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DOES IT PAY TO BE GREEN? AN EMPIRICAL EXAMINATION OF THE RELATIONSHIP BETWEEN EMISSION REDUCTION AND FIRM PERFORMANCE

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Evidence can be marshalled to support either the view that pollution abatement is a cost burden on firms and is detrimental to competitiveness, or that reducing emissions increases efficiency and saves money, giving firms a cost advantage. In an effort to resolve this seeming paradox, the relationship between emissions reduction and firm performance is examined empirically for a sample of S&P 500 firms using data drawn from the Investor Responsibility Research Center's Corporate Environmental Profile and Compustat. The results indicate that efforts to prevent pollution and reduce emissions drop to the 'bottom line' within one to two years of initiation and that those firms with the highest emission levels stand the most to gain.

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INTRODUCTION

In 1975, 3M Company pioneered a new path to control pollution. Rather than merely collecting and treating waste after it had been created (as required by law), they also sought to prevent the creation of waste in the first place. The program, Pollution Prevention Pays (3P), served as a model for scores of other companies over the next 20 years. For the first time, line workers and employees were involved (rather than just pollution control engineers and lawyers) in the identification of waste reduction opportunities and projects. Between 1975 and 1990, 3M reduced their total pollution by over 530,000 tons (a 50% reduction in total emissions) and, according to company sources, saved over $500 million through lower raw material, compliance, disposal and liability costs. In 1990, 3M embarked on 3P+. This program sought to reduce the remaining emissions by 90% by the year 2000, with the ultimate goal being zero pollution (3M, 1992). Based on the 3M example, many companies and analysts have adopted a 'win–win' view of the relationship between business and the environment: strict environmental regulation to lower emissions might actually improve competitiveness by encouraging efficiency and innovation. Proponents of this view include US Vice-President Al Gore (Gore, 1992), Michael Porter (Porter and van der Linde, 1995), Robert Repetto (Repetto, 1995) and many others (e.g. Smart, 1992; Willig, 1994; Bonifant *et al.*, 1995).

Coincident with this experience, however, are some sharply contrasting facts. Expenditures for pollution control in the US now represent more than 2% of the GNP, approaching $200 billion per year (EPA, 1990). It is estimated that compliance with the new Clean Air Act alone will cost the US oil industry $37 billion over the next decade. Texaco, for example, plans to invest $1.5 billion per year over the next five years on environmental compliance and emission reduction for a total investment of over $7 billion, three times the book value of the company and twice its current asset base. Indeed, environmental costs now account for as much as 20% of corporate capital expenditures in pollution-intensive industries such as petrochemicals (Buzzelli, pers. comm.). These data suggest a potential trade-off between environmental and economic goals. Adherents to this view include Haveman and Christainsen (1981), Portney (1994) and McKinsey's environmental management practice group. They write: 'The idea that environmental initiatives will systematically increase profitability has tremendous appeal. Unfortunately, this popular idea is also unrealistic . . . Talk is cheap, environmental efforts are not' (Walley and Whitehead, 1994: 46–47).

These competing streams of experience seem paradoxical. They raise fundamental questions about the economic and strategic implications of environmental regulation and corporate 'greening'. Does reducing pollution and emissions really produce bottom-line results or just add investment burden and cost? Although a few investigators have begun to tackle aspects of this conundrum (e.g. Russo and Fouts, 1993; Cohen *et al.*, 1995; Douglas and Judge, 1995; Hamilton, 1995; Levy, 1995; White, 1995), we were unable to find any direct empirical examination of this question. This paper therefore examines specifically the relationship between emissions reduction and firm performance in S&P 500 firms using two databases: Environmental performance and emissions reduction measures were derived from the Investor Responsibility Research Center's (IRRC's) Corporate Environmental Profile. Operating and financial performance measures as well as selected control variables were operationalized from Compustat.

THEORY AND HYPOTHESES

Emission reduction can be achieved through two primary means: (i) **control**, emissions and effluents are trapped, stored, treated and disposed of using pollution control equipment; or (ii) **prevention**, emissions and effluents are reduced, changed or prevented altogether through better housekeeping, material substitution, recycling or process innovation (Frosch and Gallopoulos, 1989; Cairncross, 1991; Willig, 1994). The latter approach prevents pollution during the manufacturing process itself, at the same time that it produces saleable goods, whereas the former approach entails expensive, non-productive pollution control equipment to achieve compliance with existing regulations. Reducing emissions through pollution prevention would thus appear to be much cheaper than cleaning it up at the 'end of the pipe' (Smart, 1992).

