the high cost industries decreased during the regulatory period. The coefficient of the time dummy for 1972-1977 is insignificant so there was no general reduction in the coefficient of variation in both the high and low cost industries between 1972 and 1977. In column 3 dummy industry variables for selected industries with systematic larger increases in the coefficient of variation during both periods are introduced without causing a major change in results. The results



Table 8

MEAN PERCENTAGE CHANGE IN THE COEFFICIENT  
OF VARIATION FOR HIGH AND LOW GROUPS<sup>a</sup>

Period	Type of Pollution Cost Industry	
	High Group	Low Group
1958 - 1972	4.77 (22.8)	-2.69 (20.5)
1972 - 1977	-7.68 (20.5)	2.73 (12.78)

<sup>a</sup> Standard deviation of the percentage change in coefficient of variation in brackets.

Table 9

EFFECTS OF COMPLIANCE ON THE  
COEFFICIENT OF VARIATION  
(N = 80)

Independent Variable	EST	EST	EST
1. Constant	1.604 (.6)	1.039 (.3)	-.109 (.1)
2. Dummy-High Cost Pollution Industry	-9.28 (1.8)	-10.41 (1.7)	-12.71 (2.6)
3. Time Dummy		1.69 (.3)	
4. Industry Dummy Variables			
a) Phosphatic Fertilizer			21.74 (1.6)
b) Explosives			25.19 (1.9)
c) Primary Zinc			21.94 (1.7)
d) Blast Furnaces			33.88 (2.6)
5. $R^2$ (adjusted)	.030	.098	.142
6. Standard Deviation of Residuals	19.47	19.58	18.30

of these tests suggest the variance of the size distribution of plants in the high pollution cost industries decreased and the mean plant size increased during the regulatory period. These changes were caused primarily by the elimination of small plants. Environmental regulation has had more damaging effects on small plants.

A variant of the survivorship method has been used to isolate the effects of environmental regulation on different parts of the size distribution of plants.<sup>15</sup> For each industry the size distribution was divided into three size classes: small, medium and large. The upper boundary of the smallest size class was determined by including the lowest quartile of plants in the industry in 1958.<sup>16</sup> Similarly, the lower bound of the largest size class was determined by including the largest quartile of plants in 1958. The middle 50 percent of plants was assigned to the medium size class. The employment size class boundaries in each industry were found by interpolation and are presented in Appendix A. In 1958, the base year, each industry begins with 25 percent of plants in the small size class, 50 percent in the medium size class and 25 percent in the large size class. The class boundaries naturally differ from industry to industry but remain stationary at their 1958 limits in subsequent years. Table 10 shows the mean share of plants in each class from 1958 to 1977 for the high cost and low cost groups. For industries in the high cost group the mean share of plants in the small size class rose from 25 percent in 1958 to 30.2 percent by 1972. The mean of the annual growth rates from 1958 to 1972 in market share of plants in the small class was .81 percent per year for the high cost industries.<sup>17</sup> Much of this increase came from the share of plants in the medium size class. The growth in the share of small plants during the pre regulatory period in the high cost industries was not matched by the small plants in the low cost

Table 10

CHANGES IN THE SIZE DISTRIBUTION IN PLANTS  
1958-1977 <sup>a</sup>

	Twenty Industries With Highest Values of Relative Pollution Costs			Twenty Industries With Lowest Values of Relative Pollution Costs		
	Plant Size			Plant Size		
	Small	Medium	Large	Small	Medium	Large
I. Market Share of Plants <sup>b</sup>						
1958	25%	50%	25%	25%	50%	25%
1963	27.5 (6.0)	47.6 (5.0)	25.1 (4.3)	27.1 (6.6)	47.8 (4.8)	25.1 (3.9)
1967	29.5 (8.7)	45.3 (5.9)	25.2 (9.2)	26.6 (5.7)	45.1 (4.6)	28.3 (5.3)
1972	30.2 (11.9)	42.8 (7.6)	26.9 (7.7)	25.5 (6.4)	47.0 (4.6)	27.5 (5.6)
1977	25.0 (12.9)	45.4 (9.1)	29.7 (10.1)	27.4 (6.7)	46.1 (4.9)	26.6 (5.2)
II. Mean of the Annual Percent Change in Market Share						
1958-1972	.81% (3.1)	-1.00% (1.3)	.12% (2.7)	.02% (1.6)	-.46% (.7)	.55% (1.6)
1972-1977	-3.51 (11.1)	1.22 (4.7)	1.32 (7.2)	1.43 (3.1)	-.30 (1.5)	-.55 (2.5)
III. Number of Industries In Each Size Class With Decreases in Market Share						
1958-1972	7	16	8	11	15	7
1972-1977	12	10	6	6	9	13

