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**ENVIRONMENTAL SELF-REGULATION: IMPLICATIONS FOR ENVIRONMENTAL  
EFFICIENCY AND PROFITABILITY**

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# **ENVIRONMENTAL SELF-REGULATION: IMPLICATIONS FOR ENVIRONMENTAL EFFICIENCY AND PROFITABILITY**

## **Abstract**

There continues to remain considerable controversy about the potential for firms to improve environmental performance while simultaneously increasing their productivity and about the benefits of environmental self-regulation (ESR) for firms. This paper uses non-parametric techniques to examine the “win-win” potential to simultaneously reduce input-use and pollution while increasing output, for a sample of S&P 500 firms. An environmental efficiency index that indicates the costs of increasing efficiency when pollution disposal is costly is developed for each firm. We find that win-win opportunities are non-existent or modest for 89 percent of the sample firms. The maximum extent to which efficiency gains could increase output and reduce aggregate toxic releases varies across industries and ranges from 1% to 6% and from 0.1% to 4%, respectively. We find that ESR does increase environmental efficiency of firms indicating that it leads them to internalize their environmental externalities. ESR is found to have both a direct effect on market values, as measured by Tobin’s  $q$ , as well an indirect effect, by influencing environmental efficiency, except in industries that are either very small or very large polluters. Additionally, we find that poor environmental performance and greater risk of environmental liabilities have a significant negative impact on profitability.

## **ENVIRONMENTAL SELF-REGULATION: IMPLICATIONS FOR ENVIRONMENTAL EFFICIENCY AND PROFITABILITY**

Firms are increasingly becoming proactive in their approach to dealing with the environmentally harmful by-products of their production processes. A growing number of firms are participating in voluntary programs such as 33/50 Program, Green Lights and WasteWise<sup>1</sup> and adopting environmentally friendly management practices such as formally articulating environmental goals and plans; implementing those plans by assigning responsibility and providing resources, training and incentives to employees; establishing organizational structures to gather information and track progress towards meeting environmental targets, and applying the concept of total quality management (TQM) to make continuous efforts at improving efficiency and performance across the firm's activities including its environmental performance. These initiatives represent a self-motivated effort at internalizing environmental externalities and integrating environment and production decisions. We refer to these efforts as environmental self-regulation (ESR) and recognize that firms have flexibility in the extent to which they undertake ESR.

ESR may be motivated by a number of factors, such as the view that pollution is a defect of the production process and represents inefficient and wasteful use of resources (Porter and van der Linde, 1995a, 1995b), the desire of a firm to differentiate its products and appeal to "green consumers" and investors in order to gain market share and lower the costs of raising capital from the market, as well as by the opportunity it offers to lower the costs of compliance with existing or anticipated regulations (Khanna, 2001). By fostering decision-making based on full information about the processes, technologies and resources needed to make environmental improvements, ESR can enable firms to select pollution control strategies that are cost-effective.

If “win-win” opportunities for pollution control (that reduce pollution and save money for the firm) exist, ESR may allow firms to discover them as efforts to reduce waste generation lead to improvements in process efficiency of the firm and increase competitive advantage and value for shareholders (Alberini and Segerson, 2002; Coglianesi and Nash, 2001).

Although this potential for “win-win” opportunities is appealing to firms and policy makers and been supported by some scholars (Porter and van der Linde, 1995a, 1995b), others such as Palmer et al (1995) have questioned the presence of such opportunities and the existence of inefficiency in firms. Walley and Whitehead (1994) suggest that environmental programs and improvements are costly and have little economic payback. ESR imposes costs of coordination, employee training, audits, product and process changes and although it may enable firms to identify some “low hanging fruit,” it may also impose real economic costs that overshadow any gains from its adoption.

This paper has three purposes. First, it seeks to determine the extent to which there exists productive and environmental inefficiency among a sample of S&P 500 firms that produce both priced or desirable outputs and undesirable outputs or pollutants. To capture a firm’s performance over multiple dimensions with a single measure we use data envelopment analysis (DEA) developed by Fare et al. (1989). We measure productive efficiency using a hyperbolic measure of distance of each firm from the best-practice industry frontier<sup>2</sup>; this distance measures the potential for simultaneous increase in outputs and contraction in inputs and undesirable outputs. Environmental efficiency is measured by the ratio of the hyperbolic measures of efficiency under two alternative assumptions about the disposability of undesirable outputs<sup>3</sup> (Fare, et al., 1989). Environmental efficiency is high if the opportunity cost (in terms of loss of desirable outputs) of reducing undesirable outputs is low. Boyd and McClelland (1999) estimate the environmental efficiency of firms in the paper industry while Zofio and Preito (2001) and

Zaim and Taskin (2000) use macro data to estimate the environmental efficiency of countries. This paper contributes to this literature by investigating not only the extent of environmental efficiency among firms but also the determinants of its level and its impact on a firm's profitability. In particular, the second purpose of this paper is to explore whether firms that undertake more comprehensive ESR choose production plans (that is, mix of desirable outputs, pollution and inputs), which are more environmentally efficient, while controlling for other firm-specific characteristics that can also influence environmental efficiency of a firm.

This paper differs from existing studies that have focused on the factors motivating firms to adopt environmentally friendly practices (Henriques and Sadosky, 1997; Dasgupta et al., 2000; Khanna and Anton, 2002a, 2002b) and on examining the impact of adoption on environmental performance. Studies examining the latter issue have found mixed evidence. While Dasgupta et al. (2000) find that adoption of ISO 14001 management practices led to a significant improvement in the compliance status of Mexican firms, King and Lenox (2000) find that participation in the Responsible Care program with its codes of management had an insignificant impact on the performance of members as compared to non-members. Anton et al. (2002) find that adoption of a higher quality environmental management system did have a negative impact on its toxic pollution per unit output. This paper examines the impact of ESR on a stricter measure of performance, environmental efficiency rather than pollution per unit output.

The third purpose of this paper is to examine whether the market value of a firm reflects the value (if any) that investors attach to proactive ESR and the environmental efficiency of a firm. By interpreting environmental efficiency using Georgescu-Rosen's (1951) notion of "return to the dollar" we show that it is higher for firms that are more efficient in the conventional sense (when pollution generation is disregarded) and that have the highest potential to increase their return to the dollar even when pollution generation is constrained. Although investors may not

directly observe the environmental efficiency of a firm, *per se*, our purpose here is to examine if it can explain systematic differences in profitability of firms.

A number of studies have examined the relationship between environmental and financial performance of firms using event study methods (Hamilton, 1995; Konar and Cohen, 1997; Khanna et al., 1998; Klassen and McLaughlin, 1996) and found that in general stock prices are sensitive to environmental performance of firms, although in some cases this evidence is weak (see survey by Alberini and Segerson, 2002). Some studies have also used multivariate regression methods to examine the effect of pollution output ratio (Konar and Cohen, 2000), the extent of pollution reduction (Hart and Ahuja, 1996) and adoption of voluntary environmentally friendly initiatives (Khanna and Damon, 1999; Dowell et al., 2000) on firm profitability. These studies find that environmental performance/efforts do have a significant positive impact on profitability, either immediately or with some lag. This study extends that literature by examining both the direct effect (if any) of ESR on firm profitability (through a social reputation effect) as well any indirect effect it may have (by raising environmental efficiency and therefore competitiveness) while controlling for other aspects of environmental performance (such as its pollution intensity and risk of environmental liabilities) that are more directly observable and could also affect profitability.

The remainder of the paper is organized as follows: Section II presents the conceptual framework underlying this study. The data and the empirical methods are described in Section III while the results of our analysis are presented in Section IV. Conclusions and policy implications are discussed in Section V.