The logic for pollution prevention is analogous to the quality management principle that preventing defects is superior to finding and fixing them after the fact (Imai, 1986). The philosophy holds that pollution is a sign of inefficiency within manufacturing processes and waste is a nonrecoverable cost (Shrivastava and Hart, 1992). By integrating pollution prevention into existing total quality management (TQM) programs through the use of employee involvement (Lawler, 1986; Cole, 1991) and 'green' teams (Makower, 1993; Willig, 1994), significant reductions in emissions appear possible using continuous improvement methods focused on environmental objectives (Rooney, 1993). Thus not only does pollution prevention appear to save the cost of installing and operating end of pipe pollution control devices, but it may actually increase productivity and efficiency – less waste means a better utilization of inputs resulting in lower raw material and waste disposal costs (Young, 1991; Schmidheiny, 1992). Furthermore, pollution prevention strategies offer the potential to cut emissions well below the levels required by law, reducing the firm's compliance and liability costs (Rooney, 1993).

There would appear, however, to be some time lag between the initiation of emissions reduction efforts and the realization of 'bottom line' benefits. Firstly, pollution prevention requires up-front investment in training and equipment. Just as in TQM, pollution prevention appears to require the proper bounding of the system or process to be improved, the involvement of key stakeholders in the process and the establishment of clear goals and targets for improvement (Ishikawa and Lu, 1985; Imai, 1986). Secondly, the savings from emissions reduction may take some time to be realized as renegotiation of supply and waste disposal contracts and internal reorganization may be required (White *et al.*, 1993; Wood, 1994). For example, cutting emissions by 50% may mean that dramatically less raw material is needed. Supply contract renegotiations may be required to reduce the inventory to realize the cost savings. Similarly, drastically lower emissions and waste may also mean renegotiating waste disposal contracts or storage and treatment arrangements. Finally, to realize savings in compliance costs it may be necessary to reassign or reduce internal personnel involved in legal compliance or pollution control activities (Hunt and Auster, 1990).

Evidence also suggests that in the early stages of pollution prevention there is a great deal of 'low-hanging fruit' – easy and inexpensive behavioral and material changes that result in large emission reductions relative to costs (Rooney, 1993; Hart, 1994). As the firm's environmental performance improves, however, further reductions in emissions become progressively more difficult, often requiring more significant changes in processes or even entirely new production technology (Frosch and Gallopoulos, 1989). For example, a pulp plant might make significant reductions in emissions through better housekeeping, equipment maintenance and incremental process improvement. Eventually, however, diminishing returns set in and no significant additional reduction is possible without entirely new technology such as de-ink pulping equipment for processing recycled fibre or chlorine-free bleaching equipment to eliminate organochloride emissions. Thus as the firm moves closer to 'zero pollution', emission reductions will become more technology- and capital-intensive (Walley and Whitehead, 1994).

We consider five hypotheses.

(i) Hypothesis 1. Emissions reduction in time period t will enhance operating performance (ROS) in time period $t + 1$ through lower raw material, compliance, disposal and liability costs.
(ii) Hypothesis 2. Emissions reduction in time period t will enhance operating performance (ROA) in time period $t + 1$ through the more efficient use of assets.
(iii) Hypothesis 3. Emissions reduction in time period t will enhance financial performance (ROE) in time period $t + 1$ through corresponding improvements in ROS and ROA.
(iv) Hypothesis 4. Emissions reduction in time period t will show no relationship to operating or financial performance in that period as time is required for cost savings to be captured.
(v) Hypothesis 5. Emissions reduction will enhance the operating and financial performance more for firms with higher emissions levels than those with lower emissions levels.

METHODS AND MEASURES

The sample of firms for this study was drawn from the Standard and Poor's 500 list of corporations. Although this population is clearly biased towards the largest of firms, this was not deemed to be a problem for this study as there was ample evidence that environmental performance and emissions levels varied considerably among the largest firms (e.g. Rice, 1993).

Two screens were applied in selecting firms. Firstly, only those firms involved in manufacturing, mining or production of some kind (SIC codes below 5000) were selected, as the main research variable, emissions reduction, was most salient to these firms. Secondly, as the pollution intensity of industries varies widely, a minimum of four firms per industry (four digit level) was required to ensure stable and reliable industry means. After applying these two screens to the population, we ended up with 127 firms in the study sample.

