Does It *Really* Pay to Be Green?

An Empirical Study of Firm Environmental and Financial Performance

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Keywords

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Summary

Previous empirical work suggests that firms with high environmental performance tend to be profitable, but questions persist about the nature of the relationship. Does stronger environmental performance really lead to better financial performance, or is the observed relationship the outcome of some other underlying firm attribute? Does it pay to have clean-running facilities or to have facilities in relatively clean industries? To explore these questions, we analyze 652 U.S. manufacturing firms over the time period 1987±1996. Although we find evidence of an association between lower pollution and higher financial valuation, we find that a firm's fixed characteristics and strategic position might cause this association. Our findings suggest that "When does it pay to be green?" may be a more important question than "Does it pay to be green?"

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Scholars had long assumed that investments to protect the natural environment provided few financial benefits to firms. In the last 20 years, however, a growing number of researchers have challenged this assumption. In the field of industry ecology, scholars argue that there are situations where beyond-compliance behavior by firms is a win-win for both the environment and the firm (Nelson 1994; Panayotou and Zinnes 1994; Esty and Porter 1998; Reinhardt 1999). Scholars now suggest that firms may be both green and competitive (Porter and van der Linde 1995; Reinhardt 1999). Qualitative research has identified numerous examples of profitable pollution prevention opportunities (Denton 1994; Deutsch 1998; Graedel and Allenby 1995; Porter and van der Linde 1995; King 1995). Many scholars now argue that discretionary improvements in environmental performance often provide financial benefit (e.g., Hart 1997).

In response, a growing empirical literature shows that researchers have applied econometric techniques to test the "pays to be green" hypothesis. Several studies have provided evidence that higher environmental performance is associated with better financial performance, but these early studies often lacked the longitudinal data needed to fully test the relationship. Several years of data are needed if one wants to rule out rival explanations for the apparent association or show that environmental improvement causes financial gain. Furthermore, the empirical literature does not clarify whether the apparent association is generated by a firm's choice to operate in cleaner industries or to operate cleaner facilities. Existing research cannot answer whether it pays to be green or whether it pays to operate in green industries.

In this article, we review and comment on the empirical "pays to be green" literature. We discuss how a firm's stable attributes (i.e., the characteristics of the firm that persist over time) and strategic position may jointly cause both lower pollution levels and better financial performance and thereby create the appearance of a direct relationship between the two. For example, innovative firms may have both lower emissions levels and greater profits. Alternatively, managers may choose to improve their firm's environmental performance when they have an especially profitable year.

To help distinguish the effect of pollution reduction from other underlying factors, we adopt empirical methods that account for unmeasured firm attributes. Furthermore, to differentiate between pollution reduction and divestiture of operations in dirtier industries, we separate environmental performance into two constructs: 1) relative performance within a given industry and 2) the average performance of the industries in which one chooses to operate. We analyze 652 U.S. manufacturing firms over the time period 1987–1996. We find evidence of a real association between lower pollution and higher financial performance. We also show that a firm's environmental performance relative to its industry is associated with higher financial performance. We cannot show conclusively, however, that a firm's choice to operate in cleaner industries is associated with better financial performance, nor can we prove the causal direction of the observed relationships. Thus, our research provides support for a connection between some means of pollution reduction and financial performance, but it also suggests that the reason for this connection remains to be established.

Evidence to Date

Proponents of a causal link between environmental and financial performance have argued that pollution reduction provides future cost savings by increasing efficiency, reducing compliance costs, and minimizing future liabilities (Porter and van der Linde 1995; Reinhardt 1999). Porter and van der Linde (1995) theorized that opportunities for profitable pollution reduction exist because managers often lack the experience and skill to understand the full cost of pollution (Jaffe et al. 1995). Hart (1997) proposes that excess returns (i.e., profits above the industry average) result from differences in the underlying environmental capabilities of firms. Managers may possess unique resources or capabilities that allow them to employ profitable environmental strategies that are difficult to imitate.

