Exploring the Locus of Profitable Pollution Reduction

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In this paper, we explore the locus of profitable pollution reduction. We propose that managers underestimate the full value of some means of pollution reduction and so under exploit these means. Based on evidence from previous studies, we argue that waste prevention often provides unexpected innovation offsets, and that onsite waste treatment often provides unexpected cost. We use statistical methods to test the direction and significance of the relationship between the various means of pollution reduction and profitability. We find strong evidence that waste prevention leads to financial gain, but we find no evidence that firms profit from reducing pollution by other means. Indeed, we find evidence that the benefits of waste prevention alone are responsible for the observed association between lower emissions and profitability.
(*Environmental Strategy; Waste Prevention; Information Economics*)

Historically, scholars have argued that discretionary reductions in pollution by firms should lead to lower financial performance (Friedman 1970). According to this view, the cost of pollution is borne by the public. Reducing this public harm represents philanthropy, not profit maximization. Recently, however, some scholars have argued that pollution reduction provides both a public and a *private* benefit (Hart 1995, Porter and van der Linde 1995, Russo and Fouts 1997). Reducing pollution may increase production efficiency, increase demand from environmentally sensitive consumers, discourage stakeholder activism, and allow a firm to attract better workers (Reinhardt 1999).

The dispute over whether and where it "pays to be green" is more than simply a debate over the private cost of pollution: It is a debate about whether managers systematically miss profit opportunities. Whatever the private cost of pollution, rational managers should choose the level of pollution that balances the costs and benefits (McWilliams and Siegel 2001). Beyond this level, additional pollution reduction should *reduce* profits. As Palmer et al. (1995) note, a viable "pays to be green" theory must explain why "[the private sector] systematically overlooks profitable opportunities" (p. 91).

Most scholars argue that managers tend to underestimate one particular method of pollution reduction—waste prevention (Majumdar and Marcus 2001, Klassen and Whybark 1999, Hart 1995, Porter and van der Linde 1995). They argue that preventing waste (as opposed to treating waste once produced) provides unexpected and valuable information about process improvement opportunities. According to these scholars, such process improvements may more than offset the cost of pollution reduction (Ashford and Heaton 1983, Porter and van der Linde 1995).

While central to most "pays to be green" arguments, this provocative idea has not been directly tested. A number of scholars have found evidence that less-polluting firms have higher financial performance (e.g., Hart and Ahuja 1996). Scholars have also uncovered evidence that waste prevention, in particular, can provide unexpected learning benefits (King

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1995, Klassen and Whybark 1999, Majumdar and Marcus 2001). In this paper, we disaggregate pollution reduction into its component factors and jointly test for the profitability of each factor. We account for unobserved differences among firms to determine if the link between pollution reduction methods and financial performance is real or merely an artifact of some other firm attribute. In our analysis, we find support for the "pays to be green" hypothesis, but we show that this finding is likely caused by one factor alone—increased waste prevention.

Theory and Hypotheses

Firms can reduce their pollution in a number of ways. Firms may reduce their emissions by treating waste onsite, transferring waste to a third party processor, or by preventing waste at the source (often referred to as source reduction or pollution prevention). A profit-maximizing manager should choose among these means of pollution reduction so that the ratio of the marginal productivity of each activity to the cost of that activity is the same. As a result, for a profit-maximizing firm, the marginal cost of reducing a unit of pollution will be the same for all pollution reduction options and equal to the marginal benefit of pollution reduction.

However, if information about the value of each pollution reduction factor is costly to acquire, some factors may be under exploited while others may be overused. Theories of information search propose that prior expectations combined with costly information acquisition can cause managers to under (or over) invest in some forms of process improvement (Arrow 1974, von Hippel 1994). Absent new information, managers' prior expectations determine the location and intensity of search for profitable opportunities (Arrow 1974, Jensen 1982). If managers expect little benefit from certain pollution reduction strategies, they may not search for such profitable pollution reduction opportunities, and thus, may not find them.

