Environmental Regulations and Manufacturing Plant Exit: A Preliminary Analysis

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July 2013

This work is in fulfillment of EP-W-11-003 WA 1-23 (Task 4) and WA 2-23 (Task 4). Although the research described in this document has been funded by the U.S. Environmental Protection Agency (EPA), it has not been subject to the Agency's review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.

We thank the EPA National Center for Environmental Economics working group for helpful comments, Jim Davis at the Boston RDC for his continued help; Wang Jin and Shital Sharma for excellent research assistance; and Diane Ferguson for editorial assistance. The opinions and conclusions expressed are those of the authors and not the U.S. Census Bureau. All papers using Census data are screened to ensure that they do not disclose confidential information.

1 Introduction

Studies of the impact of environmental regulation on the output or employment levels of manufacturing plants have generally relied on a balanced panel that includes only facilities continuing to produce over the entire period. This is a preliminary analysis of the impacts of pollution abatement operating costs (PAOC) on plant exit probability and the associated changes in industry-wide employment in 10 manufacturing industries. It complements an updated analysis of the effects of PAOC on employment at continuing plants, which is summarized in a separate technical paper (see Belova, Gray, Linn, and Morgenstern, 2013; hereafter, BGLM). We describe the empirical strategy to estimate the effect of environmental expenditure on plant exit; the construction of the panel we used to estimate the exit regression models; and the results we obtained.

2 Empirical Strategy

Exit is a dynamic decision that depends on a plant's expectations of future changes in profitability as well as its current level of profitability. Our model builds on work by Olley and Pakes (1996), which specifies the plant's exit probability as a function of its efficiency (or productivity), age, and capital stock. We added the costs associated with environmental regulation as an explanatory variable.

Unlike factor prices and market structure, which vary little across plants within an industry, PAOC can vary quite a lot across plants. Because of this variation, PAOC can affect exit independently of the plant's age, capital stock, or efficiency, which motivates our inclusion of this variable. Environmental regulation could affect exit decisions through either the costs of current regulatory requirements or the expectations of future regulatory requirements. Consider a plant operating in period t. All else equal, the plant is less likely to continue operating into the next time period if it expects its future PAOC to be high, either because they are already high or because they will rise in the future.

We used two variables to proxy for the current and future regulatory requirements. For the current requirements, we used the ratio of the plant's PAOC to its production costs in period t. For the future requirements, we used the median increase in this PAOC ratio, calculated between the current and future period for all other plants in the industry that continue operating into the future period (in our data the future was the next Economic Census, five years later). We would expect both PAOC variables to have a positive effect on exit, although there are circumstances under which a negative relationship might be observed, at least for the current PAOC ratio. PAOC might be endogenous to the exit decision. For example, firms owning multiple plants may concentrate their PAOC on plants expected to continue operating. For example, Deily and Gray (1991) found evidence that firms allow plants on the verge of exit to slip into non-compliance. There might also be a negative relationship between a plant's current PAOC level and future changes in its PAOC, with some plants having adjusted to new regulatory requirements already, while others must increase their spending in the future. However, these concerns apply to the plant-level PAOC variable and not the industry-level variable, which motivated our inclusion of the latter.

A further concern is that a failure to control for unobserved profitability shocks could cause a spurious correlation between PAOC and exit if profitability and PAOC happen to be correlated. A positive profitability shock, combined with an increase in regulatory stringency, could cause a plant to increase its PAOC. The shock would also decrease the probability of exit, resulting in a negative correlation between PAOC and exit. As we discuss below, we added several variables to control for expected productivity.

Because our primary interest was in determining whether PAOC expenditure affects exit, we estimated the effect of expenditure on exit using a simple probit model:

$$P(EX_{it} = 1) = \Phi\left\{\left(\beta_0 \left(\frac{RC_{it}}{PC_{it}}\right) + \beta_1 E\left[\mathrm{d}\left(\frac{RC_t}{PC_t}\right)\right] + \boldsymbol{X}_{it}\boldsymbol{\delta}\right)\right\} \quad (1)$$

The dependent variable is a dummy equal to one if the plant exits between the current and subsequent Census year. The first two variables on the right-hand-side capture the effect of PAOC on exit. The first variable (denoted RC_{it}/PC_{it}) is the ratio of PAOC to production costs. The second PAOC variable (denoted $E[\mathrm{d}(RC_t/PC_t)]$) is the median increase, between the current period and five years later, among continuing plants in the industry for the ratio of PAOC to production costs.

The vector $\boldsymbol{X}_{it}$ includes a number of other variables that may affect exit. These include the plant's period t real capital stock and investment spending (in logs), a dummy to identify plants built after 1963, and second-degree polynomial expansion terms of these variables and the two PAOC expenditure variables (unfortunately, it is not possible to construct a precise age variable for all plants in the sample). The polynomials are included to allow for nonlinear effects of the variables on exit. The specification also includes output and input prices, capital's cost share, and annual industry growth. The industry growth variable was included only among the second degree polynomial expansion terms. The Olley and Pakes (1996) exit model includes only capital stock, age, and investment (which proxies for current and expected profitability), but we include other variables to control for industry or plant-level shocks (we cannot simply control for such shocks by adding year fixed effects because they would be collinear with the industry PAOC variable).

We estimated equation (1) separately for each industry. We then used the estimated coefficients to simulate the effect on exit probability of PAOC, which we expressed using either the plant's current PAOC or the industry's future growth in PAOC. Because the model includes second-degree terms involving the PAOC variables, the impacts are non-linear, and we considered the effects of both small and large changes in PAOC.

3 Data

The estimation sample for each industry consisted of all plants that appeared in any of the five Economic Census years from 1977 to 1997 (the time period for which we had relatively complete PACE survey data). Because the Economic Census includes all active plants in the particular year, we set the dependent variable, exit, equal to one if the plant did not appear in the following Census. We confirmed the quality of the exit variable by comparing it with flags in the Longitudinal Business Database that identified why the plant was not included in the subsequent Census (Jarmin and Miranda 2002), and by checking that the plant did not appear in any subsequent Census year.