## II. Conceptual Framework

### *Measurement of Environmental Efficiency of a Firm*

We use DEA to assess the environmental performance of a set of producers by grading their ability to produce the largest equiproportional increase in the desirable output and decrease in the bad outputs. A nonparametric approach is used to obtain the piecewise linear production frontier defined by the best practice firms from observed data on inputs, outputs and pollution, against which we compare each firm's performance. From this frontier, a hyperbolic efficiency measure in which desirable outputs are expanded and undesirable outputs are contracted while simultaneously contracting inputs is defined. Desirable outputs are assumed to be strongly disposable which implies that the disposal of any output can be achieved without incurring any cost in terms of reduced production of other outputs. Undesirable outputs may, however, be only weakly disposable; that is, the plant may have to expend resources (or reduce the good output) to reduce them. The environmental efficiency index is developed by comparing the maximum simultaneous equiproportionate expansion of desirable outputs and contraction of inputs and undesirable outputs possible when pollution disposal is costless to that possible when it is costly. It represents the extent to which a firm would be constrained in increasing its desirable output when pollution reduction is costly. Firms with lower opportunity costs of pollution reduction are considered to be more environmentally efficient.

To estimate hyperbolic efficiency under alternative assumptions about disposability of pollution, we denote inputs by  $x = (x_1, x_2, \dots, x_N)\hat{\mathbf{I}}\hat{\mathbf{A}}_+^N$ , desirable outputs by  $y = (y_1, y_2, \dots, y_M)\hat{\mathbf{I}}\hat{\mathbf{A}}_+^M$  and undesirable outputs by  $b = (b_1, b_2, \dots, b_J)\hat{\mathbf{I}}\hat{\mathbf{A}}_+^J$ . Together they define the technology as:  $T = \{(x, y, b): x \text{ can produce } (y, b)\}$  (1)

Under the assumption that the production process satisfies strong disposability of both good and bad outputs and inputs, the constant returns to scale (CRS) output set  $P_s$  can be constructed as

$$\text{follows: } P_s = \{(x, y, b): zM^{\geq} y, zJ^{\geq} b, zN \leq x, z\hat{I}\hat{A}_+^K\} \quad (2)$$

where  $z$  is a  $K \times 1$  intensity vector, and  $K$  is the number of firms.  $M$ ,  $J$  and  $N$  are the matrices of the good and bad outputs, and inputs respectively. Similarly, a CRS technology assuming weak disposability of bad outputs can be defined as:

$$P_w = \{(x, y, b): zM^{\geq} y, zJ = b, zN \leq x, z\hat{I}\hat{A}_+^K\} \quad (3)$$

Intuitively these definitions construct a reference technology from the observed inputs and outputs relative to which the technical efficiency of each firm can be calculated. The hyperbolic measure of technical efficiency for a CRS technology is defined as:

$$F(x_k, y_k, b_k) = \min\{I: (Ix_k, I^{-1}y_k, Ib_k)\hat{I}P\} \quad (4)$$

Under the assumption of strong disposability of undesirable outputs, this can be computed for every firm  $k$  as the solution to the following programming problem:

$$F_s(x_k, y_k, b_k) = \min I_s \quad (\text{LP1})$$

subject to:  $zM^{\geq} I_s^{-1}y_k; zJ^{\geq} I_s b_k; zN \leq I_s x_k; z\hat{I}\hat{A}_+^K$  (5)

This particular problem is non-linear in  $I_s$  and thus cannot be solved by linear programming techniques. Fare et al (1989), therefore, proposed taking a linear approximation to the non-linear set of constraints. However, Zofio and Prieto (2001) show that the linear approximation is equal to the non-linear restriction only if  $I_s=1$ ; when  $I_s$  diverges from unity the gap between the true and approximate  $I_s$  values increases making results sensitive to that difference. The above problem can be transformed into an easily computable linear programming problem by multiplying both sides of each constraint by  $I_s$ , defining  $G_s = I_s^2$  and  $Z = I_s z$  and solving for  $\sqrt{G_s}$ . Here it should be noted that for any  $(x_k, y_k, b_k) \hat{I}P$ ,  $I_s \hat{I} [0, 1]$  measures the maximum equiproportionate contraction of all inputs and bad outputs and expansion of all good outputs that remain technically feasible. The new linear programming problem can be written as

$$F_s(x_k, y_k, b_k) = \min G_s \quad (\text{LP2})$$

$$\text{subject to: } ZM \geq y_k, ZJ \geq G_s b_k, ZN \leq G_s x_k, Z \hat{I} \hat{A}_+^K \quad (6)$$

Fare et al. (2002) relate this measure of technical efficiency to the ‘return to the dollar’ by introducing prices and profits. If pollution disposal is assumed to be free (that is, pollution generation is not penalized) then the maximum profits of a firm,  $p_s$ , can be defined using a vector of output prices  $p$  and a vector of input prices  $r$  as:  $p_s(p,r) = \max \{py-rx : (x,y,b) \in P_s\}$ .

We can also write:  $p_s(p,r) \geq py-rx$  for all  $(x,y,b) \in P_s$ . Since  $(\sqrt{G_s} x_k, \sqrt{G_s}^{-1} y_k, \sqrt{G_s} b_k) \in P_s$ , we have  $p_s(p,r) \geq p\sqrt{G_s}^{-1} y - r x \sqrt{G_s}$ . Under CRS, maximum feasible profit is zero, that is,  $p_s(p,r) = 0$ . This implies that the ratio of observed revenue to cost can be written as:

$$py/rx \leq G_s \quad (7)$$

The left hand side of (7) is the private return to the dollar obtained by a firm when pollution generation is not penalized. The right hand side is a measure of its hyperbolic efficiency under the assumption of freely disposable pollution. Firms that are more efficient in a conventional sense also earn a higher private return to the dollar.

Similarly, the linear programming problem for a technology that assumes weak disposability of bad outputs and strong disposability of good outputs can be written as:

$$F_w(x_k, y_k, b_k) = \min G_w \quad (\text{LP3})$$

$$\text{subject to: } ZM \geq y_k, ZJ = G_w b_k, ZN \leq G_w x_k, Z \hat{I} \hat{A}_+^K \quad (8)$$

This can be solved for  $\sqrt{G_w}$  for each firm  $k$ . As the pollution disposability constraint becomes increasingly binding,  $\sqrt{G_w}$  increases and the “win-win” opportunities for firms to increase productive efficiency (when pollution disposal is costly) and reduce pollution diminish. It must be noted that because we measure inefficiency by the amount by which inputs and pollution could be reduced while simultaneously increasing output by the same proportion, we obtain a very conservative estimate of the opportunities for win-win improvements<sup>4</sup>.

We can further interpret this measure by supposing that pollution generation is regulation and the vector of penalties for pollution generation is denoted by  $\mathbf{t}$ . The vector of prices of inputs and outputs faced by the firm in the market is now denoted by  $p'$  and  $r'$ . Equilibrium prices of inputs and outputs with environmental regulation may be different from those in the absence of regulation. Maximum profits of a firm,  $\mathbf{p}_w$ , are:  $\mathbf{p}_w(p', r', \mathbf{t}) = \max \{p' y - r' x - \mathbf{t}b : (x, y, b) \in P_w\}$  and these are greater than or equal to actual profits earned by a regulated firm  $[p' y - r' x - \mathbf{t}b]$ . Following the same steps as above and assuming that an efficient firm maximizes profits, (which under CRS are zero), we obtain  $0 = p' \sqrt{\mathbf{G}_w}^{-1} y - r' x - \mathbf{t}b \sqrt{\mathbf{G}_w}$ . We can now write:

$$\frac{1}{\mathbf{G}_w} = \frac{1}{p' y / (r' x + \mathbf{t}b)} = \frac{(r' x + \mathbf{t}b)}{p' y} \geq 1 \quad (9)$$

The expression on the right hand side represents the maximum multiple by which a regulated firm can expect to increase its profits by increasing its hyperbolic efficiency to the maximum level possible given the constraint that pollution reduction is costly. A higher value of this expression represents a bigger opportunity to increase efficiency and return to the dollar when there is a constraint on pollution. We would expect that firms that have already internalized a larger portion of their environmental externality are less likely to be adversely constrained by environmental regulation and would find it less costly to comply with environmental constraints.