The independent variable, emissions reduction (EMRED), was derived from the IRRC's 1993 Corporate Environmental Profile. This data set provides a summary of the reported emissions of selected pollutants from domestic (US) manufacturing facilities owned by each company and its subsidiaries. [These reported emissions are drawn from the toxic release inventory (TRI), an annual report of releases of over 300 chemicals required for manufacturing facilities in the US under the Emergency Planning and Community Right-to-Know Act 1986 (EPCRA). For a discussion of the advantages and disadvantages of the TRI as a measure of environmental performance, see Hamilton (1995).] It includes a tabulation of an emissions efficiency index, which is the ratio of reported emissions in pounds to the company's revenues in thousands of dollars. To measure emissions reduction, we computed the percentage change for each firm in the emissions efficiency index from 1988 to 1989. [This period (1988–1989) was chosen as the most appropriate to measure emissions reduction for several reasons. Firstly, 1988 marked the first year that facilities in the US were required by law to disclose their emission levels under the TRI. Secondly, 1989 was the most recent year for which complete emissions data were available in the 1993 IRRC Corporate Environmental Profile.]

The dependent variables, operating and financial performance were secured from the Compustat database. Operating performance data – return on sales (ROS) and return on assets (ROA) – and financial performance data – return on equity (ROE) – for each firm were collected for the years 1989–1992. Several control variables were also compiled for this period, both at the firm and industry level. Firm-level controls included R&D intensity (RDSALES), advertising intensity (ADSALES), capital intensity (KAPSALES) and leverage (KAPSTRUCTURE) [Although leverage (i.e. debt to equity ratio) is most likely to influence ROE rather than ROS or ROA, we included leverage controls in all the analyses for completeness.] As the performance variables were unstandardized, it was necessary to include these control variables to blunt the effect of differences in firm commitments

Table 1. Impact of emissions reduction on firm performance. Dependent variable: ROS.

	1989	1990	1991	1992
INTERCEPT	0.0150	0.0080	0.1000***	−0.0124
INDUSTRY	−0.0065***	−0.0087***	−0.0054**	−0.0082***
KAPSTRUCTURE	−0.0000	0.0011	0.0017	−0.0039
KAPSALES	0.0375**	0.0229**	−0.1111***	0.0231
ADSALES	−0.0415	0.1060	0.1452	0.2625
RDSALES	−0.0184	−0.1527	0.5016*	0.0161
EMRED	−0.0014	0.0122*	0.0204**	0.0122*
AdjR2	0.4307	0.4889	0.4247	0.4693
F	12.979***	15.665***	12.318***	13.972***

$P \leqslant 0.05^{*}$; $P \leqslant 0.01^{**}$; and $P \leqslant 0.001^{***}$.

resources and strategies (Wernerfelt, 1984; Ghemawat, 1991) [firm size was initially included among the controls, but was later dropped as it turned out not to be a significant factor]. Industry effects (Porter, 1980) were controlled by including the industry (four digit level) average performance for each example as a predictor in all analyses (INDUSTRY). Including the controls in the analysis forced the emissions reduction measure to explain variance in performance above and beyond these powerful firm- and industry-level predictors.

Multiple regression analysis was used to test the hypotheses. Three separate models were run for ROS, ROA and ROE as dependent variables. To test hypotheses 1–4, an initial run was made with 1988–1989 independent variables and 1989 dependent variables (time t). Additional runs were then made lagging the dependent variables one additional year each time, i.e. 1990 (time $t + 1$), 1991 (time $t + 2$) and 1992 (time $t+3$). To test hypothesis 5, the sample was split on the industry means of the emissions efficiency index for 1988, yielding high and low polluting firms within each industry. These firms were then aggregated into either a high or low polluting subsample. This procedure ensured that the most and least polluting firms (rather than industries) were captured. Separate regressions were then run on these two subsamples.