Most of the explanatory variables we used in the analysis (real capital stock and investments, output and input prices, and capital's cost share) have already been described in some detail in BGLM. The exit analysis also includes a measure of plant age, which is a dummy for plants that began operating after 1963 (i.e., the dummy variable equals one for all plants that are not included in the 1963 Census of Manufactures). BGLM also provided summary statistics for the sample of continuing plants used in that analysis. Because of the substantial degree of overlap between the continuing plants used in BGLM and the set of plants used in the exit analysis, we have not presented summary statistics for the explanatory variables in the exit analysis. Table 1 provides information on the sample size for each industry, along with summary statistics for exit rates and median PAOC growth.

The first PAOC variable in equation (1) is the same as that used in the cost function estimation, measuring the plant's own abatement costs. For the second PAOC variable, we calculated the PAOC-to-production cost ratio (RC/PC) value for each plant in each Census year, then calculated the plant's growth in that ratio between Census years for plants with data in both years.[1] Finally, we calculated the median of these plant-level growth rates across all the other plants in the industry, excluding this particular plant, which we interpreted as the expected growth in PAOC over the next five years.

The limited years of PAOC data required some adjustment to the PAOC growth rate calculations. Because there was no PACE survey in 1987, we estimated PAOC in 1987 as the average of 1986 and 1988. The 1972-to-1977 growth rate used the growth rate measured from 1974 to 1977 and multiplied by 5/3; the 1992-to-1997 growth rate used the growth rate measured from 1992 to 1994 multiplied by 5/2; and the 1997-to-2002 growth rate used the growth rate measured from 1994 to 2005 multiplied by 5/11. We imputed the plant's own PAOC in 1997 using its own 1994 PAOC value. Note that we did not use the 1999 PACE data in the exit analysis. The 1999 survey reported much lower PAOC than in surrounding years (Becker and Shadbegian 2005). This discrepancy made it difficult to estimate growth rates using the 1999 survey.

4 Results

Table 2 presents the coefficient estimates for each industry for the basic model, including the full second-degree polynomial estimation. Because the coefficients in the nonlinear probit model were hard to interpret, we focused on simulations of the effects of PAOC on exit and employment.

Table 3 uses the estimated coefficients to predict the impact of a given change in PAOC abatement costs on the probability of plant exit in each industry. We considered three changes: a $1 million increase in PAOC spread proportionately across all plants in the industry, which matches the simulations for continuing plants in the BGLM but corresponds to a very small increase for the typical

[1] We measured growth as the change over the five years. For example, if the ratio of PACE to total costs increased from 1% to 2%, the increase would be measured as a 1% increase and not a 100% increase. To avoid reducing the sample size, we did not consider growth rates measured over longer periods of time.

observation; a 0.1% increase in the PAOC ratio for all plants in the sample; and a 1% increase in the PAOC ratio. Given that the industry average PAOC ratios ranged from 0.32% (for pipe-fitting) to 2.26% (for Portland cement), a 1% increase represents roughly a doubling of abatement costs for most of these industries. The first thing to note is that the effect of PAOC on exit probabilities is often negative. For a 0.1% increase in PAOC ratio, five of the current PAOC and only two of the future PAOC effects showed an increased probability of exit. There are only a few statistically significant effects of PAOC increases on exit probability. The impact of a 1% increase in current PAOC significantly reduced exit probability in the rolling and drawing industry (by 5.9%) and in the miscellaneous wood industry (by 8.7%). With the mean PAOC value in these industries being roughly 0.40%, such an increase represents a tripling of abatement costs and is therefore far out of sample. The impact of increase in expected future PAOC significantly decreases the probability of exit in the paper industry (by 0.2% for a 0.1% increase in PAOC and 1.7% for a 1% increase in PAOC) and increases this probability in the steel industry (by 0.4% for a 0.1% increase in PAOC).

We provided some support for the exit model results by simulating the effects of industry output growth on exit. Output growth is likely to be a strong predictor of future profitability, and we expected the variable to have a negative effect on exit. The last column of Table 3 shows much larger impacts of future industry output growth on exit probabilities. Many of the estimated effects are statistically significant, and a one standard deviation increase in industry output growth over the next five years is expected to reduce exit probabilities by 3.6% to 10.6%. This indicates that our model is capable of identifying factors that theory predicts should affect exit, and reinforces our conclusion that abatement costs, at least as captured by our measures of current and expected future PAOC, do not have a large effect on exit in these industries.

Figure 1 shows the non-linear nature of these exit effects for a range of increases in both current and expected future PAOC, with the horizontal axis measuring the increase in PAOC at the average plant and the vertical axis measuring the predicted change in exit probability. The first box on the left of the graph is the change caused by a $1 million aggregate PAOC increase, as displayed in columns 2–4 of Table 3; the other boxes show larger PAOC increases. Consistent with Table 3, none of the industries exhibit much of an increase in exit probability associated with PAOC, and several show decreases, especially for large increases in PAOC.

Table 4 translates the impacts on exit probability into impacts on expected industry employment, calculated by multiplying the change in each plant's exit probability by its employment level. Consistent with the earlier results in Table 3, most of these impacts on employment are positive, but all are relatively small. Except for the positive employment effect of expected future PAOC in the paper industry, none of these impacts are statistically significant. By contrast, the impacts of industry output growth on employment are generally larger, uniformly positive, and sometimes statistically significant. Figure 2 shows the non-linear impacts on employment for a range of increases in current and expected future PAOC, similar to Figure 1. Again we see very little impact of increased PAOC, this time on employment, unless the PAOC increases are very large.