Research has shown that differences in search costs can influence the degree to which managers exploit other production techniques like lean production and quality management (Ocana and Zemel 1996). Juran (1988) argues that managers underestimate the value of total quality management (TQM) because information about the value of defect reduction is often both delayed and obscured (Juran 1988). On the other hand, the value of catching and fixing defects at the end of the line is clear (e.g., doing so allows the firm to meet customer requirements). As a result, managers often overuse rework departments to fix quality problems at the end of the line and underuse practices that improve quality in the production process (Flynn and Schroeder 1995). Womack et al. (1990) argue that the difficulty of observing the true value of lean production and TQM practices delayed their diffusion for years. During this time, managers who understood the value of such practices could improve their firm's financial performance by improving process quality and reducing end of line quality control.

Similarly, a number of authors argue that *waste prevention* provides hard-to-observe benefits and thus is underexploited (Hart and Ahuja 1995, Klassen and Whybark 1999, Russo and Fouts 1997). Waste prevention requires both conceptual and operational learning (Larpe et al. 2000). Cebon (1992) argues that the "contextual embeddedness" of waste prevention makes it difficult for managers to measure its full value. King (1999) finds that while waste prevention improves worker incentives and encourages development of worker skills, these benefits are often overlooked. Hart (1995) argues the benefits of waste prevention are distributed and thus difficult to attribute to waste prevention. Other scholars argue that unexpected synergies may exist between waste prevention and lean production techniques (Rothenberg 1999, King and Lenox 2001).

Increased process innovation is often cited as an example of unexpected benefit from waste prevention (Porter and van der Linde 1995). Ashford and Heaton (1983) argue that managers often overlook the abundant innovations from waste prevention. Berube et al. (1992) provide an explanation for this oversight. They argue that waste prevention allows improved measurement of the production process, and thereby facilitates process innovation. They describe one striking example where mandated waste prevention led to numerous unexpected and highly profitable process-improving innovations. King (1995) shows that, in the printed circuit industry, pollution prevention activities contributed a disproportionate number of process-improving innovations. Porter and van der Linde (1995) argue that these innovation offsets are often hard to link to their source, and thus, managers underestimate the value of the underlying process that engendered them. If managers do not factor in the value of such innovation, they will underinvest in waste prevention, and those firms that increase their investment in such activities will improve their financial performance.

HYPOTHESIS 1. *The* more *a firm prevents waste*, *the higher its financial performance*.

While waste prevention may provide unexpected benefits, several scholars have argued that waste treatment activities often entail unexpected *costs* (Cebon 1992, Hart 1995). The idea that end-of-pipe treatment might entail hidden costs derives from Thompson's (1967) argument that organizational buffers both insulate the firm from disturbances and reduce the information flowing to managers. Cebon (1992) extends this argument by suggesting that waste treatment activities reduce the incentives to improve the production process. Waste-processing operations allow the firm to continue to engage in sloppy practices and then clean up the resulting problems "at the end of the pipe" (Cebon 1992, Hart 1995). King (1999) finds evidence that managers in one industry systematically overinvested in waste treatment activities and that reduction in the size and capacity of these end-of-pipe operations encouraged waste treatment personnel to improve the process itself. If managers overlook the hidden cost of waste treatment, they will choose to do more onsite waste treatment than is economical.

HYPOTHESIS 2. *The* less *a firm treats waste onsite*, *the higher its financial performance*.

Data and Measures

Our sample is drawn from publicly traded U.S. manufacturing firms that are both listed in the Compustat database and have at least one facility that meets the reporting requirements of the U.S. EPA's Toxic Release Inventory (TRI). Facilities must complete TRI reports if they manufacture or process 25,000 pounds of any listed chemical during a calendar year, use more than 10,000 pounds, and employ 10 or more full-time people. Prior to 1991, firms did not provide detailed information about waste generation or waste-processing onsite, thus we cannot use data from the years 1987–1990. At the initiation of this paper, 1996 was the last year of reported data. By matching the two sets, we created an unbalanced sample of 614 firms constituting 2,837 firm-year observations for the years 1991–1996.