<sup>a</sup>Standard deviation in brackets

<sup>b</sup>Market shares may not add to 100 because of rounding

industries. The mean share in these industries barely changed from 1958 to 1972. The mean of the annual growth rate was .02 percent per year. It is significant that small plants were entering industries that were to become high pollution cost industries. This significance is highlighted by the events that unfolded during the regulatory period. The increase in market share of plants in the small size class was not only terminated by environmental regulation but reversed. By 1977 the mean share of plants in the small class had dropped back to 25 percent, the initial market share in 1958. Did the small plants do as badly in the low cost industries? In the low cost industries the mean market share of plants in the small class rose from 25.5 percent in 1972 to 27.4 percent in 1977 or by 1.43 percent per year. This average increase was caused by factors other than environmental regulation. These other causes, e.g., the increase in the price of energy, changes in technology, etc., appear to have reduced the optimal size of plant in the low cost industries during the 1972-1977 period even as small plants were exiting from the high cost industries. Panel III shows the number of industries where the market share declined for each size class. The market share of plants in the small class dropped from 1958 to 1972 in 7 of 20 industries in the high cost group and in 11 of the 20 industries in the low cost group. Under regulation the pattern reverses. The market share in the small class falls in 12 of the high cost industries and in only 6 of the low cost industries. The mean market share of plants in the medium and large size classes increases under regulation in the high cost industries. In review, this evidence indicates environmental regulation is responsible for the decline in the market share of plants in the small class and the corresponding increases in the medium and large classes.

The effect of environmental regulation on the average annual growth rate of the market share of plants can be estimated for both small and large plants.<sup>18</sup> For each of these two classes, the following equation was estimated by ordinary least squares.

$$(10) \quad g_{it} = \alpha_0 + \alpha_1 D_{it} + \alpha_2 T_{it} + \sum_{i=1}^{i=39} \beta_i I_i + \eta_{it} \quad \begin{array}{l} i = 1, \dots, 40; \\ t = 1958-1972 \text{ or from} \\ 1972-1977 \end{array}$$

where  $g_{it}$  = annual growth rate of market share of plants of the small (large) size class in the  $i$ th industry from 1958-1972 or from 1972-1977.  $D_{it}$  is a dummy variable equal to one if the industry is a high pollution cost industry during the regulatory period and zero otherwise.  $T_{it}$  is equal to one during the regulatory period for all industries.  $I_i$  equals one if the observation is for the growth rate of the  $i$ th industry. The coefficient of  $D_{it}$  measures the difference between the mean annual growth rates of high and low pollution cost industries during the regulatory period. The coefficient  $T_{it}$  captures any general economy wide shift that may have raised or lowered the growth rate of all small (large) plants during the regulatory period. The coefficient of each industry dummy captures any industry effect that might have affected the growth rate of small (or large) plants over the entire period from 1958 to 1977. There are 80 growth rate observations in each regression, two for each of the 40 industries.

Regression results are presented in Table 11. In the high cost industries, the growth rate in the market share of small plants declined significantly while the market share of large plants increased during the

Table 11

DETERMINANTS OF THE ANNUAL GROWTH RATE OF MARKET SHARE  
(N = 80)

Variable	Small Plants			Large Plants		
	(1)	(2)	(3)	(4)	(5)	(6)
1. Constant	.740 (1.0)	.393 (.4)	.843 (1.0)	.040 (.1)	.335 (.5)	.483 (.8)
2. Pollution Abatement Dummy (D)	-4.245 (2.8)	-4.940 (2.6)	-4.040 (2.4)	1.280 (1.2)	1.869 (1.5)	2.165 (1.9)
3. Time Dummy (T)		1.042 (.6)	.592 (.4)		-.884 (.8)	-1.032 (1.1)
4. Industry Dummy Variables						
a) Lime			-17.989 (4.7)			8.446 (3.3)
b) Cyclic Crudes						-8.504 (3.3)
c) Phosphatic Fertilizers						-5.864 (2.3)
R <sup>2</sup> (adjusted)	.077	.070	.220	.006	.001	.2481
Standard Deviation of Residuals	5.97	6.00	5.31	4.07	4.08	3.54

regulatory period.<sup>19</sup> Because of the large variability in industry results, the precision of some of the coefficient estimates is low. The pollution abatement dummy and the time dummy tend to be correlated, so it is difficult to disentangle the effect of pollution abatement from the effect of the period on the growth rate. Generally, the coefficients of the time variable are not significant and erratic in size. A few of the industry coefficients proved to be statistically significant. The more important determinant of whether the market share of small plants declined from 1972 to 1977 was whether the small plants were members of a high pollution abatement cost industry.