5 Conclusions

For each of 10 industries we tested whether abatement spending reduces employment by increasing exit. None of our results support such a finding. Our models yielded relatively small impacts of abatement spending on exit, with most of those effects going in the opposite direction (reducing exit rather than increasing it), and nearly always statistically insignificant. When we translated these predicted exit effects into expected changes in industry employment, most industries showed employment increases rather than decreases, though none of the effects were statistically significant. This is not because our model is unable to predict exit decisions – we found that industry output growth has a large, statistically significant, and negative effect on exit. Some of the negative impacts of a plant's current PAOC might be driven by endogeneity; for example, a firm is more likely to invest in pollution abatement at plants it expects to continue operating. However, this concern should not affect the estimated effects of future PAOC increases, which are measured at the industry level. The consistently small exit effects of the plant and industry PAOC variables support our conclusion that PAOC has had a quite small effect on exit in the industries and time periods we examined.

6 References

Bartelsman, E. J., and W. B. Gray. 1994. NBER Productivity Database [online]. URL: http://www.nber.org/nberces/.

Becker, Randy, and Ronald Shadbegian. 2005. "A Change of PACE: Comparing the 1994 and 1999 Pollution Abatement Costs and Expenditures Surveys." *Journal of Economic and Social Measurement* 30:63-95.

Belova, Anna, Wayne B. Gray, Joshua Linn, and Richard D. Morgenstern. 2013. "Environmental Regulation and Industry Employment: A Reassessment." US Census Bureau Center for Economic Studies Paper No. CES-WP- 13-36

Bender, R., and S. Lange. 2001. "Adjusting for Multiple Testing—When and How?" *J. Clin. Epidemiol.* 54(4): 343-349.

Davis, Steven, John Haltiwanger, and Scott Schuh. 1998. *Job Creation and Destruction.* MIT Press.

Deily, Mary E., and Wayne B. Gray. 1991. "Enforcement of Pollution Regulations in a Declining Industry." *Journal of Environmental Economics and Management* Fall 1991, 260-274.

Foster, Lucia, John Haltiwanger, and Chad Syverson. 2008. "Reallocation, Firm Turnover, and Efficiency: Selection on Productivity or Profitability?" *American Economic Review* 98(1):394–425.

Holm, S. 1979. "A Simple Sequentially Rejective Multiple Test Procedure." *Scandinavian Journal of Statistics* 6:65–70.

Jarmin, Ron S., and Javier Miranda. 2002. “The Longitudinal Business Database.” Center for Economic Studies Discussion Paper CES-WP-02-17.

Jorgenson, Dale W. 1990. “Productivity and Economic Growth.” In Ernst R. Berndt and Jack E. Triplett, eds, *Fifty Years of Economic Measurement: The Jubilee Conference on Research in Income and Wealth.* Chicago, IL: University of Chicago Press.

Jorgenson, Dale W., Frank M. Gollop, and Barbara M. Fraumeni. 1987. *Productivity and U.S. Economic Growth.* Cambridge, MA: Harvard University Press.

Jorgenson, Dale W., and Kevin J. Stiroh. 2000. “Raising the Speed Limit: U.S. Economic Growth in the Information Age.” Brookings Papers on Economic Activity 1:125-211.

Morgenstern, Richard D., William A. Pizer, and Jhih-Shang Shih. 2002. “Jobs Versus the Environment: An Industry-Level Perspective.” *Journal of Environmental Economics and Management* 43:412-436.

Olley, S., and A. Pakes. 1996. “The Dynamics of Productivity in the Telecommunications Equipment Industry.” *Econometrica* 64(6):1263–1297.

7 Tables and Figures

Table 1
Industry Definitions, Growth Data, and Available[a] Summary Statistics

Industry	NAICS Industry Definition	Compound Annual Industry Growth Rate of Real Shipments 1976–2005[b] (%)	Number of Observations in the Analysis	Probability of Exit during the Next 5 Years[c] (%)	Median Change in PAOC-to-production cost ratio over next 5 Years (%),
1 Paper	322110, 322121, 322130	1.71	924	6.06	-0.16
2 Petroleum	324110	3.77	658	4.48	0.17
3 Plastics	3252	1.41	1009	5.15	-0.10
4 Steel	331111	-1.46	469	4.05	-0.15
5. Portland Cement	327310	0.70	415	--	--
6. Rolling and Drawing	331421; 331422; 331491	-0.20	627	11.96	0.00
7. Pipe Fitting	332911; 332912; 332919	0.83	458	9.39	0.02
8. Misc. Wood Products	321911, 321912, 321918, 321920, 321991, 321992, 321999	1.83	736	12.50	0.01
9. Pharmaceuticals	3254	3.86	546	5.49	-0.04
10. Other Electrical Equipment	3359	1.08	839	10.97	0.04

Notes: (a) Because we concurrently disclosed descriptive statistics for the continuing plant analysis samples, only limited statistics could be disclosed for the exit samples. Descriptive statistics for continuing plants are reported in BGLM, Appendix Table A1. (b) These values were calculated based on industry-level growth rates from the growth rates of the underlying NAICS industries using NBER Productivity Database (Bartelsman and Gray, 1994). (c) That is, probability to exit during: 1977–1982, 1982–1987, 1992–1997, 1997–2002. (--) Values did not pass Census disclosure test.

