Toxics Release Information: A Policy Tool for Environmental Protection

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Toxics Release Information: A Policy Tool for Environmental Protection

This study examines investor reactions to the repeated public disclosure of environmental information about firms in the chemical industry and the effectiveness of this information as a decentralized mechanism for deterring their pollution. It shows that these firms incur statistically significant negative stock market returns during the one day period following the disclosure of the Toxics Release Inventory in the years 1990-1994. These losses have a significant negative impact on subsequent on-site toxic releases and a significant positive impact on wastes transferred off-site, but their impact on total toxic wastes generated by these firms is negligible.

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I. INTRODUCTION

A growing realization of the steeply rising costs of existing command and control regulations for environmental protection is leading to a shift in the national environmental policy in the U.S. towards more decentralized instruments that promote flexible and self-regulated environmental management. Providing public access to environmental databanks is an innovative effort to reduce the role of big government bureaucracy and engage private sector participation in regulating the environment. The Toxics Release Inventory (TRI), mandated by the Emergency Planning and Community Right to Know Act of 1986, offers one such source of environmental performance information about firms. It requires all manufacturing facilities operating under SIC codes 20-39, with 10 or more employees, to submit a report of their annual on-site releases and off-site transfers of each of over 300 specified toxic chemicals.

The Congress envisioned that public provision of the TRI would give investors, consumers, journalists and environmental groups an unprecedented access to environmental data about firms and lead to a devolution of responsibility for regulating the toxic emissions generated by firms. Well functioning product and financial markets have the potential to transmit public reaction to environmental performance information directly to firms, through changes in demand for products and changes in stock prices. By signaling public preferences for "green" firms, such changes may prompt firms to control emissions.

There is evidence that investors are paying increasing attention to environmental compliance records of companies (Schueth, [14]). Environmental performance is now becoming a common component of corporate annual reports. Public disclosure of the TRI is accompanied by coverage in the media and in reports by environmental groups (GAO [17]). Cross-sectional studies show that companies incurred significantly negative stock returns on the day of the disclosure of the TRI, for the first time in 1989, and on the day of media coverage of their toxic releases (Hamilton, [7], Konar and Cohen, [10]). These studies, however, also show that the magnitude of investor reaction depends on the extent to which the TRI provides unanticipated news to investors about the environmental performance of firms. Consequently, the largest 'penalties', in the form of the largest declines in stock prices, were not targeted towards the largest emitters but towards firms that were not 'known' to be polluters on the basis of prior environmental information available to investors.

This suggests that the greater the prior environmental information that investors have about a firm, the smaller the impact of the provision of additional information on their stock market returns. In other words, it implies diminishing effects on investors of providing additional information about known polluters. It also implies that *repeated* public provision of the TRI over time may not lead to significantly negative stock market returns, since the pollution levels of *all* firms are for the most part already known. However, one of the features of the TRI data is that it establishes benchmarks of the environmental performance of a firm at a point in time. Repeated provision of this information allows tracking of changes in a firm's environmental performance relative to that of other firms as well as relative to its own previous levels. Lanoie, Laplante and Roy [11] show that firms that appear more than once on a list of polluters published by the Canadian government experienced more significant changes in their stock market returns.

This paper explores the impact on investors of repeated provision of information and its effectiveness as a long-run policy tool for deterring toxic pollution by firms known to be large polluters. It focuses on the U.S. chemical industry, which is the largest contributor to toxic releases generated by manufacturing industries and accounted for 53 percent of the total toxic releases reported in the 1989 TRI (EPA [15])[1]. First, it examines the impact on stock market returns, of provision of TRI data over a six year period (1989-94) about firms in this industry. It therefore extends the cross-sectional studies by Hamilton [7] and Konar and Cohen [10]. Second, it develops an econometrically estimable model of the response of a firm's emissions to the negative stock market returns experienced by firms following the release of the TRI. Konar and Cohen [10] show that the decline in total toxic wastes per dollar revenue in 1992 by a sample of firms that received abnormally negative returns in 1989 was significantly higher than that for an industry-weighted group of firms and attribute this decline entirely to the negative stock market returns received by the sample firms in 1989. This comparison is, however, appropriate only if the firms receiving abnormal losses and the firms in the industry-weighted group are identical in all respects other than the change in market value experienced. Since this is typically not the case, our analysis controls for the effects of other firm-specific factors that might influence these releases. It also distinguishes between wastes discharged on-site to the environment and those transferred off-site for abatement and disposal in order to examine whether information provision has differential impacts on these two methods of dealing with the toxic wastes generated.