How large an effect has environmental regulation had on the market share of the number of plants? The coefficients in columns 1 and 2 (or 4 and 5) of Table 1 can be used to predict the annual growth rate in market share of small (or large) plants in the high cost industries in the absence of environmental regulation. The predicted growth rate in the market share of small plants is .74 percent per year (column 1) or 1.435 percent per year (column 2) in the absence of environmental regulation.<sup>20</sup> Therefore, the predicted mean market share of small plants would have increased to 31.3 percent or 32.4 percent in 1977 from 30.2 in 1972.<sup>21</sup> The difference between the predicted and actual shares by size class is shown in panel 3 of Table 12. Small plants have lost share while large plants have gained share because of the effects of environmental regulation. Table 12 indicates the trend toward smaller plant size that appeared from 1958 to 1972 would have continued through 1977. Compliance with environmental regulation appears to be the principle reason for the trend reversal in the high cost industries.



Table 12

ACTUAL AND PREDICTED MARKET SHARES IN THE  
ABSENCE OF ENVIRONMENTAL REGULATION  
(Number of Establishments Method)

	Size of Plant		
	Small	Medium	Large
1. Actual Mean Market Share in High Pollution Cost Industries			
a) 1958	25.0%	50.0%	25.0%
b) 1972	30.2	42.8	26.9
c) 1977	25.0	45.4	29.7
2. Predicted Mean Market Share in 1977			
a) Using Coefficients in Columns 1 and 4, Table 11	31.3	41.7	27.0
b) Using Coefficients in Columns 2 and 5, Table 11	32.4	41.1	26.2
3. Difference Between Actual and Predicted Market Share, 1977 <sup>a</sup>			
a) Using Coefficients in Columns 1 and 4, Table 11	-6.3 (21)	3.7 (9)	2.7 (10)
b) Using Coefficients in Columns 2 and 5, Table 11	-7.4 (25)	4.0 (9)	3.5 (12)

<sup>a</sup> Number in brackets represents the absolute value of the difference in share divided by 1972 share.

### Conclusions

The results of the paper suggest that environmental regulation has had larger effects on business than regulations to protect worker health and safety. Environmental regulation has not only reduced the number of plants in affected manufacturing industries but has placed the greater burdens on small than on large plants. Besides these intra industry redistributions of market shares, environmental regulation raised capital's share of total output. An intriguing and unanswered question is whether the rise in capital's share is not only caused by an increase in capital intensity or might also be caused by a rise in the rate of return earned on capital by those plants remaining in the high pollution abatement cost industries.

Much of this paper has been directed at identifying the effects of environmental regulation on the number and size structure of plants. A compelling reason to focus on the plant is that plant not company emissions and discharges are regulated. Because there is a positive correlation between plant size and company size, there is reason to believe that the effect of environmental regulation on the market share of small plants provides some information about the likely effect of environmental regulation on the market share of small companies. Still, a companion study of the effect of environmental regulation on the size distribution of companies would be a useful addition. If larger companies are more effective in negotiating with the regulators, then plant compliance costs for any given size plant will be lower for a large than for a small company. With this reservation in mind there remains a temptation to speculate from effects to causes. Because the effects of environmental regulations have fallen disproportionately on small plants, one can conclude that the regulations have been uniformly applied to both small and large plants and small plant exemptions have been the exception

rather than the rule. Something equivalent to uniform enforcement appears to have been a more reasonable description. The owners of small plants have not been among the beneficiaries of environmental regulation. The disproportionate burden placed on small plants may have been an unforeseen and unintended effect of regulation. If the effects were unforeseen, they can and will be easily modified and the small plants' market share will have increased after 1977. If no competing groups have really gained from this supposed regulatory oversight, then one might ask why Congress and/or the Environmental Protection Agency took no important actions between 1970 and 1977 in response to complaints by organizations representing small business. A more plausible explanation is that effective opposition by environmental groups and by other firms prevented special treatment for small plants and firms. If this latter interpretation is closer to the truth, one can expect a continuation of past policy as long as the political capital of environmental groups and larger business firms remains intact.