Table 2 Estimated Parameters of the Probit Model for the Five-Year Exit Probability[a]

Industry:	Paper	Petroleum	Plastics	Steel	Portland Cement	Rolling and Drawing	Pipe Fitting	Misc. Wood Products	Pharmaceu-ticals	Other Electrical Equipment
Variable to which the effect corresponds	Point Estimates (Robust Standard Errors in Parentheses)									
Log of Capital	0.535	-5.509	-0.429	-4.443	50.806	-4.052	0.053	1.791	-2.919	-0.895
	(1.323)	(3.326)	(1.413)	(2.696)	(15.294)	(2.243)	(2.967)	(1.236)	(2.030)	(0.725)
Log of Investments	-0.712	5.218	1.098	6.186	-34.427	5.238	1.133	-0.284	2.827	1.499
	(0.613)	(2.796)	(0.905)	(1.588)	(11.740)	(2.047)	(1.043)	(0.512)	(1.688)	(0.552)
RC/PC	409.354	1,447.358	124.679	-850.059	401.060	-5,401.016	-999.148	102.183	204.349	-50.521
	(205.270)	(968.759)	(209.736)	(298.434)	(704.150)	(2,245.593)	(671.345)	(290.513)	(336.123)	(193.277)
Log of Capital Squared	-0.084	0.047	0.055	0.172	-4.244	0.098	-0.044	-0.127	0.338	0.103
	(0.092)	(0.059)	(0.088)	(0.121)	(1.309)	(0.129)	(0.189)	(0.090)	(0.133)	(0.060)
Log of Capital * Log of Investments	0.090	-0.078	-0.114	-0.350	4.966	-0.210	-0.138	0.054	-0.644	-0.247
	(0.096)	(0.086)	(0.111)	(0.091)	(1.905)	(0.118)	(0.135)	(0.081)	(0.199)	(0.082)
Log of Capital * (RC/PC)	-20.378	-99.337	-2.899	-5.979	17.404	-107.855	-9.578	-28.994	-27.916	-12.965
	(19.839)	(58.172)	(19.198)	(24.560)	(90.514)	(71.920)	(83.929)	(48.109)	(29.040)	(26.585)
Log of Investments Squared	0.022	-0.039	-0.003	0.065	-1.436	0.085	0.070	-0.013	0.195	0.062
	(0.033)	(0.050)	(0.045)	(0.054)	(0.739)	(0.042)	(0.047)	(0.031)	(0.086)	(0.031)
Log of Investments * (RC/PC)	-14.600	13.878	-5.708	-10.695	-117.034	101.623	84.302	-23.372	54.243	23.170
	(11.963)	(78.411)	(11.571)	(20.748)	(85.364)	(49.217)	(50.799)	(30.917)	(26.391)	(16.777)
(RC/PC) Squared	-4,509.774	-6,526.596	-18.891	380.653	-14,051.840	-3,210.292	-11,295.421	-6,325.462	-6,122.221	175.227
	(1,372.807)	(6,838.627)	(231.178)	(2,047.769)	(6,691.799)	(16,286.856)	(13,468.712)	(5,179.401)	(3,711.125)	(248.856)
Expected growth of PAOC-to-production cost ratio, E[d RC/PC]	-6,009.855	1,182.827	-1,272.231	-9,239.697	-8,510.768	-9,268.709	17,454.232	-3,742.265	-30,211.332	4,199.556
	(1,209.949)	(1,236.490)	(1,510.435)	(2,513.012)	(3,193.239)	(4,803.987)	(6,756.725)	(1,611.674)	(27,091.617)	(2,273.458)
Log of Capital * E[d RC/PC]	-0.855	296.580	83.480	260.629	32.798	2,031.681	642.074	333.830	816.546	187.920
	(46.226)	(205.578)	(74.001)	(113.415)	(112.427)	(940.759)	(376.276)	(163.308)	(891.274)	(100.096)
Log of Capital * E[d RC/PC]	-30.676	-264.575	5.880	-353.051	150.075	-2,889.368	-214.229	41.020	214.358	178.447
	(26.353)	(157.812)	(29.326)	(136.933)	(77.382)	(1,292.222)	(265.320)	(42.346)	(1,446.830)	(69.501)
(RC/PC) * E[d RC/PC]	-21,234.460	-21,152.401	19,857.268	77,820.968	31,750.640	3,697,359.600	160,364.990	37,448.551	-242,582.150	-15,102.324
	(8,335.555)	(59,035.489)	(30,381.909)	(27,355.041)	(11,384.042)	(1,472,404.200)	(101,625.310)	(23,642.213)	(111,299.840)	(7,162.457)