The index of environmental efficiency of a firm is now computed as in Fare et al. (1989) by comparing the hyperbolic efficiency measure with and without the disposability constraint. The ratio of the hyperbolic measure of technical efficiency obtained under the assumption of strong disposability to that obtained under the assumption of weak disposability of bad outputs is referred to as the environmental efficiency of the firm  $E$  and  $(1-E)$  indicates the extent to which a binding pollution constraint would reduce desirable output (as in Boyd and McClelland 1999, Zaim and Taskin 2000). We define:

$$E = \sqrt{G_s} / \sqrt{G_w} \quad (10)$$

If a change in the assumption about pollution disposability has no effect on the measure of productivity of the firm relative to the frontier then the two linear programs (LP2 and LP3) above will provide the same value of hyperbolic efficiency and this ratio will equal 1. This would imply that the firm might dispose of its pollution without incurring any additional costs. Alternatively,  $E < 1$  indicates that weak disposability constrains the production process and the percentage of unconstrained output that current output would be after recognizing that good output will be foregone to reduce pollution while increasing efficiency. Firms with a higher  $E$  are those that are generating relatively low levels of pollution and high levels of good outputs with their inputs and thus are likely to be less adversely affected by the hypothesized environmental constraint. Such plants can therefore be considered as more environmentally efficient<sup>5</sup>.

The concept of environmental efficiency is illustrated graphically in Figure 1 (as in Zaim and Taskin, 2000; Fare et al., 1989) where  $y$  and  $b$  denote good output and bad output respectively. Suppose that three firms use the same input vectors to produce output vectors labeled  $\mathbf{a}$ ,  $\mathbf{d}$  and  $\mathbf{e}$ . The intensity vector  $z$  constructs convex combinations of the observed inputs and outputs forming a feasible polytope with facets connecting the observed points. All other firms are either using more inputs or producing output vectors that lie within this polytope. The inequality  $y \leq zM$  allows for a vertical extension south of  $\mathbf{e}$ , reflecting strong disposability of  $y$  and the inequality  $b \leq zJ$  allows for a horizontal extension to the left of  $\mathbf{d}$  reflecting strong disposability of the undesirable output. The output set  $P_s$  is the region **Ocdef**. With weak disposability of undesirable output  $b$  (implied by the equality  $b = zJ$ ) a reduction in pollution below  $\mathbf{a}$  involves a radial contraction in good output  $y$ . The output set  $P_w$  is **Oadef**. The region **Oeda** represents production possibilities that are feasible under strong disposability of all outputs but not feasible under weak disposability of undesirable outputs.

The hyperbolic graph measure of technical inefficiency of point  $Q$  with respect to a technology that assumes weak disposability of undesirable outputs is obtained by comparing point  $Q$  to  $T$ . Its technical inefficiency when strong disposability is assumed, is obtained by comparing point  $Q$  to  $V$ . The environmental efficiency of the unit at  $Q$  is measured graphically by the ratio of the hyperbolic distances  $TQ/VQ < 1$ . Environmental efficiency takes a value of 1 for producing units located on segments **ed** (such as point N) and **ef** or for producing units whose hyperbolic expansions fall on these segments so that their  $G_w$  is the same as  $G_s$  (such as point P). If a firm is located along the line segment **Oa** or **ad**, or in the interior part of the weakly disposable output set, then its environmental efficiency is less than one. For example, at points T and L,  $G_s < 1$  but  $G_w = 1$ , thus  $E < 1$ . Zaim and Taskin (2000) show that this measure of environmental efficiency may differ from other measures of environmental performance such as pollution per unit of output. According to the environmental efficiency index developed here, even if two firms (such as, those at  $Q$  and  $K$ ) have the same pollution output ratio, the firms at  $K$ , with the larger desirable output will be measured as being more environmentally efficient<sup>6</sup>.

Equations (7) and (9) imply that  $E$  represents the private return to the dollar as a percentage of the internalized cost to return ratio and  $0 \leq E^2 = \frac{py}{rx} \cdot \frac{r'x + tz}{p'y} \leq 1$ . (11)

Thus, an environmentally efficient firm is one that has a high private return to the dollar and a high potential to raise its return to the dollar even when pollution reduction is costly. Such firms are likely to be more profitable in conventional terms (in the absence of regulation) and to have a higher potential to increase their return to dollar ratio in the future when pollution generation is constrained. We now empirically examine if ESR does infact lead firms to internalize their environmental externalities and increase their environmental efficiency. Following that, we examine if capital markets reward firms that are engaging in self regulation and that are more

environmentally efficient, because such firms are more likely to be profitable in the future (or less adversely affected by regulations), and whether this is reflected in the market value of firms.

Our empirical analysis, therefore, consists of the following set of three equations:

$$ESR = \mathbf{q}_1 \mathbf{b}_1 + u_1 \quad (12)$$

$$E = \mathbf{a}_2 (ESR) + \mathbf{q}_2 \mathbf{b}_2 + u_2 \quad (13)$$

$$\mathbf{P} = \mathbf{a}_{31} (ESR) + \mathbf{a}_{32} E + \mathbf{q}_3 \mathbf{b}_3 + u_3 \quad (14)$$

where ESR is proxied by the sum of proactive practices adopted by a firm (as in Khanna and Anton, 2002 and defined below),  $E$  is the environmental efficiency of a firm and  $\mathbf{P}$  its profitability. The variables  $q_1$ ,  $q_2$ , and  $q_3$  represent vectors of observed exogenous firm-specific controls and  $u_1$ ,  $u_2$  and  $u_3$  are unobserved random factors. Equation (12) examines the determinants of the degree of ESR or the extent to which a firm is undertaking ESR. Equation (13) examines the impact of ESR on the environmental efficiency of the firm while controlling for other firm-specific characteristics that could also influence its efficiency. Equation (14) examines the impact of ESR and of environmental efficiency of firms on their profitability. We use the Hausman test to test for correlations among the three random variables and for possible endogeneity of ESR and E in equations (13) and (14). The test does not reject the null hypothesis that  $Cov(u_i, u_j) = 0$  for  $i \neq j = 1, 2, 3$ . We, therefore, use ordinary least squares to obtain unbiased and consistent estimates of the parameters in these equations. We focus here on estimating equations (13) and (14). The determinants of the extent of ESR have been analyzed in Khanna and Anton (2002a, 2002b). We now describe the variables included in  $\mathbf{q}_2$  and  $\mathbf{q}_3$ .

#### *Determinants of Environmental Efficiency*

We hypothesize that several firm characteristics could influence the environmental efficiency of a firm. These include the (1) comprehensiveness of ESR ( $ESR$ ), (2) age of its assets ( $Age$ ) (3) financial health ( $Sales-Asset Ratio$ ), (4) innovativeness ( $R\&D Intensity$ ), (5) threat of

liabilities (*Superfund Sites*) (6) past environmental performance (*On-Site Release Intensity*, *Off-site Transfer Intensity*) (7) industry-specific factors (*Industry Dummies*) and (8) time (*Time*).

ESR can enable a firm to identify opportunities to reduce waste generation, increase efficiency and foster decision-making based on full information about the processes, technologies and resources needed to make environmental improvements. It provides firms with flexibility in deciding how to reduce environmental impacts and to select strategies that are cost-effective. Firms can choose to adopt a variety of environmentally friendly activities. These include having a formal written environmental policy, rewarding workers who are instrumental in attaining environmental goals, setting stringent corporation-wide internal standards, applying the TQM philosophy to pollution reduction, and undertaking internal environmental audits to identify opportunities for preventing pollution and ensuring compliance with regulatory requirements. Firms may also choose to set aside funds and purchase insurance to cover liability or remediation costs of environmental incidents as well as conduct environmental risk assessments of their business partners, suppliers and clientele. Additionally, firms can participate in voluntary programs such as the 33/50 Program, Green Lights and Waste Wise. Firms can differ in the practices they adopt and thus in the extent to which they are undertaking ESR. We use the count of environmental practices adopted by a firm, as a measure of the extent of ESR where a greater number of practices indicates a higher degree of ESR.

We expect that firms with younger assets would be more environmentally efficient. Newer assets are likely to use resources more productively and possibly generate lower waste and pollution. Age of assets is measured by dividing the total assets of a firm by its gross assets (Khanna and Damon 1999). Total assets are defined as current assets plus net property, plant and equipment plus other non-current assets. Gross assets are defined as total assets plus accumulated depreciation on property, plant, and equipment. Age of assets takes a value between 0 and 1,

with higher values indicating newer plant and equipment, more current assets and smaller accumulated depreciation.