Using a variety of measures (tables 1 and 2), much of the empirical "pays to be green" litera-

Table 1 Measures of corporate financial performance used in "pays to be green" scholarship

Measure	*Description*	*Examples*
Tobin's *q*	Firm market valuation over replacement value of assets	Dowell et al. (2000)
Return on Assets	The ratio of income to total assets	Hart and Ahuja (1996), Russo and Fouts (1997)
Return on Equity	The ratio of income to firm equity	Hart and Ahuja (1996), Russo and Fouts (1997)
Return on Investment	The ratio of operating income to book value of assets	Hart and Ahuja (1996), Russo and Fouts (1997)

Table 2 Measures of corporate environmental performance used in "pays to be green" scholarship

Measure	*Examples*
Capital expenditures on pollution control technology	Spicer (1978) Nehrt (1996)
Emissions of toxic chemicals (typical source: TRI)	Hamilton (1995) Hart and Ahuja (1996)
Spills and other plant accidents	Karpoff et al. (1998)
Lawsuits concerning improper disposal of hazardous waste	Muoghalu et al. (1990)
Rewards or other recogition for superior environmental performance	Klassen and McLaughlin (1996)
Participation in environmental management standards	White (1996) Dowell et al. (2000)
Rankings of superior environmental performers (e.g., CEP)	White (1996) Russo and Fouts (1997)

ture has supported the proposed positive relationship between pollution reduction and financial gain by relying on correlative studies of environmental and financial performance. A series of studies conducted by the Council on Economic Priorities (CEP) in the 1970s found that expenditures on pollution control were significantly correlated with financial performance among a sample of pulp and paper firms (Spicer 1978).[1] More recently, Russo and Fouts (1997) found a significant positive correlation between various financial returns and an index of environmental performance developed by the CEP. Dowell and colleagues (2000) found that firms that adopt a single, stringent environmental standard worldwide have higher market valuation (Tobin's *q*) than firms that do not adopt such standards.

In the finance literature, a number of studies have examined the market returns of portfolios of environmentally friendly firms. Cohen and colleagues (1995) used several measures of environmental performance derived from U.S. Environmental Protection Agency (U.S. EPA) databases to construct two industry-balanced portfolios of firms. They found no penalty for investing in the green portfolio and a positive return to green investing. Similarly, White (1996) found a significantly higher risk-adjusted return for a portfolio of green firms using the CEP ratings of environmental performance.[2]

To the extent that one cares merely about correlation and little about causation, these correlative studies are informative. Market analysts, for example, increasingly gather environmental performance data as an indicator of future capital market returns (Kiernan 1998). For their purposes, it matters little whether environmental performance leads to financial performance or simply provides an indicator of firms that have high financial performance.

From the perspective of corporate managers and policy analysts, however, the distinction is critical. The prescription that often follows from the "pays to be green" literature is that managers should make investments to lower their firm's environmental impact (Hart and Ahuja 1996). To fully demonstrate that it pays to be green, research must demonstrate that environmental improvements produce financial gain.

Event studies are one means of demonstrating that greening indeed causes financial gain. Such studies look at the relative changes in stock price following some environmental event. By isolating a single environmental event within a narrow time frame, event studies control for important differences among firms that cannot be observed. The limitation with event studies is that they often study the effect of events that are only partially environmental in nature. Klassen and McLaughlin (1996), White (1996), Karpoff and colleagues (1998), and Jones and Rubin (1999) studied the effect of published reports of events and awards on firm valuation and found a relationship between the valence of the event (positive or negative) and the resulting change in market valuation. Blacconiere and Patten (1994) estimated that Union Carbide lost $1 billion in market capitalization, or 28%, following the Bhopal chemical accident in 1984. Muoghalu and colleagues (1990) found that firms named in lawsuits concerning improper disposal of hazardous waste suffered significant losses in capital market value. Each of these events has environmental elements, but each is affected by other firm attributes. King and Baerwald (1998) argued that size, market power, and unique firm characteristics influence how events are reported and interpreted. A firm with good public relations may be able to put a positive spin on negative news. A firm that possesses good legal resources may better forestall lawsuits.