Financial Performance

We measure financial performance in two ways: return on assets (ROA) and Tobin's q. ROA is a standard accounting measure of financial performance found commonly in strategy research. ROA is calculated by dividing earnings before interest by average total firm assets. We use Tobin's q in addition to ROA, because Tobin's q better reflects the inherent value of the firm. Tobin's q reflects expected future gains and is in accordance with more recent "pays to be green" studies (see Dowell et al. 2000). We calculated Tobin's q by dividing the sum of firm equity value, book value of long-term debt, and net current liabilities by total assets (see Chung and Pruitt 1995). We do not use the more complicated measure of Tobin's q as proposed by Lindenberg and Ross (1981), because past research has found little qualitative difference between this measure and the simplified version used in this analysis (Chung and Pruitt 1995).

Pollution Reduction

Previous research has measured firm pollution by dividing annual firm emissions of toxic chemicals by firm size (Hart and Ahuja 1996). We improve on this measure by analyzing performance at the facility level and by separating out the various means of pollution reduction. By comparing performance at the facility level, we can better control for industry effects. By distinguishing among waste prevention and onsite and offsite waste treatment, we can explore where profit opportunities lie.

To measure each facility's emissions, we sum releases of the 246 "core" toxic chemicals that have been consistently reported in the U.S. EPA's Toxic Release Inventory. We weigh each chemical by its toxicity using the Reportable Quantities (RQ) list in the

CERCLA statute (cf., King and Lenox 2000). To measure the firm's total pollution, we create a firm-level variable (total emissions) by taking the natural log of the total toxicity weighted emissions across all of a firm's facilities.

Total emissions are the outcome of a firm's waste generation and its efforts to reduce this waste by prevention and treatment. Creating measures of each of these requires several steps. We first measure the total toxic waste generated at a facility in a given year by calculating the toxicity-weighted sum of all core chemicals released into the environment, treated onsite, and transferred offsite. Next, we estimate a quadratic function between facility size and total waste generation for each 4-digit Standard Industry Classification (SIC) code within each year using standard OLS regression.

$$W_{it} = e^{\alpha_{jt}} s_{it}^{\beta_{1jt}} s_{it}^{\ln(s)^{*}\beta_{2jt}} e^{\varepsilon_{jt}} \tag{1}$$

$$\ln W_{it} = \alpha_{jt} + \beta_{1jt}(\ln s_{it}) + \beta_{2jt}(\ln s_{it})^2 + \varepsilon_{jt}, \tag{2}$$

where W_{it} is aggregate waste generated for facility i in year t, s_{it} is facility size, α_{jt}, β_{1jt}, and β_{2jt} are the estimated coefficients for sector j in year t, and ε_{jt} is the residual.

We use the estimated function to predict the amount of waste each facility would generate given its size, industry, and year. We use the residual to measure the relative performance of each facility in reducing this waste generation.

$$W_{it}^{*} = e^{\alpha_{jt}} s_{it}^{\beta_{1jt}} S_{it}^{\ln(s)^{*}\beta_{2jt}} \tag{3}$$

$$RW_{it} = -e^{\varepsilon_{jt}/\sigma\varepsilon_{jt}}, \tag{4}$$

where W_{it}^{*} is predicted waste generation for facility i in year t, RW_{it} is the standardized relative performance for facility i in year t, and $\sigma_{\varepsilon_{jt}}$ is the standard error of the residual for the SIC and year pair. We use the exponential form of the equation because we wish to sum these estimates for all facilities in firm before taking the log. We standardize the residuals to reflect the relative confidence of different estimations and we change the sign of the residual so that positive scores indicate more waste prevention. Unweighted aggregations and nonstandardized residuals deliver similar results.