Firms with a higher sales-asset ratio, which is a proxy for the financial health of a firm, are more likely to have the resources to improve environmental efficiency. Furthermore, a higher sales per unit asset ratio also indicates a larger level of desirable output per unit input which is expected to raise the efficiency of the firm. A firm's innovativeness, as indicated by lagged R&D expenditures could also lead to lower pollution, if it is directed towards lowering costs of abatement and finding ways to prevent pollution. On the other hand, if research is directed towards raising the level of desirable outputs while treating pollution as freely disposable then it could result in firms that are less environmentally efficient. We also expect that firms that are facing a stronger threat of liabilities because they are listed as potentially responsible for a larger number of Superfund sites are more likely to seek to improve their environmental efficiency and find lower cost approaches to pollution control. There is some empirical evidence supporting this argument that the threat of liabilities induces firms to go beyond compliance. Khanna and Damon (1999) and Videras and Alberini (2000) find that firms listed as potentially responsible parties for a large number of Superfund sites under the Superfund Act of 1986 were more likely to participate in 33/50 program and in Green Lights while Khanna and Anton (2002) find that such firms were more likely to adopt a higher quality environmental management system.

We also examine if firms that were more pollution intensive in the past were more likely to make improvements in efficiency and include lagged values of on-site releases per unit sales and off-site transfers per unit sales as explanatory variables. Firms with poorer environmental performance in the past were more likely participate in voluntary programs such as the 33/50 program (Khanna and Damon, 1999), to adopt a higher quality EMS (Khanna and Anton, 2002) and to make greater efforts to lower their current toxic release intensity (Anton et al., 2002).

Such firms may therefore be more likely to make efforts to internalize environmental externalities and raise environmental efficiency. The best-practice firms, against which efficiency of all firms in the industry are compared, are identified separately for each industry and for each year; thus our measure of environmental efficiency is industry- specific and year-specific. We control for differences in technologies across industries and over time by including industry dummies and time as explanatory variables.

#### *Determinants of the Profitability of a Firm*

A firm's market value is based on its future profitability. Assuming efficient capital markets, stock prices provide the best available unbiased estimate of the present value of discounted future cash flows (Fama, 1970). Like several other studies investigating the relationship between environmental performance and financial performance, we use Tobin's  $q$  as the market-based measure of financial performance (Konar and Cohen, 2001; Dowell et al., 2000). Tobin's  $q$  is defined as the ratio of the market value to the replacement cost of assets of the firm. Konar and Cohen (2001) show that for a firm with no intangible asset value, its market value would equal the replacement value of its tangible assets and Tobin's  $q$  should equal 1. As the value of the firm's intangible assets increases, the value of Tobin's  $q$  will increase. We measure market value by the sum of the value of common stock, the market value of preferred stock and total liabilities (short term debt and long term debt). The replacement value of assets is the sum of the property, plant and equipment of the firm, cash and short-term investments, receivables and inventories.

While our primary interest is in examining the impact of the environmental efficiency and the comprehensiveness of the ESR of the firm on its financial performance, we also include several other explanatory variables that have been shown to influence performance in the

literature (see surveys by Schmalansee, 1989; Capon et al., 1990). These include: (1) concentration ratio of the industry, measured by the Herfindahl-Hirschman index (*HHI*) (2) innovativeness (*R&D Intensity*), (3) age of assets (*Age*), (4) change in revenue (*Sales Growth*), (5) the degree to which the firm is leveraged (*Leverage*), (6) threat of liabilities (*Superfund Sites*), (7) environmental performance (*Toxic Release Intensity*) (8) type of industry – final or intermediate good producing (*Final Good*) and (9) industry-specific factors (*Industry Dummies*).

Several studies have examined the effect of concentration of the industry on profitability of firms. We measure concentration of the industry by the HHI, which equals the sum of the squared percentages of market shares of each firm in the industry. It is expected that profits would be higher in more concentrated industries because firms in those industries have greater market share and thus market power. The value of HHI increases as the share of some firms in the industry increases and as the number of firms in the industry decreases. However, a small number of firms in an industry could be an indicator of low expectations of future profitability of the industry. This, together with the possibility that concentration leads to X-inefficiency, could result in a negative relationship between HHI and profitability. Capon et al. (1990) report mixed results after examining 100 studies with over 1100 tests for the relationship between industry concentration and profitability; while 779 tests indicated a positive relationship, 353 tests indicated a negative relationship. Similar mixed results are reported in Schmalansee (1989).

R&D intensity has been found to be positively related to profitability by several studies (Schmalansee, 1989; Konar and Cohen, 2001; Dowell et al., 2000). We measure this by the ratio of R&D expenditures per unit sales. Age of assets, defined above, is included to control for the effect of technological differences that could influence efficiency and profitability. Growth in firm-level sales has also been found by some studies to be positively correlated with profitability (Schmalansee, 1989; Konar and Cohen, 2001). We measure sales growth by the increase in sales

over the previous five years. The ratio of total debt to equity is used as a measure of leverage of the firm as in Dowell et al. (2000). Environmental performance is measured using two variables: the five-year lagged value of the toxic release output ratio (*Toxic-Release Intensity*) and the accumulated number of Superfund sites for which the firm is listed as potentially responsible (*Superfund Sites*). Firm profitability has also been found to be positively related to advertising expenditures of firms. Advertising enables firms to differentiate products and build brand equity (Konar and Cohen, 2000). We would expect final good producing firms to be larger advertisers than intermediate good producing firms. We use the 4-digit secondary SIC code of the sample firms to create a dummy variable *Final Good* equal to 1 if that firm is primarily selling final products or providing services (e.g. pharmaceutical preparations, cosmetics, food products, retail stores, restaurants, banks) directly to consumers. Industry wide effects on the asset value of the firm are controlled for by including industry dummies at the two-digit SIC code level.

### **III. Data**

The data for this study are drawn from four main sources. Data on the adoption decision for 14 environmental management practices, such as the number of environmental staff, environmental auditing and reporting procedures, are obtained from surveys conducted by the Investor Research Responsibility Center (IRRC) in 1994 and 1995 and published in the Corporate Environmental Profile Directories. Data on environmental performance for current years (1994 and 1995) as well as five year lagged values (for 1989 and 1990) are obtained from the Toxics Release Inventory (TRI). The TRI database contains facility-level information on on-site releases and off-site transfers of chemical-specific toxic pollutants. On-site toxic releases are defined as the sum of toxic releases to air, land, water and underground injections of all TRI chemicals by each facility of a parent company and off-site transfers are toxic releases being sent

for treatment, incineration, energy recovery and disposal. We aggregate releases by each facility of a parent company to obtain data at the parent company level. Financial and other firm-specific information is obtained from the publicly available Standard & Poor (S&P) 500 and Super Compustat databases which provide company specific information on all publicly traded firms that file 10-K forms with the Securities and Exchange Commission. This includes data on employment, total and gross assets, total sales, R&D expenditures, Tobin's  $q$  and the total debt to equity ratio. Lastly, data on the accumulated number of Superfund sites for which firms are held potentially liable in 1994 and 1995 are obtained from the Site Enforcement Tracking System, a USEPA database system designed to track the names of potentially responsible parties (PRPs) who have been issued special or general notice letters pertaining to previous activities at an identified Superfund sites as provided under provisions of Comprehensive Environmental Response, Compensation and Liability Act.

We select those industries from the S&P 500 list that had at least 8 firms for which complete data to estimate environmental efficiency and for its hypothesized determinants for each year were available. This resulted in a pooled sample of 186 firms from eight industries, Food and Kindred Products (SIC 20), Paper and Allied Products (SIC 26), Chemicals (SIC 28), Petroleum refining (SIC 29), Primary Metal Industries (SIC 33), Electric and Other Electrical Equipment (SIC 36), Transportation (SIC 37) and Instruments and Related Products (SIC 38).