In some event studies, researchers have sought to avoid these problems by using the annual release of toxic emission data through the U.S. EPA's Toxic Release Inventory (TRI) program as the event. Hamilton (1995), Konar and Cohen (1997), and Khanna and colleagues (1998) all found that polluting firms lost market value in a one-day window following the release of TRI information. These important studies still may suffer from construct validity, however. Given the complexity of analyzing TRI data, it seems possible that same-day stock price movements probably reflect contemporaneously reported pollution rankings. These rankings are strongly affected by firm size and industry choice, and thus the stock market effect may be the result of temporary bad press rather than a real change in perception of a firm's long-term value. In fact, stock values often return to pre-event levels within a five-day window following the TRI data release. Proponents of event studies, however, claim that the return of the price to pre-event levels is most likely to be a response to new, unrelated information.

Another way to account for unobserved firm differences is to use standard regression techniques to evaluate the effect of changes in pollution on changes in financial performance. This in essence is the approach used in a widely cited study by Hart and Ahuja (1996). They showed that changes in pollution (emission per sales dollar) predate changes in financial performance. Although an important advance in the literature, their measure of environmental performance conflates reduction of pollution at current operations and divestiture of dirty operations, making it difficult to interpret the meaning of their study. Is it that it pays to be green or does it pay to operate in clean industries?

This issue underscores a larger debate within the strategy literature on the source of returns in excess of investments of similar risk (Rumelt 1991; McGahan and Porter 1997). The industrial organization literature in economics suggests that excess returns result from differences in the underlying structure of industries. According to this logic, greener industries may have higher returns than dirtier industries because of lower compliance and regulatory costs. In contrast, the resource-based view of strategic management suggests that individual firm capabilities may lead to excess returns when they are difficult to imitate, not substitutable, rare, and valuable (Barney 1986; Wernerfelt 1984). According to this view, superior ability to manage environmental problems relative to others in your industry may lead to higher returns. In much of the empirical "pays to be green" literature, researchers have used strategy resource-based logic to justify a relationship between environmental and financial performance. Unfortunately, they fail to disentangle the effects of industry choice from the effects of variation in environmental strategies among firms in the same industry.

An Empirical Approach

In the following sections, we analyze whether it really "pays to be green" using a methodology that allows us to explore whether unmeasured firm and industry characteristics may explain the observed link between environmental and financial performance. We also use a measure of environmental performance that untangles the effect of a firm's relative performance within its industries and the average performance of the industries in which it chooses to be.

We created a sample of publicly traded U.S. manufacturing firms during the period 1987–1996 by combining the U.S. EPA's Toxic Release Inventory (TRI) with facility data from Dun & Bradstreet and corporate data from Standard & Poor's Compustat database. The U.S. EPA started the TRI in 1987 to track emissions of more than 200 toxic chemicals from U.S. manufacturing firms. Facilities must complete annual TRI reports if they manufacture or process 25,000 pounds (or about 11,340 kg), use more than 10,000 pounds of any listed chemical during a calendar year, and employ ten or more full-time people. To be in our sample, a firm must have at least one facility that meets these requirements and be among the public corporations listed in the Compustat database. Matching the two sets, we created an unbalanced sample of 652 firms constituting 4,483 firm-year observations for the years 1987 through 1996.[3]

Measures

Financial Performance

The dependent variable for our analysis is financial performance as reflected by Tobin's *q*. Tobin's *q* measures the market valuation of a firm relative to the replacement costs of tangible assets (Lindenberg and Ross 1981). Essentially, it reflects what cash flows the market thinks a firm will provide per dollar invested in assets. It should be higher if future cash flows are expected to be greater or if they are expected to be less risky. In accordance with more recent "pays to be green" studies, we use a simplified measure of Tobin's *q* (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 the book value of total assets.[4] All financial data were obtained from the Compustat database.