The empirical analysis in this paper demonstrates that the provision of environmental information about firms in the chemical industry causes them to incur negative average stock market returns during the one day period following the disclosure of the TRI. These returns were not statistically significant in 1989, the first year of the release of the TRI. However, repeated provision of the TRI information causes these negative returns to be statistically significant in the years 1990-1994, particularly for firms whose environmental performance worsened over time and relative to other firms. This paper therefore does not find support for the hypothesis of diminishing effectiveness of providing additional information about known polluters. Instead it shows that the repeated provision of TRI enables benchmarking of environmental performance of firms and reveals changes in a firm's performance over time and relative to other firms. It is this feature of the TRI that appears critical to causing even known polluter firms to incur statistically significant negative returns due to investor reactions to the disclosure of the TRI over time. This result provides important insights into how similar information programs may be designed in the future in order to be effective as signaling mechanisms to firms.

Furthermore, the paper demonstrates that losses in market values incurred by firms did induce them to significantly reduce their on-site toxic releases subsequently. These losses also had a significant positive impact on wastes transferred off-site. However, the net effect of these losses on aggregate toxic releases is insignificant. Since a very large part of the off-site transfers by the chemical industry, over the period studied, were for recycling and energy recovery (EPA [15]), the substitution of abatement for on-site discharges by these firms could reduce the net risks associated with toxic waste generation and lead to positive net benefits for society.

Section 2 presents the theoretical rationale for investor reactions to environmental performance information about firms. It also develops a model to analyze a firm's response to these investor reactions. Section 3 describes the data and Section 4 discusses the empirical methodology and the results.

2. CONCEPTUAL FRAMEWORK

2.1 Impact of Environmental Information on Investors

In an efficient capital market, stock prices on any day fully reflect all available information about the present value of the stream of profits that the firm is expected to earn in the future (Fama, [6]). The provision of new information about a firm's pollution level may cause abnormal changes in its stock prices if this new information diverges from the expectations that investors hold about that firm's pollution level and is perceived by them to affect the profitability of that firm. In the absence of mechanisms for providing environmental performance information to investors continuously, investors lack complete information about the exact level of pollution Z_{it} generated by firm i at time t. For instance, the TRI provides environmental information to investors with a lag and is released once a year. Therefore, investors are likely to formulate beliefs Z_{it}^{A} about the level of pollution generated by the *ith* firm at time t, that could be based on previous TRI information Z_{it-1} and on other indicators of performance such as the number of Superfund sites where a firm is a potentially responsible party. Investors are also likely to compare a firm's pollution level relative to other firms and anticipate a rank R_{it}^{A} for that firm at time t. The actual level of pollution revealed to investors at time t is: $Z_{it} = Z_{it}^{A} \pm \varepsilon_{it}$, which could be larger or smaller than the anticipated level. Similarly, the actual rank of a firm at time t, R_{it}, could be higher or lower than the anticipated rank. A lower R_{it}, that is a higher rank, implies that the *ith* firm is a larger polluter, relative to other firms, than anticipated by investors.