Our financial performance measures are at the corporate level, so we must aggregate our facility level data up to the company level. *Waste generation* is calculated as the sum of predicted waste generation (W_{it}^{*}) across all facilities owned by a firm. Essentially, this is our best guess for how much waste the company would have generated if it were an average performer for its size in its industry. *Waste prevention* is the weighted average of a firm's facility-level scores (RW_{it}) based on the percentage of total production that each facility represents for the company.

We also construct measures of relative waste treatment. We first calculate the ratio of the material treated onsite (e.g., treated, burned, or recycled) to the total waste generated. We then calculate the average and standard deviations for these amounts for each SIC code in each year. From this, we calculate a deviation for each facility. These deviations are then summed to form a firm measure of onsite management (*waste treatment*). Similarly, *waste transfer* measures the percentage of waste that is processed offsite and is calculated in the same way.

Controls

We include a number of measures commonly used in the analysis of financial performance as controls (e.g., Berger and Ofek 1995). A company's size (*firm size*) is calculated as the log of the company's assets. The amount a firm is growing (*growth*) is calculated as the annual percent change in sales. The capital intensity (*capital intensity*) of the firm is calculated by dividing capital expenditures by sales. The degree to which the firm is leveraged (*leverage*) is expressed as the ratio of its debt to assets. Finally, the research and development intensity of the firm (*R&D intensity*) is calculated by dividing research and development expenses by total assets.

In addition to these common financial controls, we also include an estimate of a firm's labor prices in our regressions (*regional wages*). Because employees were used as a proxy for facility level production, differences in labor efficiency among the firms in our study might bias our analysis. Lower labor prices would encourage managers to substitute labor for waste. For example, managers could hire workers to search for problems, engage in maintenance, or improve existing

Table 1 Descriptive Statistics

Variable	Description	Mean	Std. Dev.	Min	Max
Tobin's q	Market valuation over replacement values of assets	1.67	1.02	0.28	12.05
ROA	Return on assets	5.75	6.18	−19.90	39.94
Total emissions	Log of total emissions of firm (+1)	5.40	3.31	0	13.49
Waste generation	Log of predicted waste generation of firm (+1)	5.52	2.96	0	18.00
Waste prevention	Deviation of actual to predicted waste generation	−0.24	0.73	−2.40	5.25
Waste treatment	Std. ratio of onsite treatment to waste generation	0.08	0.83	−2.65	14.21
Waste transfer	Std. ratio of offsite transfers to waste generation	0.04	0.69	−2.45	4.97
Firm size	Natural log of firm assets	6.35	1.92	0.76	12.52
Capital intensity	Capital expenditures over sales	0.06	0.06	0	0.86
Growth	Change in sales over sales	0.13	0.45	−0.82	13.24
R&D intensity	R&D outlays over firm assets	0.04	0.05	0	1.03
Leverage	The ratio of debt to firm assets	0.17	0.16	0	1.93
Regional wages	Labor price for the states the firm operates in	12.58	1.98	8.53	19.36
Regulatory stringency	Stringency of the states the firm operates in	0.47	0.78	0	6.87
Permits	Firm environmental permits over firm size	0.51	0.75	0	5.95

Note. $n = 2,837$ except for ROA, where $n = 2,120$.

processes. These lower labor prices would also reduce the marginal cost of production and increase profits. To rule out this rival explanation, we gathered information on annual state-level labor prices for unskilled labor from the county business pattern database of the U.S. Census Department. We create our measure by calculating the weighted average of state labor prices of all the states in which a firm has facilities operating.