RESULTS

The results for the full sample are presented in Tables 1 (ROS), 2 (ROA) and 3 (ROE). The results for the split sample are presented in Tables 4 (ROS), 5 (ROA) and 6 (ROE). An extensive sensitivity analysis was conducted to ensure the robustness of these results. For example, both medians and means were used as well as adjusted and unadjusted ROA measures. The results were unaffected by these minor changes in variable definition. Tables 1–3 clearly show that reducing emissions has an effect on the operating and financial performance net of the control variables of R&D intensity, capital intensity, advertising intensity, leverage and industry-average performance. [The relationships among the control variables and the three measures of firm performance are generally as would be expected: At the firm level, leverage (KAPSTRUCTURE) is significant only in relation to ROE, and is a positive factor in 1989, turning negative in 1991 with the onset of the recession in the US. Capital intensity (KAPSALES) is a significant predictor for both ROS and ROA, again turning negative in 1991 with the advent of the recession. Advertising intensity (ADSALES) is a consistently positive predictor of both ROA and ROE, whereas R&D intensity (RDSALES) is a drag on ROA until the recession, when it becomes positively associated with both ROS and ROA. Finally, the industry

Table 2. Impact of emissions reduction on firm performance. Dependent variable: ROA.

	1989	1990	1991	1992
INTERCEPT	0.0439*	0.0184	0.0345	0.0094
INDUSTRY	0.0082	−0.0190	−0.0078	−0.0095
KAPSTRUCTURE	−0.0007	0.0004	−0.0006	−0.0053
KAPSALES	0.0012	0.0012	−0.0411*	−0.0067
ADSALES	0.4858**	0.8400***	0.7506***	0.8265***
RDSALES	−0.2524*	0.1425	0.5392**	0.3577*
EMRED	−0.0000	0.0143*	0.0168*	0.0138*
AjdR2	0.1113	0.1980	0.2903	0.2744
F	2.984*	4.785***	7.272***	6.547***

$P \leqslant 0.05^{*}$; $P \leqslant 0.01^{**}$; and $P \leqslant 0.001^{***}$.

Table 3. Impact of emissions reduction on firm performance. Dependent variable: ROE.

	1989	1990	1991	1992
INTERCEPT	0.1025*	0.0471	0.0648	−0.0329
INDUSTRY	−0.0159	0.0084	−0.0227	−0.0633**
KAPSTRUCTURE	0.0522***	0.0113	−0.0523***	−0.0961***
KAPSALES	−0.0043	0.0021	−0.0729	0.0273
ADSALES	1.2714***	2.3046***	2.2542***	3.0306***
RDSALES	0.1357	0.0470	0.7794	0.3685
EMRED	−0.006	0.0250	0.0501*	0.0643*
AdjR2	0.3611	0.2443	0.2744	0.4282
F	9.950***	5.958**	6.798***	11.982***

$P \leqslant 0.05$*; $P \leqslant 0.01$**; and $P \leqslant 0.001$***.

control (INDUSTRY) shows a consistently negative sign with performance and displays a negative and significant relationship with ROS. This curious result can be explained as a sampling bias: Our study included only the largest (i.e. dominant) firms in each industry.]

The relationship between 1988–1989 emissions reduction (EMRED) and both ROS and ROA became significant in 1990, became even stronger in 1991, then began to dwindle in 1992. Thus hypotheses 1 and 2 are confirmed: emissions reduction in time period t enhances operating performance in time period $t + 1$. Furthermore, the effect continues for at least two more years, peaking in period $t + 2$. Interestingly, the relationship between EMRED and ROE did not become significant until 1991 and gained a little in strength the following year. Thus hypothesis 3 is only partially confirmed: emissions reduction in time period t enhances financial performance in time period $t + 2$ rather than period $t + 1$. EMRED had no significant effect on any of the performance measures in 1989, confirming hypothesis 4: emissions reduction in time period t shows no relationship to operating or financial performance in that period as time is required for the cost savings to be captured.

Finally, the results of the split sample analysis (Tables 4–6) show that EMRED had no significant effect on performance in any of the years for the low polluting subsample, but had a positive and significant effect on performance for the high polluting subsample. Thus hypothesis 5 is also confirmed: emissions reduction enhances the operating and financial performance more for firms with high emissions levels than for firms with low emissions levels.

DISCUSSION

The results of this study suggest that it does indeed pay to be green. Efforts to reduce emissions through pollution prevention appear to drop to the bottom line within one to two years after initiation. Operating performance (ROS, ROA) is significantly

Table 4. Emissions efficiency subsetting. Dependent variable: ROS.