Industry:	Paper	Petroleum	Plastics	Steel	Portland Cement	Rolling and Drawing	Pipe Fitting	Misc. Wood Products	Pharmaceu-ticals	Other Electrical Equipment
Variable to which the effect corresponds	Point Estimates (Robust Standard Errors in Parentheses)									
E[d RC/PC] Squared	-361,588.230	-325,893.760	-138,706.800	-184,639.530	-148,271.150	-1,970,807.500	-4,983,921.700	-165,339.810	-4,501,034.800	-78,207.790
	(118,568.080)	(187,112.260)	(108,646.770)	(58,705.361)	(55,170.908)	(469,641.230)	(3,619,335.900)	(308,133.710)	(3,034,244.700)	(369,133.210)
Capital cost share	0.861	3.079	2.415	1.217	1.196	3.126	-0.344	2.139	1.727	2.256
	(0.967)	(0.964)	(0.746)	(0.891)	(2.482)	(0.699)	(1.043)	(0.658)	(0.844)	(0.601)
Log of Output Price	0.561	-1.801	0.274	2.591	-210.749	-0.913	-1.688	-0.267	0.676	-0.834
	(0.498)	(0.672)	(0.397)	(2.608)	(90.984)	(0.739)	(0.650)	(0.676)	(0.702)	(0.527)
Log of Capital Price	-306.656	9.853	-1.215	-105.569	229.046	-8.460	8.170	1.309	-8.459	-2.422
	(61.176)	(29.792)	(6.779)	(32.655)	(95.620)	(8.006)	(5.557)	(1.378)	(17.358)	(2.164)
Log of Production Labor Cost	-0.145	0.325	-0.152	0.053	2.269	-0.450	0.674	-0.204	0.260	-0.105
	(0.489)	(0.570)	(0.150)	(0.758)	(1.022)	(0.414)	(0.485)	(0.287)	(0.402)	(0.273)
Log of Energy Price	-0.615	0.838	0.137	-0.885	0.092	0.456	-1.592	1.103	-0.188	0.798
	(0.323)	(0.344)	(0.348)	(0.601)	(0.661)	(0.415)	(0.819)	(0.406)	(0.550)	(0.339)
Log of Materials Price	-0.064	15.711	0.160	-0.548	-7.669	3.597	-3.928	0.101	-2.608	3.712
	(2.328)	(7.113)	(1.427)	(19.609)	(10.355)	(1.305)	(4.311)	(0.827)	(2.354)	(1.113)
Log of Capital * Industry growth	0.979	--	-3.464	-8.911	--	-20.679	-3.030	-0.197	-38.625	-2.242
	(4.701)		(3.348)	(3.075)		(10.928)	(4.593)	(1.232)	(27.758)	(2.368)
Log of Investments * Industry growth	3.951	--	-0.404	10.347	--	29.372	1.902	-2.139	1.272	-5.527
	(3.107)		(2.026)	(3.834)		(15.034)	(3.758)	(0.990)	(45.499)	(1.920)
(RC/PC) * Industry growth	1,243.844	--	-930.631	-2,943.993	--	-39,577.372	2,909.695	-1,290.061	6,826.675	65.384
	(925.356)		(1,106.253)	(832.615)		(15,956.244)	(1,411.519)	(360.629)	(3,638.560)	(457.817)
E[d RC/PC] * Industry growth	8,112.428	--	-16,946.296	79,011.181	--	115,983.520	114,596.980	1,212.851	481,006.900	-94,904.165
	(17,698.164)		(11,238.137)	(20,444.447)		(46,642.260)	(93,129.007)	(21,428.501)	(427,609.130)	(48,690.711)
Industry Growth Squared	6,899.031	--	741.332	-2,224.007	--	-838.509	1,503.487	-19.797	-7,199.272	1,322.426
	(1,302.994)		(568.644)	(579.800)		(404.548)	(738.951)	(133.117)	(6,263.734)	(1,249.780)
Constant	-210.120	17.325	-10.204	-6.321	-117.603	7.970	-45.172	-5.683	25.250	-3.597
	(40.473)	(27.473)	(9.086)	(12.070)	(44.107)	(10.267)	(20.139)	(4.811)	(27.865)	(4.856)
Number of Observations	924	658	1,009	469	415	627	458	736	546	839
Log-likelihood	-106.866	-56.011	-126.143	-38.016	-17.819	-133.576	-95.693	-205.238	-55.240	-205.277

Notes: Coefficients of the dummy variable for post-1963 plant vintage could not be disclosed. (a) That is, probability to exit during: 1977–1982, 1982–1987, 1992–1997, 1997–2002. (--) Models with industry growth could not be estimated for the industry.

Table 3 Estimated Impacts of PAOC Increase on the Five-Year Plant Exit Probability[a]

Industry	Impact Type: I. $1M increase in aggregate PAOC for continuing plants (in all available years sample)[b]			II. Increase in plant-level PAOC by 0.1% of plant's total (production and compliance) cost			III. Increase in plant-level PAOC by 1% of plant's total (production and compliance) cost			IV. Increase in industry growth by one standard deviation	
	Average increase[c] in PAOC per plant (thous. 1997$)	Percent change[d] in 5-year exit probability due to change in:		Average increase[c] in PAOC per plant (thous. 1997$)	Percent change[d] in 5-year exit probability due to change in:		Average increase[c] in PAOC per plant (thous. 1997$)	Percent change[d] in 5-year exit probability due to change in:		Increase[e] in industry growth (%)	Percent change[d] in 5-year exit probability
		RC/PC	E[d RC/PC]		RC/PC	E[d RC/PC]		RC/PC	E[d RC/PC]		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1 Paper	0.3	0.0001	-0.0004*	216.8	0.0729	-0.2729*	2,167.8	-0.3750	-1.7814*	7.55	-6.8488*
		(0.0002)	(0.0001)		(0.1332)	(0.0615)		(1.0257)	(0.3830)		(0.7560)
2 Petroleum	0.4	0.0000	0.0000	1,035.5	-0.0659	-0.0093	10,354.9	-0.7751	-0.0842	--	
		(0.0001)	(0.0000)		(0.3336)	(0.0164)		(1.8112)	(0.1549)		
3 Plastics	0.3	-0.0001	-0.0002	179.5	-0.0286	-0.0822	1,795.0	0.0774	-0.7269	8.88	-5.2259
		(0.0003)	(0.0001)		(0.1365)	(0.0565)		(1.0506)	(0.4801)		(3.0643)
4 Steel	0.5	0.0002	0.0004*	508.7	0.3020	0.4144*	5,086.9	2.2425	0.5746	23.92	-4.0366*
		(0.0002)	(0.0001)		(0.1878)	(0.1203)		(1.0683)	(1.0937)		(0.9270)
5. Portland Cement	0.9	0.0010	-0.0007	60.6	0.0669	-0.0469	605.9	0.1732	-0.3564	--	
		(0.0015)	(0.0003)		(0.0983)	(0.0222)		(0.6457)	(0.1728)		
6. Rolling and Drawing	0.6	-0.0147	-0.0003	87.5	-1.3354	-0.0347	875.1	-5.9784*	-0.3331	9.25	-9.3078*
		(0.0086)	(0.0001)		(0.6467)	(0.0187)		(1.7265)	(0.1838)		(1.6631)
7. Pipe Fitting	1.0	0.0228	0.0010	35.4	0.7806	0.0338	353.8	-2.4141	0.3533	6.58	-10.4841*
		(0.0330)	(0.0009)		(0.9610)	(0.0305)		(2.5853)	(0.3110)		(2.7034)
8. Misc. Wood Products	0.7	-0.0333	-0.0001	29.8	-1.3461	-0.0050	298.2	-8.7740*	-0.0501	7.77	-3.6230
		(0.0145)	(0.0008)		(0.5207)	(0.0329)		(1.7582)	(0.3279)		(4.4375)
9. Pharmaceuticals	0.6	0.0007	-0.0001	181.2	0.2102	-0.0237	1,812.4	0.5640	-0.1854	2.94	-3.8573
		(0.0009)	(0.0001)		(0.2554)	(0.0300)		(1.5130)	(0.2719)		(1.9988)
10. Other Electrical Equipment	0.5	-0.0028	-0.0002	59.2	-0.3135	-0.0236	591.9	-2.2002	-0.2202	5.58	-10.6053
		(0.0037)	(0.0006)		(0.4253)	(0.0641)		(3.4052)	(0.6308)		(4.8400)