Environmental Performance

Previous research has measured the environmental performance of a firm as the degree to which that firm emits toxic pollution given its size (Hart and Ahuja 1996). We create a similar measure (*Total Emissions*) by calculating the log of total facility emissions of toxic chemicals. Unfortunately, the meaning of this variable is ambiguous because it confounds pollution that results from industry positioning with pollution that results from poor environmental management. Consequently, we form two additional variables to separate the effect of environmental management from the effect of industry positioning. *Relative Emissions* measures the firm's ability to manage and reduce its pollution by comparing the degree to which a firm's facilities are more or less polluting than other facilities in the same industry (measured by the four-digit Standard Industrial Classification (SIC) code and adjusted for differences in size). *Industry Emissions* measures the degree to which a firm tends to operate in industries where production entails pollution. If a firm operates in industries where the average facility has higher emissions, this variable will have a larger value. Please refer to the appendix for a detailed description of the construction of these variables.

Controls

We include a number of measures commonly used in the analysis of financial performance as controls (tables 3 and 4). These measures include 1) the company's size (*Firm Size*) calculated as the log of the company's assets, 2) the capital intensity of a firm (*Capital Intensity*) calculated by dividing capital expenditures by sales, 3) the annual growth of the firm (*Growth*) calculated as the percentage change in sales, 4) the degree to which the firm is leveraged (*Leverage*) divided as the ratio of its debt to assets, and 5) the research and development intensity (*R&D Intensity*) calculated by dividing research and development expenses by total assets.

In addition, we control for the stringency of the regulatory environment in which the firm

Table 3 Descriptive statistics

Variable	*Description*	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Tobin's *q*	Firm market valuation over replacement value of assets	1.58	0.94	0.28	12.67
Total Emissions	Log of total emissions of facilities	5.82	3.28	0.00	13.76
Relative Emissions	Average relative emissions of facilities based on sector and size (in employees)	0.21	0.77	− 7.08	9.41
Industry Emissions	Average total emissions per employee of sectors in which the firm operates	0.22	0.50	− 1.80	1.62
Firm Size	Natural log of firm assets	6.27	1.94	0.76	12.52
Capital Intensity	Capital expenditures over sales	0.07	0.06	0.00	1.19
Growth	Percent change in sales	0.12	0.44	− 0.91	13.36
R&D Intensity	Research and development outlays over firm assets	0.04	0.04	0.00	1.03
Leverage	The ratio of debt to firm assets	0.18	0.16	0.00	1.93
Regulatory Stringency	The regulatory stringency of the states the firm operates	0.51	0.84	0.00	7.01
Permits	The number of firm Clean Water Act and Resource Conservation and Recovery Act permits over firm size	0.49	0.74	0.00	5.95

Note: $n = 4{,}483$.

operates (*Regulatory Stringency*). Environmental regulation varies across regions and imposes greater (or lesser) penalties for pollution from facilities operating in those regions. We measure a state's regulatory stringency by calculating the inverse of the log of toxic emissions divided by total employees in four main polluting industries: chemicals, petroleum, pulp and paper, and materials processing (Meyer 1995). The logic for this measure is that higher regulation leads to lower emissions per employee (for these industries) and thus increases the inverse of this ratio (*Regulatory Stringency*). For each firm, we create a measure of the average regulation it faces by calculating the weighted-average of the regulatory stringency for all the states in which the firm operates.

To create an alternative measure of the degree to which the different facilities in our sample are regulated, we count the number of performance criteria with which each facility must comply (i.e., the number of permits issued to a facility). Under the U.S. Clean Water Act (CWA 1977), regulators may impose limits on water flow, suspended solids, and chemical concentration. Although guidelines exist for administering the law, substantial discretionary power remains. We created an alternative measure of regulatory stringency, *Permits*, by summing the number of federal permits and then dividing by firm size.

Results

Previous studies have found that pollution precedes poor financial performance by one or more years (Hart and Ahuja 1996). To test these findings, we use least-squares regression analysis to find a linear relationship between our independent variables and the firm's future Tobin's *q* (table 5).[5] Because firms may differ in ways that we do not capture with our independent variables, we include dummy variables that allow each firm to have a different constant value. This is often called a "fixed effects" analysis because it reduces the possibility that a firm's fixed attributes confound the analysis. In essence, this fixed-effect regression requires that changes in independent variables (rather than their baseline level) be associated with changes in dependent variables.