The market value of the *ith* firm at time t, V_{it}, can be represented as a function of various firm-specific indicators of financial health at time t, denoted by the vector $\boldsymbol{Q}_{it}$, the level of waste generated Z_{it} and its environmental rank, R_{it}. Assuming that investors have complete information about $\boldsymbol{Q}_{it}$ but lack information about Z_{it} and R_{it}, the market value ascribed to the firm is denoted by $V_{it}^{A}=V(\boldsymbol{Q}_{it}, Z_{it}^{A}, R_{it}^{A})$. When the true level of pollution is revealed to investors, it is likely that the actual market value $V_{it}=V(\boldsymbol{Q}_{it},Z_{it},R_{it})$ differs from V_{it}^{A}

and that $V_{it}^{A} \gtreqless V_{it}$ when $Z_{it}^{A} \lesseqgtr Z_{it}$ and/or $R_{it} \gtreqless R_{it}^{A}$. The change in market value of the *ith* firm is thus: $V_{it}-V_{it}^{A}=\Delta V_{it}(Z_{it}^{A}, Z_{it}, R_{it}, R_{it}^{A}, \boldsymbol{Q}_{it})$.

Several reasons can be suggested to rationalize this association between pollution levels and profits. These include the possibility that investors view pollution as a waste of purchased inputs that are not used productively or as an indicator of poor management practices and lack of innovativeness. Additionally, the environmental discharge of waste or its abatement after it is generated necessitate expenditures by a firm on discharge permit fees, on meeting the technical standards for safe disposal and on mandated abatement technologies. Firms with larger waste levels may also face greater penalties due to enforcement actions by the EPA, greater pressure from the EPA to implement strategies for reducing their waste generation in the future (GAO [17]) and a greater risk of environmental liabilities and lawsuits. Investors are therefore likely to prefer firms that generate lower levels of waste to begin with and relative to other firms in the industry. The extent to which this is the case with the repeated provision of the TRI is an empirical question, and we address it in Section 4.

2.2 Impact of Investor Reactions on Firms

We now develop a model to examine the impact that the change in market value of a firm, due to investor reactions, has on the firm's choice of pollution level. Consider a price taking firm (i) that uses a material input X_{it} (such as chemicals) and capital equipment K_{it} at time t to produce output Y_{it}. Only a part $\varphi_t X_{it}$ of the input X_{it} is used effectively during production and becomes embodied in the final output. The fraction φ_t of input X_{it} that is used effectively during production is defined as the efficiency of input-use. It varies between 0 and 1 across firms. The level of φ_t at time t is predetermined by factors such as research and development (R&D) expenditures in the past and managerial quality, but this level can change over time. The output Y_{it} produced by the *ith* firm at time t is a function of the amount of X_{it} used effectively in production $(\varphi_{it}X_{it})$ and of the stock of capital[2]:

$$Y_{it}=F_i(\varphi_{it}X_{it},\ K_{it}) \qquad (1)$$

By the Law of Material Balances[3] the amount of the input X_{it} that is not utilized effectively in production is wasted and could manifest itself as pollution. For simplicity, we represent the pollution (waste) generation function as:

$$Z_{it}=(1-\varphi_{it})X_{it} \qquad (2)$$

and treat input-waste and pollution synonymously. This implies that pollution represents a loss of the purchased input X_{it}. A firm can either abate a part of the wastes it generates (A_{it}) or discharge them to the environment (D_{it}), thus $Z_{it}=A_{it}+D_{it}$. Substituting for X_{it} in (1), output levels can be expressed as a function of the amount of waste abated, the waste discharged and the stock of capital. Both A_{it} and D_{it} can thus be considered as inputs to the production process:

$$Y_{it} = F_i(\varphi_{it}Z_{it}/(1-\varphi_{it}),K_{it}) = F_i(\varphi_{it}(A_{it}+D_{it})/(1-\varphi_{it}),K_{it}) \qquad (3)$$

Firms are assumed to choose their cost-minimizing input allocations by minimizing the sum of their discounted total costs subject to the constraint of the production function in (3). Total costs consist of the costs of production, the discounted expected costs of environmental liabilities and the discounted costs due to changes in market value. We express these three types of costs algebraically as follows.