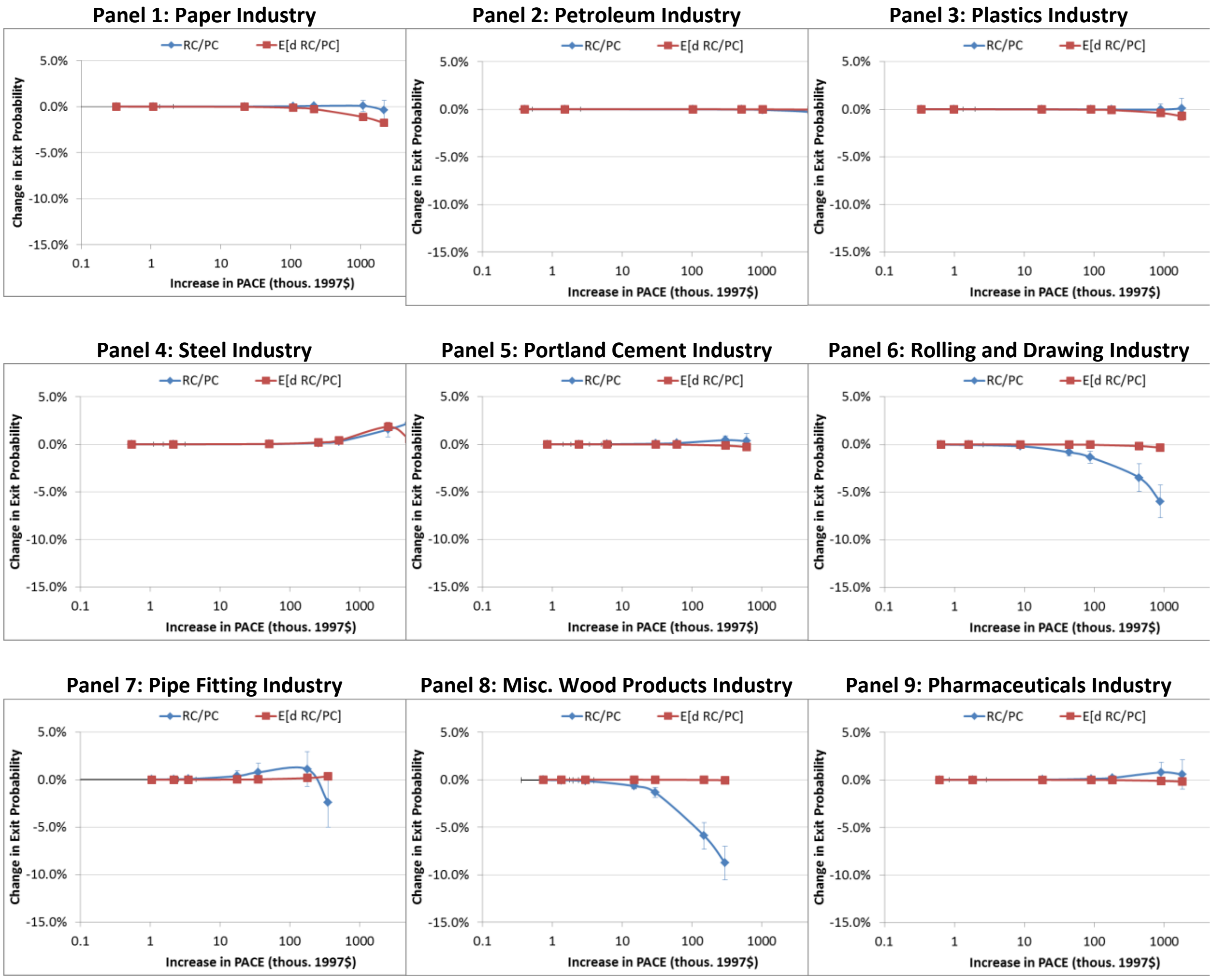
Notes: **RC/PC** – PAOC-to-production cost ratio; **E[d RC/PC]** – expected change in RC/PC in the next 5 years; (a) Probability of exit during 1977–1982, 1982–1987, 1992–1997, or 1997–2002. (b) For each industry, we calculated the ratio of average per-plant impact of $1M increase in aggregate PAOC to average total per plant cost for the continuing plants sample for all years (see BGLM for details). We used these industry-specific ratios to calculate corresponding per-plant increases in PAOC for the exit analysis sample. (c) The absolute increases in PAOC differ across plants because of variation in total costs. Sample averages are reported. (d) Changes in exit probability were calculated for each observation and then averaged. We report the point estimate and the robust standard error (in parentheses) of the average increase in exit probability. (e) In regression modeling, each plant-year observation was assigned the average annual industry-wide growth value. The values reported in this column represent standard deviation of annual industry growth in the estimation sample. A (--) indicates that the probit model with industry growth could not be estimated for the industry. (*) Denotes a statistically significant estimate at the 5% joint significance level. The Type I error was controlled using the Holm-Bonferroni procedure (Holm, 1979). To enable joint conclusions, all tests for a given category of impacts were considered a family (Bender and Lange, 2001). PAOC impact category (Types I-III) contained 60 tests, while industry growth impact category (Type IV) contained 8 tests.