Finally, environmental regulation varies across regions and imposes greater or lesser penalties for pollution. We measure a state's regulatory stringency by calculating the inverse of the log of state toxic emissions divided by total employees in four main polluting industries: chemicals, petroleum, pulp and paper, and materials processing (Meyer 1995). We create a firm-level measure, *regulatory stringency*, by calculating the weighted average of the state regulatory stringency of all the states in which a firm has facilities operating. We created an alternative measure of regulatory stringency, *permits*, by summing the number of federal waste water and hazardous waste permits possessed by a firm.

In Table 1, we present summary statistics for each of our measures. In Table 2, we present the pairwise correlation matrix for our measures. Please note that the sample is smaller for ROA than for Tobin's q. This is primarily a result of missing data on firm income levels. Misreported data caused elimination of 29 observations where ROA was more than five standard deviations away from the mean.

Analysis and Results

We hypothesize that some types of pollution reduction activities directly affect a firm's financial performance. However, it is possible that other firm attributes jointly affect both a firm's pollution reduction activities and its financial performance (Christmann 2000). It is difficult to include all of the possibly confounding firm attributes in statistical analysis; we use a fixed-effects regression to account for unobserved differences among our firms that might truly explain financial performance. The fixed-effect specification allows each firm to have a separate intercept and, thus, has the attractive property that it controls for stable firm attributes like the date of firm founding. In essence, a fixed-effect regression requires that changes in independent variables (rather than their baseline level) be associated with changes in dependent variables. Fixed effects, along with our use of lagged dependent variables, allow us to argue that changes in our independent variables are associated with and precede changes in our dependent variables.

We estimate a number of models over the entire panel controlling for both firm and year fixed effects

Table 2 Correlations

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Tobin's q	1.00														
2	ROA	0.54*	1.00													
3	Total emissions	−0.13*	−0.05	1.00												
4	Waste generation	−0.09*	−0.00	0.73*	1.00											
5	Waste prevention	0.05	0.02	−0.44*	−0.11	1.00										
6	Waste treatment	−0.04	0.00	0.04	0.08*	−0.05	1.00									
7	Waste transfer	0.04	0.04	−0.13*	−0.03	−0.01*	−0.34*	1.00								
8	Firm size	−0.03	0.04	0.48*	0.54*	−0.13*	0.04	0.01	1.00							
9	Capital intensity	0.17*	0.03	−0.01	0.08*	0.04	0.04	−0.05	0.14*	1.00						
10	Growth	0.16*	0.06	−0.06	−0.07*	0.01	0.00	0.04	−0.07*	0.06	1.00					
11	R&D intensity	0.32*	0.09*	−0.19*	−0.14*	0.08*	−0.01	−0.01	−0.06	0.18*	0.04	1.00				
12	Leverage	−0.20*	−0.27*	0.11*	0.06*	−0.06	0.01	−0.01	0.08*	−0.07*	0.00	−0.22*	1.00			
13	Regional wage	0.13*	−0.05	−0.23*	−0.13*	0.14*	−0.02	0.04	0.00	0.18*	0.08*	0.28*	−0.03	1.00		
14	Reg. stringency	0.00	0.00	0.28*	0.36*	−0.05	0.02	0.01	0.22*	0.15*	−0.05*	−0.08*	0.07*	−0.08*	1.00	
15	Permits	−0.12*	−0.04	0.56*	0.55*	−0.16*	0.04	−0.01	0.47*	−0.01	−0.07*	−0.16*	0.06	−0.15*	0.26*	1.00

Note. $n = 2{,}837$ except for correlations with ROA, where $n = 2{,}120$, $^*p < 0.001$.

(see Table 3). In Models 1 and 2, we find that lower emissions (*total emissions*) are significantly associated with higher financial performance as measured by future Tobin's q and future ROA. We therefore corroborate Hart and Ahuja's (1996) finding that reduced emissions are correlated with future financial performance. Our findings are consistent with the general findings of the empirical "pays to be green" literature (e.g., Russo and Fouts 1997, Klassen and Whybark 1999, Cohen et al. 2000).