Consistent with much of the "pays to be green" literature, we find that *Total Emissions* is

Table 4 Correlations

	1	2	3	4	5	6	7	8	9	10	11
1. Tobin's *q*	1.00										
2. Total Emissions	–0.12*	1.00									
3. Relative Emissions	–0.04	0.46*	1.00								
4. Industry Emissions	–0.09*	0.38*	–0.08*	1.00							
5. Firm Size	–0.02	0.49*	0.09*	0.05	1.00						
6. Capital Intensity	0.17*	–0.01	–0.03	0.03	0.11*	1.00					
7. Growth	0.14*	–0.05*	–0.03	–0.01	–0.06*	0.05*	1.00				
8. R&D Intensity	0.28*	–0.15*	–0.07*	0.00	–0.05	0.17*	0.04	1.00			
9. Leverage	–0.19*	0.09*	0.06*	–0.01	0.07*	–0.02	0.01	–0.23*	1.00		
10. Regulatory Stringency	0.00	0.30*	0.05*	0.13*	0.22*	0.13*	–0.03	–0.09*	0.09*	1.00	
11. Permits	–0.11*	0.55*	0.10*	0.07*	0.48*	–0.01	–0.06*	–0.15*	0.06*	0.27*	1.00

Note: $n = 4{,}483$.

* $p < 0.001$.

associated with superior financial performance even when controlling for firm fixed effects (model 1). Thus, we provide evidence that environmental performance is associated with financial performance rather than the observed relationship being the outcome of some other underlying firm attribute.

As discussed earlier, evidence of such a relationship still leaves many unanswered questions. Does it pay to have clean-running facilities, or to have facilities in relatively clean industries? To better account for these differences, we separate *Total Emissions* into two parts that reflect a firm's tendency to operate in polluting industries (*Industry Emissions*) and its tendency to operate dirtier facilities within these industries (*Relative Emissions*). In model 2, the significant and negative coefficient for *Relative Emissions* indicates that firms with lower emissions in their industries tend to experience higher financial performance in the subsequent year. The lack of significance for the coefficient for *Industry Emissions* means that we cannot conclude that firms that operate in cleaner industries have higher financial performance.

One problem with fixed effects analysis is that it can do its job too well. By eliminating the effect of all firm attributes that are relatively constant, the fixed effect may obscure evidence that a fixed attribute is actually important. If firms do not frequently change industry, and thus industry position is relatively constant, we might miss the financial effect of industry choice. To check this, we use an alternative specification called "random effects." Although this method continues to reduce the effect of fixed firm attributes, it assumes that these are normally distributed. This method suggests that firms that operate in cleaner industries (*Industry Emissions*) have higher financial performance.

What might explain the difference between model 3 and model 2? One possibility is that few firms in our sample actually move across industries, and thus the fixed effects analysis removes the effect of industry position. Another possibility is that firms benefit from being in cleaner industries but not from moving to cleaner industries. Perhaps such movement entails costs that reduce a firm's valuation or signals some difficulty or problem. It is important to note that in our particular case, statistical tests suggest that the fixed effects and not random effects analysis should carry more credence.[6]

Finally, we still have not considered the effect of causality. Which way does the relationship run? Do more-profitable firms invest more in environmental performance, or does environmental performance lead to profit? In model 4, we present one method for answering this question. To reduce the effect of a previous profitable year, we include the previous year's Tobin's *q* in the regression.[7] Unfortunately, this analysis does not provide reliable evidence that firms with lower emissions in their industries (*Relative Emissions*)