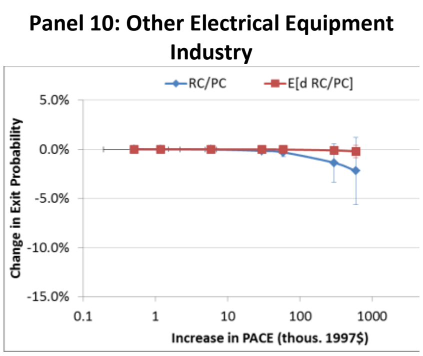
Table 4 Estimated Impacts of PAOC Increase on the Industry-Wide Employment through Changes in Exit Probability[a]

Industry	Impact Type										
	I. $1M increase in aggregate PAOC for continuing plants (in all available years sample)[b]			**II. Increase in plant-level PAOC by 0.1% of plant's total (production and compliance) cost**			**III. Increase in plant-level PAOC by 1% of plant's total (production and compliance) cost**			**IV. Increase in industry growth by one standard deviation**	
	Average increase[c] in PAOC per plant (thous. 1997$)	Change in industry-wide number of production workers[d] due to change in:		Average increase[c] in PAOC per plant (thous. 1997$)	Change in industry-wide number of production workers[d] due to change in:		Average increase[c] in PAOC per plant (thous. 1997$)	Change in industry-wide number of production workers[d] due to change in:		Increase[e] in industry growth (%)	Change in industry-wide number of production workers[d]
		RC/PC	**E[d RC/PC]**		**RC/PC**	**E[d RC/PC]**		**RC/PC**	**E[d RC/PC]**		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1 Paper	0.3	0.1	1.6*	216.8	81.6	998.6*	2,167.8	3,352.0	6,330.2*	7.55	19,109.2*
		(1.0)	(0.4)		(684.3)	(265.0)		(4,808.0)	(1,705.3)		(3,254.0)
2 Petroleum	0.4	0.2	0.0	1,035.5	369.8	4.4	10,354.9	968.5	31.2	--	
		(0.3)	(0.0)		(612.0)	(17.9)		(3,541.7)	(166.6)		
3 Plastics	0.3	0.1	0.2	179.5	46.4	95.9	1,795.0	-497.1	828.5	8.88	1,290.9
		(0.7)	(0.2)		(385.6)	(79.4)		(3,264.4)	(674.3)		(9,503.2)
4 Steel	0.5	-0.1	-1.4	508.7	-1,103.8	-1,310.9	5,086.9	-9,198.1	39.8	23.92	8,011.0
		(1.5)	(0.5)		(1,159.8)	(428.2)		(5,231.5)	(4,281.0)		(6,741.3)
5. Portland Cement	0.9	-0.3	0.4	60.6	-19.3	24.8	605.9	-83.5	184.3	--	
		(0.6)	(0.2)		(40.7)	(11.1)		(280.5)	(82.8)		
6. Rolling and Drawing	0.6	25.9	0.5	87.5	1,947.2	61.0	875.1	6,347.9	574.3	9.25	11,625.3*
		(22.9)	(0.2)		(1,220.9)	(28.0)		(3,346.8)	(267.9)		(3,036.3)
7. Pipe Fitting	1.0	-28.0	-1.1	35.4	-1,083.2	-37.9	353.8	143.8	-404.7	6.58	8,479.4*
		(33.8)	(0.9)		(1,026.0)	(29.4)		(2,955.1)	(303.5)		(2,769.7)
8. Misc. Wood Products	0.7	56.3	0.1	29.8	2,124.3	2.1	298.2	10,823.0	18.3	7.77	-129.1
		(30.0)	(1.1)		(1,070.0)	(42.4)		(3,994.5)	(422.7)		(7,151.6)
9. Pharmaceuticals	0.6	-1.2	0.1	181.2	-376.8	30.0	1,812.4	-3,051.5	205.7	2.94	1,178.6
		(1.4)	(0.2)		(398.6)	(48.7)		(3,654.2)	(442.3)		(4,209.7)
10. Other Electrical Equipment	0.5	4.5	0.3	59.2	486.7	38.2	591.9	1,810.8	333.1	5.58	16,201.8
		(9.0)	(1.1)		(1,028.0)	(132.3)		(8,940.2)	(1,301.0)		(11,390.9)

Notes: **RC/PC** – PAOC-to-production cost ratio; **E[d RC/PC]** – expected change in RC/PC in the next 5 years; (a) Changes in industry-wide due to changes in exit probability during 1977-1982, 1982-1987, 1992-1997, or 1997–2002. (b) For each industry, we calculated the ratio of average per-plant impact of $1M increase in aggregate PAOC to average total per plant cost for the continuing plants sample for all years. We used these industry-specific ratios to calculate corresponding per-plant increases in PAOC for the exit analysis sample. (c) The absolute increases in PAOC differ across plants because of variation in total costs. Sample averages are reported. (d) For each observation we calculated changes in exit probability and multiplied that by plant's employment. We then calculated the sum of plant-level employment changes. We report the point estimate and the robust standard error (in parentheses) of the total change in employment caused by change in plant exit rate. (e) In regression modeling, each plant-year observation was assigned the average annual industry-wide growth value. The values reported in this column represent the standard deviation of annual industry growth in the estimation sample. A (--) indicates that the probit model with industry growth could not be estimated for the industry. (*) Denotes a statistically significant estimate at the 5% joint significance level. The Type I error was controlled using the Holm-Bonferroni procedure (Holm, 1979). To enable joint conclusions, all tests for a given category of impacts were considered a family (Bender and Lange, 2001). PAOC impact category (Types I-III) contained 60 tests, while industry growth impact category (Type IV) contained 8 tests.