Next, we explore by what means such reductions occurred (see Table 3). To explore the locus of profitable pollution reduction, we disaggregate pollution reduction into its component parts (*waste generation, waste prevention, waste treatment,* and *waste transfer*). In combination, these separate measures explain over 90% of *total emissions*. Regressing these measures on future Tobin's q, we find a significant, positive relationship with *waste prevention* (Model 3). We also find a significant, positive relationship between *waste prevention* and future ROA (Model 4). We find no evidence in either model that onsite waste treatment or offsite transfer is associated with financial performance.

Our fixed-effects analysis helps reduce the effect of unobserved heterogeneity, but it does not demonstrate the direction of causality. For example, managers may invest in waste prevention when they have an unusually profitable year. We extend our analysis by performing a test for Granger causality (see Table 4). Granger causality may be inferred when the lagged dependent variable is included in a regression and the independent variables continue to have explanatory power (Greene 1993, Granger 1969). In Model 5, we find a moderately significant positive relationship between *waste prevention* and future Tobin's q in a model that includes Tobin's q as a regressor. In Model 6, we also find a moderately significant relationship between *waste prevention* and future ROA when including current ROA as a regressor.[1] Thus, we find support for Hypothesis 1. We note, however, that this more stringent model reduced the significance of our waste prevention coefficient estimates (from $p < 0.028$ to $p < 0.05$ in Table 3). This may be due to the reduction in our sample size as a result of including additional lagged variables.

Models 7 and 8 explore the extent to which our measure of waste prevention explains the observed

[1] Please note that in Models 5 and 6, we use an instrumental variables approach proposed by Anderson and Hsiao (1982) to correct for potential serial correlation that may arise because of the lagged dependent variable. In this approach, heterogeneity is reduced by taking first differences (Greene 1993). Two-year lagged values of the dependent variable are used as instruments. We also tested an alternative method proposed by Arellano and Bond (1991) and found consistent results.

Table 3 Analysis of Aggregated and Decomposed Emissions

	Model 1	Model 2	Model 3	Model 4
Method:	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects
Dependent variable:	Tobin's q $(t+1)$	ROA $(t+1)$	Tobin's q $(t+1)$	ROA $(t+1)$
Total emissions	−0.025**	−0.279**		
	(0.011)	(0.112)		
Waste generation			0.012	−0.063
			(0.012)	(0.115)
Waste prevention			0.058*	0.800**
			(0.028)	(0.306)
Waste treatment			−0.021	−0.311
			(0.025)	(0.272)
Waste transfer			0.018	−0.149
			(0.032)	(0.304)
Controls				
Firm size	−0.495***	−4.454***	−0.479***	−4.153***
	(0.049)	(0.555)	(0.049)	(0.561)
Capital intensity	−0.290	−8.282***	−0.331	−8.772***
	(0.297)	(3.019)	(0.298)	(3.029)
Growth	0.061**	1.861***	0.062*	1.811***
	(0.028)	(0.363)	(0.028)	(0.364)
R&D intensity	1.437*	−30.288***	1.430*	−29.894***
	(0.617)	(9.504)	(0.617)	(9.517)
Leverage	0.158	−0.681	0.149	−0.709
	(0.148)	(1.560)	(0.149)	(1.565)
Regional wages	0.039	0.754***	0.042	0.769***
	(0.023)	(0.216)	(0.022)	(0.216)
Regulatory stringency	−0.030	2.036	−0.016	2.005
	(0.130)	(1.170)	(0.130)	(1.173)
Permits	−0.106	−0.199	−0.118	−0.251
	(0.061)	(0.569)	(0.061)	(0.570)
N	2837	2120	2837	2120
Firms	614	537	614	537
R^2 (*adjusted*)	80.0%	57.1%	78.8%	56.0%
F stat	16.70***	14.76***	13.87***	12.10***

Note. Firm level and year dummies included but not presented in all models.