Table 5 Estimates of future financial performance (Tobin's q_{t+1}) 1987±1996

Method	Fixed effects 1	Fixed effects 2	Random effects 3	IV and fixed effects 4
Total Emissions	– 0.021**			
	(0.008)			
Relative Emissions		– 0.036*	– 0.029+	– 0.032
		(0.018)	(0.017)	(0.021)
Industry Emissions		– 0.027	– 0.076*	– 0.083
		(0.049)	(0.037)	(0.021)
Controls				
Firm Size	– 0.219***	– 0.219***	– 0.034*	– 0.238***
	(0.030)	(0.030)	(0.014)	(0.057)
Capital Intensity	– 0.420*	– 0.416*	– 0.147	– 1.645***
	(0.198)	(0.198)	(0.187)	(0.222)
Growth	0.053*	0.053*	0.068**	– 0.036
	(0.022)	(0.023)	(0.022)	(0.022)
R&D Intensity	3.429***	3.377***	5.062***	1.094
	(0.535)	(0.535)	(0.408)	(0.577)
Leverage	– 0.153	– 0.152	– 0.330***	0.149
	(0.101)	(0.101)	(0.090)	(0.110)
Regulatory	0.108	0.111	0.080*	0.035
Stringency	(0.071)	(0.071)	(0.032)	(0.107)
Permits	– 0.061	– 0.069	– 0.060+	– 0.090
	(0.045)	(0.045)	(0.032)	(0.054)
Tobin's *q*				– 0.321***
				(0.101)
n	4,483	4,483	4,483	3,130[a]
Number of firms	652	652	652	544
F stat	24.36***	22.80***		
χ^2 stat			505.30***	255.09***
Adj. R^2	0.667	0.667	0.714	0.756

Note: Firm and year dummies are included but not presented in all models. Standard errors are in parentheses.

[a] The sample is slightly smaller because of the inclusion of lagged instruments.

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (two-tailed test).

tend to experience higher financial performance. Thus, although we find evidence of an association between reduced emissions and profit, we cannot say with confidence which way the relationship runs. We again find no evidence that the cleanliness of the industries in which the firm has facilities (*Industry Emissions)* is associated with higher market valuation when we control for firm fixed effects.

The above analysis is illustrative of what we found throughout our analysis. Using different forms of models and different methods for measuring our variables, we often found an association between environmental and financial performance; however, we also found that variations in model specification, sample, and measurement method could reduce the significance of this effect below accepted thresholds (although it never reversed in sign). Out of the population of models we estimated, we have presented the most careful specifications and robust results.

Conclusions

In this paper, we further explore whether it "pays to be green." We use longitudinal data and statistical methods that reduce the potential for unobserved differences among firms to create a

Table 6 Summary of findings

Variable	*Description*	*Result*
Total emissions	Log of total emissions of facilities	Associated with financial performance, but direction of the relationship uncertain
Relative emissions	Emissions relative to other facilities of similar sector and size	Associated with financial performance, but direction of the relationship uncertain
Industry emissions	Emissions per employee for the sectors in which the firm operates	Apparent but possibly spurious association with financial performance; direction of relationship uncertain

misleading association between environmental and financial performance. We also test to see whether pollution reduction causes financial gain. Table 6 presents a summary of these results. We find evidence of an association between pollution reduction and financial gain, but we cannot prove the direction of causality. We also show that firms in cleaner industries have a higher Tobin's *q*, but we are unable to rule out possible confounding effects from fixed firm attributes. Moreover, we cannot show that firms that move to cleaner industries improve their financial performance.

Our research provides both additional support for the "pays to be green" hypothesis and suggests caution in interpreting its implications. Much of the variance in our study is attributed to firm-level differences. Better understanding of these differences might provide a richer understanding of profitable environmental improvement. It may be that it pays to reduce pollution by certain means and not others. Alternatively, it may be that only firms with certain attributes can profitably reduce their pollution.

Additional research is needed to explore how underlying firm characteristics affect the relationship between relative environmental performance and financial performance. The relationship between underlying capabilities and environmental management is likely to be complex and contingent. Environmental management and other capabilities may prove to be complementarities. Depending on industrial conditions, different bundles of capabilities may be important. Our research suggests that firm attributes and different strategies for environmental improvement may moderate the apparent link. It suggests that "When does it pay to be green?" may be a more important question than "Does it pay to be green?"