The description and the frequency of adoption of each of these practices are presented in Table 1. The rate of adoption of individual practices varied across firms. Almost all firms were doing some practices such as having an environmental policy and auditing while 44 percent of the sample was issuing environmental reports. The total number of practices adopted varied across the sample with 3 percent of the sample adopting 1 or less practice and 9 percent adopting 13 or more practices. The mode of the distribution is 10 practices. The summary statistics for the

variables used in this study for the entire sample of firms are reported in column 1 of Table 2. An average firm had adopted 8 environmental practices, was potentially responsible for an accumulated number of 26 Superfund sites and was generating about 5.5 million pounds of on-site toxic releases and 5.6 million pounds of off-site transfers. About 70 percent of the firms in the sample were primarily in final good producing industries.

#### **IV. Results**

We construct the environmental efficiency index for each firm using three types of data that proxy for desirable output (sales), undesirable output (on-site releases and off-site transfers), and inputs. We include two inputs, total assets and number of employees (as in Berman and Bui, 2001). We use cross section data on all firms to solve the linear programming problems (LP2) and (LP3) for each firm. These linear programming problems are solved for each industry separately and for each year so that efficiency measures for a particular firm are comparable within the industry, i.e. we generate the industry specific production frontiers under the assumptions of weak and strong disposability of pollution.

The descriptive statistics of the hyperbolic efficiency measures are reported in Table 3. They show that the industry average efficiency due to weak disposability of toxic emissions ( $G_W$ ) is between 99 percent for primary metal industries (SIC 29) and 94 percent for Chemicals and Allied Products (SIC 28) with the overall average value of this index being 97 percent. When the assumption of weak disposability of bad outputs is relaxed ( $G_S$ ), the average hyperbolic efficiency measure under the assumption of strong disposability of toxic emissions ranges from 82 percent to 95 percent. The environmental efficiency index (E) is constructed as a ratio of the two hyperbolic efficiency measures for each firm. The average environmental efficiency ranges between 0.83 for SIC 33 and 0.97 for SICs 29 and 37. This implies that the percentage loss in

desirable output due to the constraint of weak disposability ranges from 1.5 percent to 17 percent. For all the firms together, the value of this figure is 0.95, indicating an efficiency loss equal to 5 percent of firm output.

The distributions of weak hyperbolic efficiency and environmental efficiency are reported in Table 4. They show the fraction of firms in the total sample and in each industry that is on the frontier, within 10 percent of the frontier, and more than 10 percent away from the frontier as well as the fraction of firms that is environmentally efficient and have efficiency levels of less/more than 90 percent. We find that 72 percent of the entire sample of firms is fully efficient under the assumption of weak disposability. This implies that for these firms, there was at least one input or pollutant that could not be reduced any further. The table also shows that 17 percent of the firms are within 10 percent of the best-practice firms and 11 percent are more than 10 percent away from the frontier. The highest percentage of firms that are more than 10 percent away from the frontier (i.e. 20 percent) is in SIC 28.

The implications of these efficiency measures can be examined by supposing hypothetically that all firms were to move to the production frontier (obtained under the assumption of weak disposability) with existing levels of inputs constant. The percentage increase in industry output and reduction in aggregate pollution that would lead to in 1995 is shown in Figure 2. These results indicate that output could be increased by 0.94 percent to 6 percent while on-site releases could be reduced by 0.2 percent to 4 percent and off-site transfers could be reduced by 0.02 percent to 3 percent. These results suggest that “win-win” opportunities for reducing pollution and increasing desirable outputs when pollution reduction is costly are modest. The potential for output gain and pollution reduction are largest for SICs 26 and 28 and smallest for SICs 20 and 33. These results are consistent with those obtained by Boyd and McClelland (1999). Table 4 shows that such opportunities were likely to be important for only

11 percent of the sample firms. Note that our definition of “win-win” is very conservative in the sense that all inputs and pollutants must be reduced simultaneously while increasing the good output. Only those firms that can “do it all” are reckoned as having “win-win” opportunities. These results can thus be interpreted as a lower bound for these opportunities. Table 4 also presents the distribution of the environmental efficiency. About 49 percent firms have the environmental efficiency value equal to one, while 20 percent of the firms have an efficiency value less than 0.9. This implies that for 80 percent of the sample, the cost of increasing efficiency (when pollution reduction is costly) is negligible or small. SICs 20 and 33 have the two largest proportions of firms with an environmental efficiency less than 0.9. Hence, costs of increasing efficiency are relatively high for these two industries. This is consistent with the relatively low potential for gains in output and reduction in pollutants for these two industries that we observe in Figure 2.

These efficiency measures are sensitive to the specification of the problem since these are constructed as the solution to a linear programming problem (Boyd and McClelland, 1999). As one adds more dimensions (number of inputs and outputs) to the problem over which we define efficiency, there is a greater likelihood that a given firm will be isolated in production space and appear to be best-practice. By including only two inputs, i.e. number of employees and the total assets of the firm, we are likely to be underestimating average efficiency and overestimating the measure of efficiency loss due to environmental constraints.

#### *Analysis of Firm-Specific Environmental Efficiency*

We analyze the determinants of firm-specific environmental efficiency using two alternative models. Model 1 (column 1 in Table 5) examines the presence of a linear relationship between ESR and environmental efficiency while Model II (column 2 in Table 5) uses the square

root of ESR as an explanatory variable to examine nonlinearity in that relationship. Both models provide equally good fit to the data, as indicated by the adjusted  $R^2$ , the Akaike Information Criterion and the Amemiya's Criterion. These models show that the extent of ESR has a significantly positive impact on the level of environmental efficiency. Model 2 suggests that the degree of ESR has a positive but diminishing impact on environmental efficiency of firms. Additionally, firms with poorer environmental performance, i.e., having a high level of toxic emissions per unit sales in the past and being currently listed as PRPs for a larger number of Superfund sites were more environmentally efficient. This suggests that the threat of liabilities, adverse public reactions to high on-site toxic release intensity and a greater potential for reducing end-of-pipe disposal for firms with high off-site transfers per unit sales did motivate firms to change their production processes to make them more efficient and less wasteful so that they were less likely to be constrained by possible environmental constraints in the future. We also find that firms in better financial health as measured by their sales-asset ratio were more likely to be environmentally efficient. Industry-specific factors were particularly important in influencing environmental efficiency for two of the industries considered in this study, SICs 20 and 33.

The descriptive statistics for firms in these industries as compared to those in other industries (Table 2) show that the average firms in each of these two SIC codes were very different from each other and also very different from the average firm in the rest of the sample. An average firm in SIC 20 had very low levels of on-site releases (0.63 million pounds) and off-site transfers (0.13 million pounds). An average firm in SIC 33, on the other hand, had very high levels of on-site releases and off-site transfers (11.77 million pounds and 16.42 million pounds, respectively). Corresponding figures for an average firm in the remaining SIC codes is 5.29 and 4.91. An average firm in SIC 33 had adopted the least number of environmental practices (5.7) and had the lowest level of environmental efficiency (0.83) compared to the rest of the

industries. SIC 20 consisted primarily of final good producing firms while SIC 33 consisted primarily of intermediate good firms; final good firms constituted 73 percent of the rest of the sample. While an average firm in SIC 20 had the highest Tobin's  $q$  (2.34) in the sample, an average firm in SIC 33 had a relatively low Tobin's  $q$  (1.91). These differences have implications for our analysis of the determinants of profitability as discussed below.

### *Implications of Environmental Efficiency and ESR for Firm Profitability*

Table 6 lists the results from the estimation of equation (3). We use the natural log of Tobin's  $q$  as the dependent variable (as in Konar and Cohen, 2001) as previous studies have found that to be preferable to a linear specification (Hirsch and Seaks, 1993). We first estimate the model for the entire sample using White's heteroskedasticity-consistent OLS estimator. We find that neither ESR nor environmental efficiency have an impact on Tobin's  $q$ . Instead, other environmental performance variables such as the number of Superfund sites and lagged toxics release intensity have a significantly negative impact on profitability. This is consistent with the results obtained by Konar and Cohen (2001). Additionally, as expected we find that firms with younger assets and a higher R&D intensity are more profitable. Other factors such as HHI, leverage, sales growth and final good production are not found to have any significant effect on Tobin's  $q$ . Industry specific factors are found to be statistically significant for many of the industries considered here. To examine if intrinsic differences among industries could be influencing our results, we then estimate the regression for the sample that excludes SIC codes 20 and 33. We now find that for this sub-set of firms, both ESR and environmental efficiency do have a positive significant impact on profitability. The impact of ESR on Tobin's  $q$  increases but at a diminishing rate as the degree of ESR increases. Other environmental performance variables continue to have a negative impact on profitability while age of assets and R&D intensity have

positive effects. A high debt-equity ratio and a high HHI now result in lower Tobin's  $q$ .