Standard errors are in parentheses.

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$ (one-tailed tests).

relationship between *total emissions* and financial performance (see Table 4). Since *total emissions* is the outcome of different pollution reduction measures, we use a two-stage-least squares (2SLS) specification to compare the relative effect of emissions versus waste prevention on profitability. We first estimate *total emissions* as a function of waste generation, prevention, treatment, and transfer. We then estimate the effect of *total emissions*, *waste prevention*, and our control variables on financial performance. The first stage of the model predicts total releases based on operational choices and industry. The second stage predicts profits based on both releases and waste prevention. As shown in Models 7 and 8, we find evidence that more *waste prevention* is associated with Tobin's q and ROA, respectively. Controlling for the effect of waste prevention, we find no evidence that pollution (*total emissions*) is associated with financial performance. In

Table 4 Analysis of Temporal Precedence

	Model 5	Model 6	Model 7	Model 8
Method:	IV w/FD	IV w/FD	2SLS w/FE	2SLS w/FE
Dependent variable:	Tobin's q $(t+1)$	ROA $(t+1)$	Tobin's q $(t+1)$	ROA $(t+1)$
Total emissions			0.024	0.084
			(0.030)	(0.288)
Waste generation	−0.003	−0.137		
	(0.016)	(0.153)		
Waste prevention	0.063*	0.682*	0.086*	0.836*
	(0.037)	(0.405)	(0.041)	(0.390)
Waste treatment	−0.037	−0.073		
	(0.034)	(0.363)		
Waste transfer	−0.024	0.131		
	(0.040)	(0.400)		
Controls				
Firm size	−0.071	−1.751*	−0.474***	−4.191***
	(0.105)	(0.996)	(0.050)	(0.571)
Capital intensity	−0.726*	−12.960***	−0.318	−8.969***
	(0.383)	(4.021)	(0.298)	(3.041)
Growth	−0.100*	−0.693	0.063*	1.820***
	(0.042)	(0.563)	(0.028)	(0.365)
R&D intensity	−1.207	−23.200	1.396*	−30.24***
	(0.822)	(17.614)	(0.620)	(9.539)
Leverage	0.548*	3.558	0.152	−0.713
	(0.214)	(2.173)	(0.149)	(1.562)
Regional wages	−0.011	0.519*	0.047*	0.803***
	(0.031)	(0.313)	(0.023)	(0.220)
Regulatory stringency	0.076	0.953	−0.030	2.034*
	(0.181)	(1.713)	(0.130)	(1.171)
Permits	−0.048	0.270	−0.122*	−0.262
	(0.083)	(0.833)	(0.062)	(0.573)
Lagged dependent variable	0.540***	0.158		
	(0.187)	(0.120)		
N	1621	1198	2837	2120
Firms	494	456	614	537
$R^2(adjusted)$	77.2%	54.7%	75.3%	56.1%
χ^2 stat	58.66***	52.00***	29.79***	42.61***

Note. Firm level and year dummies included but not presented in all models.

Standard errors are in parentheses.

$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$ (one-tailed tests).

other words, we find evidence that reducing pollution by preventing waste is profitable but have no evidence that reducing pollution by other means is profitable.

Discussion

In general, our analysis supports the "pays to be green" hypothesis. We find a significant, negative relationship between firm emissions and financial performance. More importantly, we show that firms underexploit one means of reducing pollution—waste prevention. We find no evidence that managers underexploit other factors, or pollution reduction in total. Indeed, we find evidence that the benefits of waste prevention alone may be responsible for the association between lower emissions and profitability.

While our analysis covers many industries and a time period of six years, there are reasons to be cautious about the generalizability of our findings. The U.S. regulatory environment is a rather unique one. Compared to European and Asian nations, U.S. regulators are less conciliatory. In countries with a more cooperative relationship between government and industry, managers may be more likely to explore the benefits of pollution prevention and less likely to miss opportunities for profitable pollution prevention. We hope that future research will test our findings in different institutional and regulatory environments.