	1989	1990	1991	1992
High polluting ($n = 52$)				
INTERCEPT	0.0271	0.0538	0.0571	0.0686
INDUSTRY	−0.0034***	−0.0046***	−0.0038**	−0.0048***
KAPSTRUCTURE	−0.0194	−0.0168	−0.0140	−0.0094
KAPSALES	0.0285	−0.0082	−0.0483	−0.0610
ADSALES	0.0732	0.1200	0.1048	0.0459
RDSALES	0.1377	0.0006	0.5533*	0.2732
EMRED	0.0013	0.0123*	0.0168*	0.0193*
AdjR2	0.4899	0.4625	0.5406	0.5427
F	7.723***	7.024***	9.237***	8.912***
Low polluting ($n = 75$)				
INTERCEPT	0.0139	−0.0042	0.1168***	−0.0241
INDUSTRY	−0.0025**	−0.0035**	−0.0020	−0.0041**
KAPSTRUCTURE	−0.0001	0.0009	0.0010	−0.0021
KAPSALES	0.0482**	0.0332*	−0.1190***	0.0395
ADSALES	0.1159	0.3343	0.4269	0.3820
RDSALES	−0.1328	−0.2097	0.0887	−0.0741
EMRED	−0.0168	0.0051	0.0042	0.0004
AdjR2	0.3582	0.4411	0.4395	0.4480
F	5.838***	7.444***	7.403***	7.357***

Table 5. Emissions efficiency subsetting. Dependent variable: ROA.

	1989	1990	1991	1992
High polluting ($n = 52$)				
INTERCEPT	0.0686*	0.0949**	0.0824*	0.0781
INDUSTRY	−0.1872**	−0.2611***	−0.1763*	−0.1751*
KAPSTRUCTURE	−0.0190	−0.0196	−0.0126	−0.0107
KAPSALES	−0.0113	−0.0387	−0.0659	−0.0655
ADSALES	0.0899	0.1592	0.1812	0.0385
RDSALES	0.0971	−0.1237	0.4455	0.3475
EMRED	0.0036	0.0121*	0.0153*	0.0178*
AdjR2	0.3324	0.4082	0.4743	0.3840
F	4.485**	5.828***	7.316***	5.155***
Low polluting ($n = 75$)				
INTERCEPT	0.0708**	0.0428	0.0682*	0.0357
INDUSTRY	−0.1439*	−0.2473**	−0.2350*	−0.2304**
KAPSTRUCTURE	−0.0004	0.0008	0.0014	−0.0021
KAPSALES	−0.0030	−0.0082	−0.0543**	−0.0094
ADSALES	0.2669	0.3965	0.3453	0.5837*
RDSALES	−0.2225	−0.3814	−0.1248	−0.2970
EMRED	−0.0249	0.0111	0.0143	0.0062
AdjR2	0.2210	0.3546	0.3375	0.4514
F	3.459**	5.488***	5.161***	7.445***

benefited in the following year, whereas it takes about two years before financial performance (ROE) is affected. These are general findings based on a sample drawn from a broad range of industries; the results may be even more significant for particular industries where emissions and effluents are especially salient.

The surprising finding of a longer lag between emissions reduction and impact on ROE merits some discussion. There seem to be at least two factors which could explain this result. Firstly, ROE reflects not only operating efficiency, but also the capital structure of the firm. The impact of emissions reduction on ROE thus works through its effect on ROS and ROA with capital structure as a confounding factor. Hence a relationship that is less immediate than that between emissions reduction and ROS/ROA is not particularly surprising.

A second consideration in explaining the lagged relationship between emissions reduction and ROE has to do with reputation and cost of capital. The environmental profile of a company is known to have an effect on its liability exposure, reputation and market value (Barth and McNichols, 1993; White, 1995). Poor environmental performance may thus affect the firm's cost of capital. This 'cost of capital' effect is likely to affect the ROE with a longer lag than the direct effect through ROS and ROA as it requires that (i) the market becomes aware of the firm's environmental performance and

Table 6. Emissions efficiency subsetting. Dependent variable: ROE.

	1989	1990	1991	1992
High polluting ($n = 52$)				
INTERCEPT	0.1321	0.1808	0.1910	0.1304
INDUSTRY	0.0023	0.0053	0.0178	0.0524
KAPSTRUCTURE	0.0227	0.0369	0.0080	−0.1073
KAPSALES	−0.0595	−0.1518	−0.2479*	−0.2882
ADSALES	1.5143	2.4175*	2.0920*	3.7537
RDSALES	0.7141	0.7169	1.7640**	2.1782
EMRED	0.006	0.0257	0.0501**	0.1249*
AdjR2	0.0864	0.2434	0.3453	0.1982
F	1.662	3.252*	4.691**	2.648*
Low polluting ($n = 75$)				
INTERCEPT	0.1324**	0.0229	0.0292	0.0955
INDUSTRY	−0.0409	−0.0005	0.0081	−0.0073
KAPSTRUCTURE	0.0514***	0.0103	−0.0558**	−0.1023***
KAPSALES	0.0169	0.0232	−0.0485	0.0047
ADSALES	1.281**	2.1849***	2.3373*	2.6070***
RDSALES	−0.7051	−0.3785	0.3885	−0.3712
EMRED	−0.0681*	0.0260	0.0606	0.0063
AdjR2	0.5149	0.2283	0.2231	0.6411
F	10.2***	3.416**	3.345**	14.991***