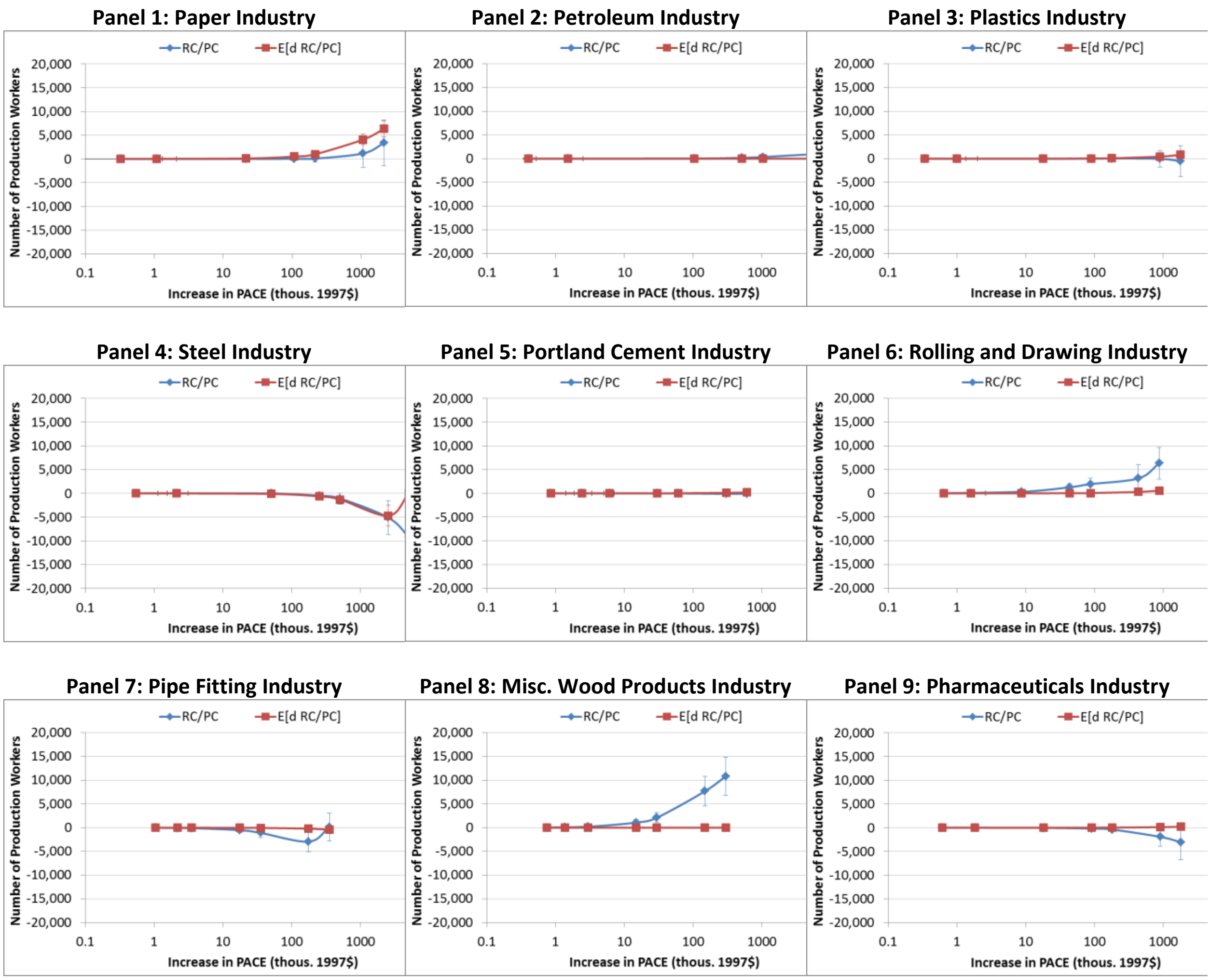
Figure 1 Estimated Impacts of PAOC Increase[a] on the Five-Year Plant Exit Probability[b]

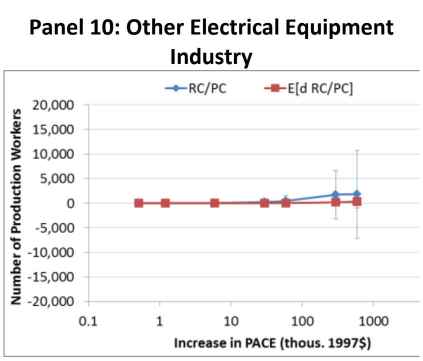




Notes: **RC/PC** – PAOC-to-production cost ratio; **E[d RC/PC]** – expected change in RC/PC in the next 5 years; (a) Changes were calculated for PAOC effect consistent with: $1M increase in aggregate PAOC (continuing plants sample); $1M increase in aggregate PAOC (exit analysis sample); and increases in plant-level PAOC corresponding to 0.01%, 0.05%, 0.1%, 0.5%, 1% of total costs. (b) Changes in probability of exit during 1977–1982, 1982–1987, 1992–1997, or 1997–2002, averaged over plant-year observations. Vertical bars represent robust standard errors that reflect sampling uncertainty.

Figure 2 Estimated Impacts of PAOC Increase[a] on the Industry-Wide Employment through Changes in Exit Probability[b]





Notes: **RC/PC** – PAOC-to-production cost ratio; **E[d RC/PC]** – expected change in RC/PC in the next 5 years; (a) Changes were calculated for PAOC effect consistent with: $1M increase in aggregate PAOC (continuing plants sample); $1M increase in aggregate PAOC (exit analysis sample); and increases in plant-level PAOC corresponding to 0.01%, 0.05%, 0.1%, 0.5%, 1% of total costs. (b) Changes in plant-level employment due to changes in plant-level probability of exit during 1977–1982, 1982–1987, 1992–1997, or 1997–2002, summed over plant-year observations. Vertical bars represent robust standard errors that reflect sampling uncertainty.