The cost of producing output Y_{it} is represented by C_{it}^{p} and is a function of input prices, input quantities, costs of discharging wastes, and costs of abating wastes:

$$C_{it}^{p} = w_{Xit}X_{it} + w_{Kit}K_{it} + c_{Ait}A_{it} + c_{Dit}D_{it} = \left(\frac{w_{Xit}}{1-\varphi_{it}} + c_{Ait}\right)A_{it} + \left(\frac{w_{Xit}}{1-\varphi_{it}} + c_{Dit}\right)D_{it} + w_{Kit}K_{it} \qquad (4)$$

where w_{Xit} is the purchase price per unit of input X, w_{Kit} is the annualized cost per unit of K, c_{Ait} is the per unit cost of abatement and c_{Dit} is the per unit cost of discharging wastes[4].

The costs of environmental liability for contamination caused by hazardous waste streams are uncertain, since there is uncertainty about the occurrence of environmental damages and of being held liable for those damages. We denote the probability of the *ith* firm being held liable at time t by ρ_{it} as in Laplante and Lanoie [12]. The extent of this liability ℓ_{it} is assumed to be a function of the accumulated discharges at time t: $\tilde{D}_{it} = \int_0^t D_{it}\,dt$.

Discounted expected liabilities for environmental discharges over an infinite time horizon are represented by:

$$L_{i0} = \int_0^\infty e^{-rt} \rho_{it} \ell_{it}(\tilde{D}_{it})\,dt \qquad (5)$$

Change in the market value of a firm when its environmental information is made available to investors is represented by: $V_{it}-V_{it}^A = \Delta V_{it} = \Delta V_{it}(Z_{it}^A, Z_{it}, R_{it}, R_{it}^A, \mathbf{Q}_{it})$. The rank of a firm R_{it} is a function of its pollution level and the pollution levels of all other firms at time t, that is $R_{it} = r(Z_{it}, Z_{jt})$ $j \neq i$. We can therefore write $\Delta V_{it} = \Delta V_{it}(Z_{it}^A, Z_{it}, Z_{jt}, \mathbf{Q}_{it})$. The discounted value of the change in market value for the *ith* firm is:

$$\Delta V_{i0} = \int_0^\infty e^{-rt} \Delta V_{it}(Z_{it}^A, Z_{it}, Z_{jt}, \mathbf{Q}_{it})\,dt \qquad (6)$$

For firms that experience $\Delta V_{i0} < (>) 0$, the discounted loss in market value is equivalent to an addition (reduction) to their discounted total costs of production. An additional unit of pollution at time t by firm i, holding investor expectations and the pollution generated by other firms constant, could increase the loss experienced by it or reduce the gain in market value experienced by it. Therefore, the change in the market value is likely to be smaller as Z_{it} increases, that is, $\frac{\partial \Delta V_{it}}{\partial Z_{it}} < 0$ for ΔV_{it} greater than or less than zero.

The *ith* firm is assumed to choose the amount of abatement, environmental discharges and capital stock at time t to minimize the sum of its discounted total costs subject to the constraints of its production function and waste generation function: It is assumed to take the anticipated level of pollution Z_{it}^{A} and the pollution levels of other firms Z_{jt} for $j \neq i$ at time t to be predetermined and not affected by its current choice of pollution level.

$$\underset{A_{it}, D_{it}, K_{it}}{Min} \quad C_{iO} = \int_{0}^{\infty} e^{-rt} C^{p}{}_{it} dt + L_{i0} - \Delta V_{i0} \quad \text{subject to:}$$

$$\begin{aligned} &(i)\ Y_{it} = F_i(\varphi_{it} X_{it}, K_{it}) \\ &(ii)\ Z_{it} = (1-\varphi_{it}) X_{it} \\ &(iii) Z_{it} = A_{it} + D_{it} \end{aligned} \qquad (7)$$

Using constraints (ii) and (iii) to substitute for X_{it} as in (3) and (4) and differentiating with respect to each of the inputs A_{it}, D_{it} and K_{it}, we obtain (after rearranging terms):

$$P_{it} \frac{\varphi_{it}}{1-\varphi_{it}} \frac{\partial F_i}{\partial D_{it}} = \left(\frac{w_{Xit}}{1-\varphi_{it}} + c_{Dit}\right) + \frac{\rho_{it} \partial \ell_{it}}{\partial D_{it}} - \frac{\partial (\Delta V_{it})}{\partial D_{it}}$$