It would be mistaken to suggest the sole reason for environmental regulation is the protection of large companies just as it would be mistaken to suggest the sole reason for environmental regulation is the protection of public health. First, this study has not shown a rise in the rate of return earned by the remaining firms in the affected industries.<sup>22</sup> Even if this finding had been shown, the regulations should be the product of a coalition of self interest groups and not one group, e.g., environmental groups, regional interests, industry groups, etc.<sup>23</sup> Within the business community the degree of opposition to or support for environmental regulations will differ. The results of this paper suggest the strongest opposition should come from the small business community.

FOOTNOTES

1. Navarro (1980) suggests the 1977 Clean Air Amendments represented a victory for the eastern-industrial-coal producers-environmental coalition and reversed the loss suffered by eastern groups with the passage of the 1970 Clean Air Act. Ackerman and Hassler (1981) have also described how the SO<sub>2</sub> standard resulted in the forced use of scrubbers and high sulfur coal. Pashigian (1982) has examined the regional and urban-rural conflict over the policy of preventing significant deterioration (PSD) and suggests PSD policy was designed to allow environmental improvement in northern cities without causing a large loss of factors to rural areas and less developed regions with cleaner than required air.
2. As mentioned above, the conflict between western low sulfur coal producers and eastern high sulfur coal producers is often reflected in environmental legislation and regulations.
3. An interesting study of the effect of compliance costs on plant costs is in Leone and Jackson (1981). The authors examined the differential effect on plant costs because of compliance in the tissue paper segment of the pulp and paper industry. Economic impact statements sometimes include predictions of the effects of a proposed standard on the costs of selected idealized plants. These statements have limited objectives and only examine the effect of the single standard. A comprehensive study of the combined effect of all standards on plant costs has never been attempted. A small number of studies have examined the effects of different regulations on large and small plants or firms. Kafogles (1978) suggests there are economies of scale in compliance but small firms benefit because of less stringent enforcement of regulations against small firms. Newman and Nelson (1982) argue the cost of operations rose more for small than for large mines because of enforcement of Coal Mine Health and Safety Act of 1969 and suggest the Act reduced competition from small mines. The entry of small airlines and truckers with deregulation of airlines and trucking suggests that small firms suffered from entry restrictions because of government regulation.
4. For a recent theoretical analysis of effects of different forms of emission regulations and of new source performance standards on the shareholders of a firm, total employment and prices, see Dewees (1983).
5. The regulatory agency will allocate resources towards investigating larger plants since there is a lumpy cost associated with each investigation.
6. This analysis is in the same spirit though it differs in important respects from the analysis by Landes (1980) who examined the effect of hour restrictions for female workers and a study by Marvel (1977) who examined the effect of child labor restrictions on small water-powered mills and on large urban mills using steam engines. In the Landes paper the regulation of hours shifts a segment of the supply function of hours supplied by women. In Marvel's paper regulation shifts the supply curve of the small water powered mills. Environmental regulation shifts the supply curves of both small and large plants. This type of regulation could reduce the rents of both types of suppliers while under the Landes and Marvel analyses the rents of the unaffected group must necessarily increase.

7. If  $\beta$  is a parameter in the demand curve, then

$$\frac{d(k_s)}{d\beta} = \frac{SL}{P} \left[ \eta_s - \eta_L \right] \frac{dP}{d\beta}$$

where

$$\frac{dP}{d\beta} = \frac{-D_\beta}{D_P - S_P - L_P} > 0$$

8. Miscellaneous industries were excluded as well as a few industries without information.
9. Pollution abatement operating costs as a fraction of industry shipments was also calculated and was found to be highly correlated with pollution abatement costs divided by value added.
10. The fraction of PACVA due to the federal regulatory program is unknown. If only a small fraction of PACVA is due to the federal program or if there are serious measurement errors in PACVA, then PACVA will not be an important or significant determinant of the size distribution of plants or of the distribution of factor shares.
11. Each of the industries must also have had consistent industry definitions from 1958 to 1977 to be included. The reason for this requirement will be clarified.
12. The insignificant and erratic effects attributed to OSHA may be due to defective proxy measures for compliance costs caused by OSHA. The absence of compliance cost data motivated the use of data on penalties imposed and resources devoted to inspections. The link between inspection probabilities and expected penalties and compliance costs incurred is not a simple one. So, the limitations of the proxy measures used in the paper may be responsible for the insignificant results attributed to OSHA. However, enforcement of OSHA has yielded modest penalties per plant. From 1973 to 1977 the average penalty assessed per manufacturing plant was \$38 and inspection hours spent per manufacturing plant was five hours per year. Other students of the OSHA program have reported similar findings, e.g., see Viscusi (1979).
13. Similar results were obtained when substitute measures for the enforcement of OSHA were used. Among the substitutes employed were serious violations per plant, total inspection hours per plant, and serious violations per plant.
14. A rise in relative energy costs raises product prices and reduces the size of market and the number of plants. In addition, a rise in relative energy costs could reduce the optimal plant size and thereby increase the number of plants. The net effect of a rise in relative energy costs is therefore ambiguous and this may explain why  $DLEN_7$  does not have a significant effect on  $DLN_7$ .
15. See Stigler (1958).