Notes

1. Interestingly, a follow-up study by Chen and Metcalf (1980) found that the effect disappeared when the analysis corrected for differences in size.
2. In contrast, White (1995) found that a group of six mutual funds that employed environmentally responsible screens performed worse than the Standard & Poor 500 in both nominal and risk-adjusted terms. White resolved the contradiction between the two findings by concluding that environmental performance and financial performance are indeed correlated, but managers of environmentally oriented mutual funds are less skilled than managers of other funds.
3. Such a sample is often referred to as a panel or longitudinal data set because we have multiple observations of the same entity over time.
4. We did not use the more complicated measure of Tobin's *q* as proposed by Lindenberg and Ross (1981) because past research in this domain has found little qualitative difference between this measure and the simplified version used in this analysis (Dowell et al. 2000). We chose to use Tobin's *q* rather than accounting measures of financial performance, such as return on assets or return on sales, because Tobin's *q* reflects expected future gains.
5. Ordinary least squares analysis is a technique for estimating the parameters of a mathematical model by minimizing the square of the difference between actual data and the predicted model.
6. Performing a Hausman test on the random-effects model suggests that a random-effects specification is recommended over a fixed-effects specification.
7. Estimating the model with a lagged dependent variable increases the likelihood of serial correlation. We use an instrumental variables ap-

proach to correct for this potential problem. The lagged values of the exogenous regressors are used as instruments. These regressors have the desirable property that they will not be correlated with the error but will be correlated with the lagged value of the dependent variable.

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Appendix: Environmental Performance Measures

To correct for differences in toxicity between emitted chemicals, we follow King and Lenox (2000) and weight each chemical by its toxicity using the "reportable quantities" (RQ) database in the U.S. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA 1980) statute. We construct aggregate releases for a given facility in a given year (E_{it}) by summing the weighted releases of the 246 chemicals that have been consistently a part of the TRI database.

$$E_{it} = \Sigma_{\forall c}\, w_c e_{cit} \qquad (1)$$

where E_{it} is aggregate emissions for facility i in year t, w_c is the toxicity weight for chemical c in year t, and e_{ci} is the pounds of emissions of chemical c.

Following King and Lenox (2000), we measure relative environmental performance at the facility level by estimating the production function relationship between facility size and aggregate toxic emissions for each four-digit SIC code within each year using standard ordinary least squares regression. The relative environmental performance of a facility (RE_{it}) is given by the standardized residual, or deviation, between observed and predicted emissions given the facility's size and industry sector. We must use employees to measure facility size because we have no measure of production units or sales at the facility level. Thus, if a facility emits more than predicted given its size and SIC code, it will have a positive residual and a positive score for environmental impact. We estimate a production function for each industry.

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

$$\ln E_{it} = \alpha_{jt} + \beta_{1jt}\,(\ln s_{it}) + \beta_{2jt}\,(\ln s_{it})^2 + \varepsilon_{jt} \qquad (3)$$

$$RE_{it} = e^{(\ln E_{it} - \ln E^*_{it})} \qquad (4)$$

where E^*_{it} is predicted emissions for facility i in year t, s_{it} is facility size, and α_{jt}, β_{1jt}, and β_{2jt} are the estimated coefficients for sector j in year t.

To create a firm-level measure of relative environmental performance, we calculate the weighted-average of the facility-level scores. We weight the scores by the percentage of total production that each facility represented for the company.

$$Relative\ Emissions_{nt} = \log \Sigma_{\forall} i \text{ in } n\ (s_{it}/s_{nt}) RE_{it} \qquad (5)$$

where s_{it} is facility i size in year t, and s_{nt} is firm size.

With the above data in hand, we can differentiate performance within an industry (*Relative Emissions*) from the degree to which a firm chooses to operate in dirty or clean industries (*Industry Emissions*). We calculate the dirtiness of the sector as the total emissions for the sector divided by the total number of employees in the sector, that is, emissions per employee. We create our firm-level measure (*Industry Emissions*) of the firm's tendency to operate in dirty or clean industry sectors by aggregating the dirtiness of the sectors in which a company owns a facility. In performing this aggregation, we use a weighted average, using the percentage of the company's total production in each sector for weights.

$$IE_{nt} = \ln[\Sigma_{\forall i \text{ in } n} (s_{it}/s_{nt})E_{jt}] \quad (6)$$
$$E_{jt} = \Sigma_{\forall i \text{ in } j} E_{it}$$

where IE_{nt} is weighted industry emissions for firm n in year t, and E_{jt} is total toxicity-weighted emissions per employee for industry j in year t.

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