(8)

$$P_{it} \frac{\varphi_{it}}{1-\varphi_{it}} \frac{\partial F_i}{\partial A_{it}} = \left(\frac{w_{Xit}}{1-\varphi_{it}} + c_{Ait}\right) - \frac{\partial (\Delta V_{it})}{\partial A_{it}}$$

(9)

$$P_{it} \frac{\partial F_i}{\partial K_{it}} = w_{Kit}$$

(10)

where P_{it} is the multiplier of the output constraint and represents the current shadow price of output. The optimal quantities of inputs D_{it}*, A_{it}*, K_{it}* at time t are chosen by equating the value of marginal product of the input to the marginal cost of that input at time t, as in (8), (9), and (10). If the second order conditions for minimization of C_{io} are satisfied, the function in (1) is minimized by choosing input-use levels that equate its instantaneous marginal benefits with its instantaneous marginal costs. The first order conditions for minimization of present value of costs, thus, do not depend on present values of future expectations (Jaffe and Stavins, [9]). Assuming that the derivatives in (8-10) are continuous functions, it is possible to solve these equations and the constraints in (7) simultaneously and express the optimal values of the endogenous variables A_{it}, D_{it}, and K_{it} as functions of exogenous variables (Chiang [3]) as discussed further in Section 4.

Since $\frac{\partial \Delta V_{it}}{\partial D_{it}} < 0$ and $\frac{\partial \Delta V_{it}}{\partial A_{it}} < 0$ irrespective of whether ΔV_{it} is positive or negative, the last term on the right hand side of (8) and (9) is positive and adds to the marginal costs of discharging and abating wastes. For firms that lower their waste generation relative to the anticipated level and experience a gain in market value, the gain is smaller if their waste generation increases by an additional unit. For firms that experience a decrease in market value because their waste generation is larger than anticipated, the decrease in market value increases with an additional unit of waste. Hence both positive and negative investor reactions imply a penalty being associated with an additional unit of waste and create incentives for firms to reduce waste. The first order conditions (8 and 9) also show that an increase in potential marginal liabilities creates incentives to reduce discharges and increase abatement. Moreover, a decrease in the output produced and an increase in the efficiency of input-use, reduces the level of waste generated, with other variables held constant. We now examine these issues empirically in the case of the chemical industry.

3. DESCRIPTION OF THE DATA

Three sources of data are used in this study: the Toxic Release Inventory (TRI), the Center for Security Prices Research (CRSP) database, and the Standard and Poor's Compustat (S&P) database. The TRI requires facilities to report the quantities of on-site toxic releases to air, water, land and underground injection and the quantities of off-site transfers on a chemical-specific basis. Each facility is identified by its name, its primary SIC code, its parent company name, and a Dun and Bradstreet (D&B) number assigned to each parent company. The TRI is made available to the public with a lag of two years. Hence the first TRI data released in 1989 provides information on toxic wastes generated in the reporting year 1987.

The sample of firms included in this study is drawn from the set of publicly-traded firms in the chemical industry. These consist of firms belonging to SIC 28 in the S&P database or the CD Corporate Directory, firms with facilities listed under SIC 28 in the TRI as well as firms that are members of the Chemical Manufacturer's Association. Since the TRI reports information on toxic releases at the facility level, while the S&P data and the stock price information are available at the corporate level, facilities reporting to the TRI were grouped together by parent company name or by the D&B number of their parent company in order to compile the TRI data at the parent company level. Several corporate directories were used to identify the parent companies of facilities that did not list D&B numbers. These include Ward's Business Directory and the Directory of Corporate Affiliations. Of the publicly-traded firms in the chemical industry, TRI data could be aggregated at the parent company level for 164 firms for 1989-91, 168 in 1992, and 176 in 1992-94. Out of this, there were 91 firms for which complete data on firm-specific characteristics and on stock market returns was available and for which no confounding events were found around the event window during the six years 1989-94.