These results suggest that in addition to environmental performance indicators such as toxic release intensity and number of Superfund sites, proactive efforts by firms to improve their environmental performance as well as more efficient use of resources do get rewarded by the market, at least in some industries. ESR has both a direct impact on firm profitability, possibly by improving a firm's reputation and reducing its environmental riskiness as well as an indirect effect by increasing a firm's environmental efficiency. Our analysis suggests that ESR and environmental efficiency are not significant in affecting Tobin's  $q$  of firms in industries with characteristics that take extreme values in our sample, for example, in terms of environmental performance. Firms in industries that are on average either very large polluters or very small polluters may not achieve significant financial benefit from ESR or gains in efficiency. The latter is also confirmed by the results in Figure 2 that show that the "win-win" opportunities for firms in SIC codes 20 and 33 were among the lowest. For very small polluters, investors may not care about pollution levels and efforts to improve environmental management. For very large polluters, ESR may not be considered "good enough" to improve environmental performance and other more fundamental changes in products and processes may be needed to convince investors that future environmental performance of such firms is likely to improve. This suggests that the market rewards environmentally friendly efforts in industries where such efforts are likely to be effective in impacting future profits.

Other firm-specific characteristics such as age of assets and R&D intensity and environmental performance indicators such as Superfund sites and lagged toxics release intensity were significant determinants of financial profitability in both the complete sample and the subsample. This suggests that these factors are likely to have been significant determinants of Tobin's  $q$  for firms in SICs 20 and 33 as well.

In order to estimate the extent to which firms can expect to be rewarded for their environmentally proactive efforts, we used the regression coefficients estimated in Model 1 in Table 5 and from column 2 in Table 6, to determine the direct and indirect effects of ESR by an average firm. The adoption of 9 practices by an average firm in the sub-sample results in an increase in environmental efficiency of 2 percent. This increase in efficiency together with the direct effect of an increased adoption of 9 practices would increase Tobin's  $q$  by 25 percent. Using the average value of the replacement cost of capital for this sample, we find that adoption of 9 practices increases market value of an average firm by \$7.6 billion. We also compare the effect of increasing environmental efficiency by 1 percent alone and of adopting 1 additional practice for an average firm. We find that a 1 percent increase in environmental efficiency increases market value of an average firm by \$226 million while the adoption of an additional practice (the ninth practice) increases it by \$815 million.

Dowell et al. (2000) found that adoption of a global environmental standard (which is one of the 14 practices considered in our study) could increase the Tobin's  $q$  for an average firm by \$8.6 billion. Although this figure appears relatively high relative to that obtained by us, it must be noted that environmental practices are seldom adopted in isolation. Synergistic relations between various management practices imply that firms are likely to be choosing a system of practices rather than a practice which by itself may achieve little (Cairncross 1995). The figure obtained by Dowell et al. (2000) could therefore be capturing a combined effect of adoption of several practices that may have been adopted simultaneously by firms.

## **V. Conclusions**

The growing popularity of ESR as a means to address environmental concerns and the potential they offer for increased efficiency, shareholder value and competitiveness have spurred

the debate on whether these voluntary environmental initiatives create “win-win” opportunities for simultaneously achieving environmental and business goals. This paper determines the extent to which such opportunities exist among a sample of S&P 500 firms generating toxic releases and it examines the impact of ESR on environmental efficiency of firms and their financial profitability. It uses DEA to develop an environmental efficiency index, which recognizes the firm’s efficiency in using its inputs in conventional terms as well as the potential it has for realizing its maximum efficiency when pollution generation is costly. This potential is expected to be higher among firms that are already internalizing their environmental externalities and adopting practices that enable them to reduce pollution generation cost-effectively.

We find that “win-win” opportunities for reducing pollution and increasing desirable outputs when pollution reduction is costly are modest and vary across industries. Efficiency gains could at most reduce on-site releases by 0.2% to 4% and reduce off-site transfers by 0.02% to 3%. The potential for pollution reduction are largest for SICs 26 and 28 and smallest for SICs 20 and 33. The environmental efficiency index shows that 80 percent of the firms could achieve these efficiency gains with low or negligible loss in desirable output and net industry output gains (at most) range from 0.94% to 6%.

Differences in environmental efficiency across firms are explained by their degree of ESR. Additionally, firms facing a higher threat of liabilities for Superfund sites and greater potential adverse reaction to high toxics release intensity are more likely to be environmentally efficient. Financial health of firms is also strongly correlated with their environmental efficiency. However, given that the potential for large gains in output while reducing input-use and pollution are limited, the ability of efficiency gains and ESR to lead to win-win outcomes is also likely to be very small. Pollution reduction even with ESR is likely to involve a net cost. Nevertheless we find, that with the exception of two industries, firms in other industries that adopt a higher degree

of ESR and have a higher level of environmental efficiency are significantly more profitable than other firms. A firm's profitability increases but at a diminishing rate as the degree of ESR increases. Thus there appears to be a net benefit to firms of adopting ESR and of internalizing their environmental externalities. The two exceptional industries for which ESR and environmental efficiency does not influence profitability represent two extremes in terms of their environmental performance in our sample. While one of these industries is a very small polluter the other industry is a very large polluter. This suggests that the market may value ESR by firms that are neither very small polluters or very large polluters and where ESR is likely to have an impact on environmental performance and costs of abatement.

This research shows that government efforts to promote ESR can be beneficial in that it makes firms internalize externalities and find less costly ways to reduce pollution than otherwise. These efforts can also provide private benefits for firms since they are rewarded in the market place both for undertaking a higher degree of ESR and for voluntarily internalizing environmental externalities and raising their environmental efficiency, although this effect differs across industries. At the same time, we also find that firms are penalized for having high toxics release intensity and for being at higher risk for environmental liabilities. These results also bring forth the importance of disclosure programs that provide environmental information about firms to the public and thereby allow the market to provide incentives to firms to internalize their externalities.

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<sup>1</sup> Green Lights is a voluntary program encouraging the use of energy-efficient lighting in buildings. The 33/50 Program was launched by the EPA in 1991 to encourage firms to voluntarily reduce their emissions of 17 high priority toxic chemicals at source. The goals of this Program were to reduce the aggregate releases of these chemicals by 33 percent by 1992 and by 50 percent by 1995. Participants in the WasteWise program, launched in 1994, commit to finding cost-effective opportunities to prevent, reduce and recycle solid waste.