16. The sensitivity of the results was checked by defining class boundaries so that 15 percent of industry value added was supplied by plants in both the small and in the large size class. This value added method produced substantially different class boundaries. The qualitative effects of environmental regulation on the size distribution of plants were found to be similar to those described below. The value added share of plants in the large size increased while the value market share of plants in the small and medium size classes decreased.
17.  $g_{ijt}$  is the annual growth rate in market share in the  $i$ th industry,  $j$ th size class during pre or regulatory period and is determined by

$$S_{ij72} = (1 + g_{ijt})^{14} S_{ij58}$$

$$S_{ij77} = (1 + g_{ijt})^5 S_{ij72}$$

where  $S_{ij}$  is the share of the  $j$ th size class in the  $i$ th industry.

18. Once the market shares in the three size classes in 1958 and 1972 are known as well as growth rates between 1958 and 1972 for any two of the three classes, the growth rate of the third class can be inferred. The regression is limited to explaining the growth rates in the small and large classes. It is assumed the residuals in the small plant equations are independent of the residual in the large plant equation.
19. Not surprisingly, the dummy variables explain only a small fraction of the variance in the average annual growth rates in market shares.
20. The growth rate estimate of .74 appears suspect since the rise in the price of energy would have raised the small plants' growth rate from 1972 to 1977 compared to the growth rate during the 1958-1972 interval.
21. The predicted market share of the medium size plants equals 100 less the sum of the predicted shares of the small and large plants.
22. For a study which suggests companies gained from the cotton dust standard, see Maloney and McCormick (1982).
23. See Peltzman (1976).

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APPENDIX A

SIZE CLASS LIMITS OF SMALL AND LARGE PLANTS

Industry	High Pollution Cost Industries	
	Upper Boundary of Smallest Size Class	Lower Boundary of Largest Size Class
1. Primary Copper	167	699
2. Primary Zinc	212	715
3. Petroleum Refining	15	287
4. Electrometalurgical Products	81	365
5. Inorganic Pigments	8	95
6. Primary Lead	133	382
7. Pulp Mills	29	394
8. Lime	5	72
9. Phosphatic Fertilizer	16	61
10. Explosives	19	250
11. Carbon Black	34	143
12. Hydraulic Cement	131	339
13. Paper Board Mills	71	250
14. Cyclic Crude	15	137
15. Paper Mills	66	484
16. Minerals, Ground or Treated	38	174
17. Primary Aluminum	5	23
18. Blast Furnaces & Steel Mills	500	1255
19. Mineral Wool	146	2124
20. Wet Corn Milling	7	90
mean	85	417
s.d.	116	497



APPENDIX A (Continued)

Industry	Low Pollution Industries	
	Upper Boundary of Smallest Size Class	Lower Boundary of Largest Size Class
1. Lace Goods	2	14
2. Periodicals	6	45
3. Miscellaneous Publishing	2	32
4. Typesetting	2	11
5. Book Publishing	2	10
6. Special Dies, Tools and Jigs	2	17
7. Industrial Patterns	2	23
8. Newspapers	3	15
9. Jewelry, Precious Metals	2	8
10. Hoists, Cranes and Monorials	2	6
11. Industrial Furnaces and Ovens	2	11
12. Set-up Paperboard Boxes	17	100
13. Blankbooks and Looseleaf Binders	15	51
14. Jewelers; Materials and Lapidary	3	75
15. Women's Handbags and Purses	2	6
16. Signs and Advertising Displays	4	43
17. Luggage	3	36
18. Conveyors	6	42
19. Fabricated Structural Metal	7	54
20. Fabricated Pipes and Fittings	4	35
mean	4	32
s.d.	4	25