While we infer from our findings that managers underexploit opportunities for profitable waste prevention, other rival hypotheses cannot be completely ruled out. We would find similar results if (1) managers tend to invest in pollution prevention only when they already possess other valuable firm capabilities, and (2) the market does not fully value these other capabilities until they observe the firm preventing waste. If so, pollution prevention might act only as an indicator of existing underlying capabilities (Morrison and Siegel 1997). Pollution prevention may be part of a moving technological frontier and firms only jump to this frontier when it is in their interest to do so. Jumping to the new frontier then provides information to the market about the firm's capabilities.

Within this rival theory, our explanation may still have merit. Search costs and prior expectations may influence the valuation that managers place on reaching the new frontier. Alternatively, it may be that pollution prevention is often part of a bundle of activities that are deployed together. For example, lean production and waste prevention may frequently be deployed together—making it difficult to untangle the financial effects of the entire bundle.[2] Waste prevention may represent the observed part of a bundle of complementary activities that provide financial gain. Such an analysis represents only a short walk from our claim that waste prevention provides hidden ancillary benefits. Nevertheless, we should be cautious in not overextending our findings. It is possible that a combination of fortuitous resources and managerial choice could cause the statistical results we observe.

It is important to recognize that we do not directly measure what managers know or what manager's expect to be the cost of identifying profit opportunities. We infer these search costs and expectations by evaluating the use of pollution reduction factors. While we try to rule out other rival explanations for our observed results, our inability to actually measure expectations and search costs suggests the need for additional work at multiple levels of analysis.

Conclusions

The dispute over whether it "pays to be green" is more than simply a debate over the private cost of pollution. It is a debate about whether and when managers systematically miss profit opportunities. Drawing upon theories of information search, we propose that prior expectations combined with costly information acquisition can cause managers to underexploit (or overexploit) some process factors and thus miss potential profit opportunities. Lacking information on the locus of profit opportunities, managers' prior expectations may determine the location and intensity of search (Arrow 1974, Jensen 1982).

In this study, we extend the "pays to be green" literature by distinguishing among methods for reducing emissions. We argue that the value of one method (pollution prevention) is hard to observe, while the cost of another (end-of-pipe waste treatment) is often obscured. As a result, we hypothesize that managers underexploit waste prevention and overexploit waste treatment. In a longitudinal analysis of U.S. manufacturing firms, we find evidence that waste prevention is indeed underused, and that firms can improve their financial performance by engaging in more waste prevention.

Our analysis reinforces the similarity between theories of waste prevention and quality. We extend theories developed to explain the effect of quality programs to argue that managers underestimate the benefit of solving waste problems at their source. We

[2] To try to distinguish this particular bundle, we also estimated each firm's participation in the ISO 9,000 quality standard and their maximum inventory levels for listed chemicals. We found that inclusion of these variables did not change the significance of our findings.

find evidence that this tendency does exist and that firms can reap profits by further investing in waste prevention. More generally, we provide a framework for predicting when such profit opportunities are likely to go underexploited. We propose that costly information acquisition and prior expectations can determine where opportunities for profitable improvements go unexploited.

In this paper, we propose that firms sometimes fail to adopt profitable practices. One may be tempted to conclude from our analysis that government regulation is needed to correct such market failure. This need not be the case. Governing authorities may gather information and provide statistics to managers to update their expectations about the profitability of engaging in certain practices (Lenox 1999). In the environmental realm, the U.S. Environmental Protection Agency has created a number of programs to inform businesses of the value of energy efficiency and waste minimization and to help them find these opportunities (e.g., the Green Lights Program). Trade associations often try to provide such information to their member firms (King and Lenox 2000). Our research extends analysis of whether and when such programs are likely to be useful. In future research, we hope to further explore these types of information provision programs.

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