reflects this in the cost of capital, and (ii) the firm raises capital at this new cost level. In this analysis we cannot distinguish between these two explanations and leave this issue for subsequent research.

As expected, the biggest bottom line benefits accrue to the 'high polluters' where there are plenty of low-cost improvements to be made. It appears that the closer a firm gets to 'zero pollution' the more expensive it gets, as further reductions mean rising capital and technology investments. Rising costs thus appear to offset cost reductions realized from the elimination of the remaining emissions. However, the results also suggest that the marginal costs of reducing emissions seldom exceed marginal benefits. Indeed, although up-front investment may increase, the data suggest that a strategy to reduce emissions does not negatively affect the bottom line, even among those firms that have already drastically reduced emission levels. It must be remembered, however, that this study was based on emission reductions data from the 1988–1989 time period, when pollution-intensive industries such as petrochemicals, forest products and automobiles had not yet achieved dramatic levels of emission reduction (i.e. there was still a great deal of 'low-hanging fruit' to be picked). Future work should examine whether or not these findings hold even after industry-average emission levels have been drastically reduced. For example, once the data become available, it would be instructive to replicate this study with 1992–1993 emissions reduction data and 1993 and 1994 performance measures. Future work should also take a more fine-grained approach to measuring emissions reduction by weighting chemicals according to their relative toxicity rather than just tabulating total toxic releases in pounds.

A narrow reading of these results suggests that pollution prevention pays, but only for the slower, more inefficient firms. However, there is an alternative interpretation of this finding: The early moving (lower polluting) firms may be moving on to other more advanced strategies that build on low emissions, but that involve other sources of sustainable competitive advantage (Ghemawat, 1986). For example, firms with very low manufacturing emissions relative to competitors may be able to gain a first mover advantage in emerging green product markets (Russo and Fouts, 1993). Indeed, attempts to differentiate products as environmentally responsible while continuing to produce comparatively high levels of waste and emissions in production is risky as outside observers (e.g. environmental groups) can easily expose this anomaly, destroying firm credibility and reputation. It has been said that 'if you green your operations, the products will follow'. In the language of the resource-based view (e.g. Dierickx and Cool, 1989; Barney, 1991) a green product strategy may be 'path dependent' on pollution prevention and emissions reduction (Hart, 1995).

Thus a fuller examination of the question 'does it pay to be green' will require an empirical study of firm strategies that extends beyond lowering production emissions (Kleiner, 1991; Hart, 1995), including product stewardship strategies based on the principles of 'design for environment' (Allenby and Fullerton, 1992) and an orientation towards sustainable technology development in emerging markets (Schmidheiny, 1992; Gladwin *et al.*, 1995). More targeted sectoral analysis is also warranted to examine the specific relationships between emissions reduction and firm performance at the industry level. For example, future work might compare models for the chemical industry (an 'early mover' industry) with the forest products industry (a 'late mover' industry). Also, comparing the relationships between environmental and business performance across industries with different technologies and product life cycles (e.g. electronics versus pharmaceuticals) might be important and instructive.

Finally, future work will need to examine critically the 'reverse causality' hypothesis: do lower emissions lead to enhanced profitability or do more profitable companies tend to invest in pollution prevention and emissions reduction activities? This is an important question requiring serious examination. As we had only one year of emission reduction measures available at the time of our study, we were unable to rule out the reverse causality hypothesis. However, future research will be able to incorporate longitudinal measures both for the environmental and firm performance measures. Our hunch is that a 'virtuous circle' exists with regard to the relationship between pollution prevention and firm performance – that is, firms can realize cost savings and plough these savings back into further emission reduction projects for a number of years before the investment/savings balance turns negative. Eventually, however, major new investments in process technology and/or product design will be required to realize further gains. At this point, the firm must shift to a new strategic logic (e.g. product stewardship) for it to continue to 'pay to be green'.

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