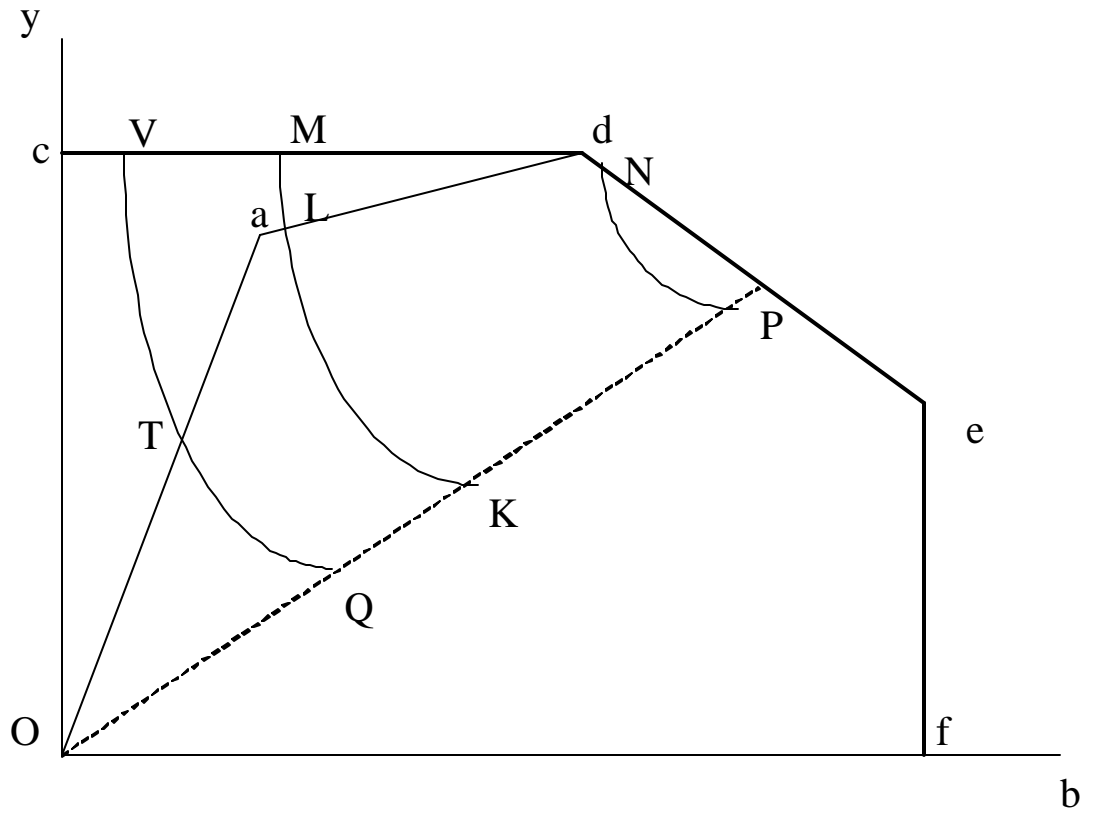
<sup>2</sup> Several other measures of efficiency have also been defined in the DEA literature. An input-oriented measure of productive efficiency is a scalar by which one can equiproportionately scale down the inputs while maintaining the production of a given level of output. An output-oriented measure of technical efficiency is a scalar by which one can scale up the outputs while maintaining the same level of input use. Fare et al. (2002) show that the input measure is the square of the hyperbolic measure under the assumption of constant returns to scale and that the input-measure is the reciprocal of the output measure of efficiency.

<sup>3</sup> One may measure hyperbolic efficiency while assuming that undesirable outputs are costlessly disposable. Alternatively, one can treat desirable and undesirable outputs asymmetrically and assume that undesirable outputs are weakly disposable, that is the disposal of pollution requires a reduction in the desirable outputs and is not costless (Fare et al., 1989).

<sup>4</sup> A plant that is unable to reduce any single input or pollutant while increasing output is considered efficient according to the measure of productive efficiency used in this paper (Boyd and McClelland, 1999).

<sup>5</sup> Here it should be kept in mind that the difference between the weak and strong disposability frontier only reflects the cost of further environmental constraints. The best practice frontiers are not able to account for all output loss due to regulation if the efficient production processes have already regulated to some extent in the past.

<sup>6</sup> The environmental efficiency of  $Q$  and  $K$  is measured by the hyperbolic distances  $TQ/VQ$  and  $LK/MK$  respectively. Since  $TQ < LK$  and  $VQ > MK$ , the firm at  $K$  is environmentally more efficient than that located at  $Q$ .



**Fig. 1: Hyperbolic Graph Measure of Technical Efficiency and Environmental Efficiency**

**Table 1. Components of Environmental Self-Regulation**

<b>Variable</b>	<b>Mean Values</b>	<b>Description of the Variable (1=yes; 0=no)</b>
<b>Staff</b>	0.57 (0.50)	Firm has an environmental staff of more than 50
<b>Directors</b>	0.52 (0.50)	Firm has more than 3 environmental directors
<b>Policy</b>	0.96 (0.19)	Firm has a formal written policy and codes of conduct on environmental issues
<b>Corp. Stds.</b>	0.52 (0.50)	Firm applies uniform standards to environmental practices worldwide
<b>TQM</b>	0.76 (0.43)	Firm applies total quality management philosophy to environmental management
<b>Payments</b>	0.67 (0.47)	Firm provides incentive compensation to employees whose efforts lead to achievement of specific environmental goals
<b>Audits</b>	0.93 (0.26)	Firm conducts audits to assess compliance with environmental regulations
<b>Suppliers</b>	0.51 (0.50)	Firm evaluates its environmental risks when selecting its suppliers
<b>Partners</b>	0.43 (0.50)	Firm evaluates its environmental risks when selecting its partners
<b>Clients</b>	0.12 (0.32)	Firm evaluates its environmental risks when selecting its clients
<b>Report</b>	0.44 (0.50)	Firm regularly releases reports about its environmental performance and activities
<b>Reserves</b>	0.54 (0.50)	Firm sets aside funds to cover the costs of penalties for environmental violation or remediation activities
<b>Insurance</b>	0.48 (0.50)	Firm purchases insurance to meet unexpected environmental liabilities
<b>Voluntary Programs</b>	0.82 (0.40)	Firm participates in a voluntary program such as 33/50, Green Lights and WasteWise

<sup>a</sup>Standard deviations are in parentheses

**Table 2: Descriptive Statistics (Mean and Standard Deviations)**

<b>Variable</b>	<b>All Firms</b>	<b>SICs 26,28,29,36,37, 38</b>	<b>SIC 20</b>	<b>SIC 33</b>
Sales (\$ Million)	14530.16 (24645.13)	15931.76 (27201.57)	12640.70 (9240.75)	5501.84 (2909.72)
Total Assets (\$ Million)	15893.13 (33383.28)	17957.58 (37058.53)	9394.46 (7146.45)	6310.74 (3288.81)
Number of Employees (‘000s)	55.19 (90.35)	54.52 (93.58)	89.21 (142.90)	26.45 (18.69)
On-Site Releases (Million Pounds)	5.5 (11.48)	5.29 (10.38)	0.64 (1.35)	11.8 (20.14)
Off-Site Transfers (Million Pounds)	5.6 (14.94)	4.91 (14.9)	0.13 (0.20)	16.42 (17.89)
Superfund Sites	26.33 (36.35)	29.98 (39.58)	5.89 (3.62)	18.37 (12.33)
Lagged Off-Site Transfer Intensity (Pounds/M \$)	305.22 (633.53)	242.39 (447.43)	20.95 (54.60)	1078.87 (1318.17)
Lagged On-Site Release Intensity (Pounds/M \$)	1769.02 (4539.71)	1558.43 (3380.79)	146.21 (235.72)	5031.79 (10199.75)
Sales Growth	2165.49 (6116.89)	1984.54 (6775.59)	4203.31 (4913.13)	474.24 (1150.03)
Current R&D Intensity	0.033 (0.037)	0.04 (0.04)	0.0042 (0.0045)	0.009 (0.01)
Lagged R&D Intensity	0.037 (0.038)	0.038 (0.036)	0.0044 (0.0047)	0.012 (0.013)
Age of Assets	0.74 (0.1)	0.74 (0.1)	0.774 (0.1)	0.66 (0.09)
ESR	8.28 (3.34)	8.73 (3.23)	7.32 (2.19)	5.74 (3.91)
Environmental Efficiency	0.948 (0.079)	0.965 (0.05)	0.927 (0.1)	0.83 (0.11)
Sales-Asset Ratio	1.06 (0.34)	1.04 (0.32)	1.39 (0.37)	0.9 (0.23)
Final Good	0.69 (0.46)	0.73 (0.45)	1.00 (0.0)	0.105 (0.315)
HHI	858.84 (800.55)	811.74 (805.21)	1033 (788.24)	1064.89 (760.08)
Leverage	0.95 (1.26)	0.91 (1.03)	1.69 (2.55)	0.483 (0.447)
Tobin’s q	1.99 (1.40)	1.91 (1.13)	3.26 (2.65)	1.32 (0.66)
Number of Observations	186	148	19	19

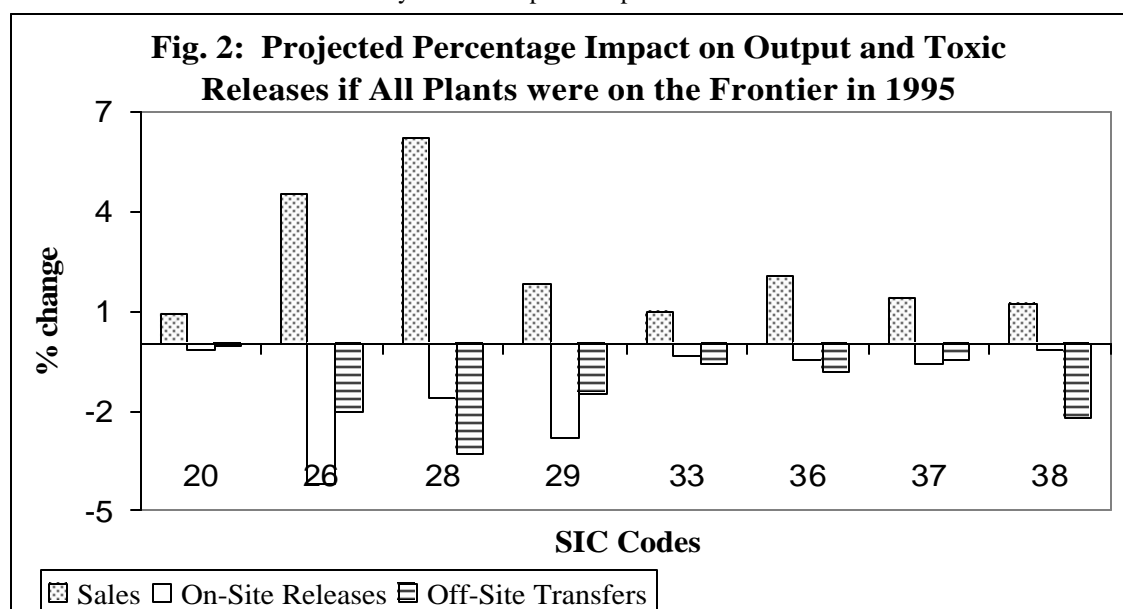
**Table 3 Descriptive Statistics of Various Measures of Efficiency  
(Mean and Standard Deviation)**

Name of the Industry	Hyperbolic Efficiency ( $G_s$ )	Hyperbolic Efficiency ( $G_w$ )	Hyperbolic Environmental Efficiency ( $E$ )
Food and Kindred Products (SIC 20)	0.911(0.11)	0.982(0.05)	0.927(0.10)
Paper and Allied Products (SIC 26)	0.949(0.06)	0.98(0.04)	0.968(0.04)
Chemicals and Allied Products (SIC 28)	0.907(0.098)	0.942(0.095)	0.965(0.062)
Petroleum and Coal Products (SIC 29)	0.952(0.07)	0.978(0.05)	0.974(0.05)
Primary Metal Industries (SIC 33)	0.824(0.12)	0.992(0.013)	0.83(0.11)
Electronic and Electrical Equipments (SIC 36)	0.928(0.08)	0.976(0.05)	0.951(0.05)
Transportation Equipments (SIC 37)	0.953(0.06)	0.978(0.05)	0.974(0.04)
Instruments and Related Products (SIC 38)	0.951(0.08)	0.992(0.03)	0.958(0.07)
All Firms	0.921(0.094)	0.973(0.06)	0.948(0.079)

**Table 4 Distributions of Firm Hyperbolic Efficiency and Environmental Efficiency**

Industry	Percent of Firms					
	Hyperbolic Efficiency			Environmental Efficiency		
	$G_w = 1$	$0.9 < G_w < 1$	$G_w < 0.9$	$E = 1$	$0.9 < E < 1$	$E < 0.9$
SIC 20 (19)	84.21	5.26	10.53	47.37	21.05	31.58
SIC 26 (24)	75.00	16.67	8.33	45.83	50.00	4.17
SIC 28 (44)	54.55	25.00	20.45	50.00	36.36	13.63
SIC 29 (18)	83.33	0.00	16.67	66.67	16.67	16.67
SIC 33 (19)	68.42	31.58	0.00	26.32	0.00	73.68
SIC 36 (20)	70.00	20.00	10.00	40.00	40.00	20.00
SIC 37 (25)	76.00	16.00	8.00	52.00	48.00	0.00
SIC 38 (17)	88.24	5.88	5.88	70.59	11.76	17.65
All firms (186)	72.04	16.67	11.29	49.46	30.65	19.89

\*The number of firms in each industry in our sample is in parenthesis



**Table 5 Determinants of Environmental Efficiency**

<b>Variables</b>	<b>Model 1</b>	<b>Model 2</b>
Constant	0.84 (0.49E-01)***	0.827 (0.49E-01)***
ESR	0.0023 (0.12E-02)**	
Square Root of ESR		0.0109 (0.55E-02)*
Number of Superfund Sites	0.63E-06 (0.23E-06)***	0.67E-06 (0.22E-06)***
On-Site Release Intensity (Lagged)	0.34E-05 (0.12E-05)***	0.35E-05 (0.12E-05)***
Off-Site Transfer Intensity (Lagged)	0.37E-04 (0.58E-05)***	0.37E-04 (0.59E-05)***
R-D Intensity (Lagged)	-0.52 (0.14)***	-0.52 (0.14)***
Age of Assets	0.011 (0.57E-01)	0.013 (0.57E-01)
Sales-Asset Ratio	0.075 (0.13E-01)***	0.076 (0.13E-01)***
Year	0.015 (0.85E-02)*	0.015 (0.85E-02)*
SIC 20	-0.065 (0.29E-01)**	-0.066 (0.29E-01)**
SIC 26	-0.0044 (0.19E-01)	-0.004 (0.19E-01)
SIC 28	0.00052 (0.19E-01)	0.0012 (0.19E-01)
SIC 29	-0.0016 (0.21E-01)	-0.00014 (0.21E-01)
SIC 33	-0.172 (0.21E-01)***	-0.171 (0.21E-01)***
SIC 36	0.0079 (0.17E-01)	0.0075 (0.17E-01)
SIC 37	-0.00016 (0.18E-01)	0.00047 (0.18E-01)
<b>Adjusted R<sup>2</sup></b>	0.453	0.452
<b>F-Stat.</b>	11.21***	11.17***
<b>N</b>	186	186

\*\*\*Statistically significant at the 1% level. \*\*Statistically significant at the 5% level. \*Statistically significant at the 10% level. Values in brackets are the standard errors.

**Table 6: Determinants of Tobin'q**

<b>Variables</b>	<b>Model I All Firms</b>	<b>Model II Group I</b>
Intercept	-1.187 (0.55)***	-1.235 (0.45)***
ESR	0.70E-03 (0.31E-01)	0.053 (0.30E-01)*
ESR squared	-0.19E-03 (0.20E-02)	-0.003 (0.18E-02)*
Environmental Efficiency	0.43 (0.38)	0.772 (0.39)**
Superfund Sites	-0.15E-02 (0.74E-03)**	-0.00083 (0.5E-03)*
Lagged Toxic Release Intensity	-0.12 (0.26E-05)***	-0.825E-05 (0.39E-05)**
Age of Assets	1.83 (0.44)***	1.37 (0.33)***
Leverage	-0.12E-02 (0.42E-01)	-0.84 (0.26E-01)***
HHI	-0.51 (0.48E-04)	-0.0002 (0.36E-04)***
R&D Intensity	2.80 (0.83)***	2.35 (0.80)***
Change in Sales	-0.37E-05 (0.41E-05)	0.16E-05 (0.36E-05)
Final Good	0.021 (0.66E-01)	0.00038 (0.62E-01)
SIC 20	0.34 (0.18)*	
SIC 26	-0.41 (0.11)***	-0.461 (0.99E-01)***
SIC 28	0.339 (0.083)***	0.302 (0.84E-01)***
SIC 29	-0.60 (0.12)	-0.214 (0.11)*
SIC 33	-0.096 (0.13)	
SIC 36	-0.198 (0.11E)*	-0.161 (0.11) +
SIC 37	-0.47 (0.11)***	-0.275 (0.92)***
<b>Adjusted R<sup>2</sup></b>	0.61	0.717
<b>F-Stat</b>	16.09***	23.61***
<b>N</b>	178	144

\*\*\*Statistically significant at the 1% level. \*\*Statistically significant at the 5% level. \*Statistically significant at the 10% level, +Statistically significant at the 15% level. Values in brackets are the standard errors.

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