Data on the environmental performance variables - on-site releases, off-site transfers, and number of records - for these 91 firms was obtained from the TRI database for the reporting years 1987-92. We aggregated releases to air, land, water and underground injections of all TRI chemicals by each facility of a parent company to form the variable ON-SITE RELEASES at the parent company level. Until the reporting year 1991, data on off-site transfers was only required to include the quantities of chemicals sent for off-site storage, treatment and disposal. In 1991 these requirements were expanded to include transfers for recycling and energy recovery. Due to changes in definition of the categories of waste included in off-site transfers it is not possible to disaggregate wastes transferred off-site for disposal from those transferred off-site for treatment, energy recovery and recycling in a consistent manner, for all the years in our study. Hence, we have aggregated all off-site transfers for energy recovery, recycling, treatment and disposal to form the variable OFF-SITE TRANSFERS. The analysis assumes that investors are interested in obtaining a measure of productive efficiency, abatement costs, and potential liabilities, which can be inferred from aggregate measures of on-site releases and off-site transfers.

The 91 firms included in this study make a substantial contribution to the on-site releases and transfers of chemicals reported in TRI. They accounted for 76.7 percent of the toxic releases and transfers from the chemical industry and 41.2 percent of those from all industries for the reporting year 1987 (Table 1). There was a steep decline in the sum of all on-site releases to air, land and water from the sample firms as well as from all firms reporting to the TRI between 1987 and 1988. This could have occurred because firms might have chosen to overestimate their releases in the first reporting year, 1987, in order to show significant reductions in subsequent years (Hamilton [7]) or because they lacked the technical information needed to estimate their releases accurately in the first year (GAO [18])[5]. Since the reporting year 1988, total releases from the sample firms and from all firms reporting to the TRI have declined more steadily. The sum of all off-site transfers declined until the reporting year 1990 but increased sharply in 1991 after the categories of wastes sent off-site were expanded to include recycling and energy recovery. Over the period 1991-93, more than 96 percent of these off-site transfers by the chemical industry were to recycling, energy recovery and treatment facilities (EPA [15]).

The number of different categories of TRI chemicals emitted by each facility in a parent company was aggregated across facilities to form the variable RECORDS, since a separate record has to be filed for each chemical emitted by each facility. We also included the cumulated NUMBER OF SUPERFUND SITES at which a company is a potentially responsible party (PRP) in each of the years 1989-94 as an indicator of the extent to which investors have prior information about a company's environmental performance. Data on the number of sites at which a company is listed as a PRP is obtained from the Site Enforcement Tracking System (EPA [16]).

The S&P database identifies companies not only by their D&B number but also by a nine-digit CUSIP number. The CUSIP numbers of parent companies were used to match parent companies in our sample with those in the CRSP database to obtain data on stock prices and daily stock market returns for these companies for the period 1989-94. The dates on which the TRI data was released to the public in each of the years over the period 1989-94 are indicated in Table 2. CRSP data for each company consists of a value-weighted market index based on daily returns on a value-weighted market portfolio, as well as daily returns for each company traded on American and New York Stock Exchanges and through the National Association of Securities Dealers Automated Quotations. A daily return is the change in the total value of an investment in a common stock per dollar of initial investment, during a day.

Data on the daily stock market returns on a value-weighted market portfolio as well as daily returns for each of the public companies selected from the TRI database were obtained from the CRSP database. Company specific data on number of shares outstanding and financial variables such as annual sales (SALES), annual expenditures on research and development (R&D), debt-equity ratio (D-E RATIO) and cost of goods sold (COGS) as well as on the number of employees (EMPLOYEES) were also obtained from the S&P database. The debt-equity ratio is defined as the ratio of total debt to common equity multiplied by 100.

4. EMPIRICAL ANALYSIS

4.1 Stock Market Reactions to Information

Stock market reactions on an event day are measured using the event study methodology (see survey in MacKinlay [13]) and estimating the market model specified as follows for each of the $i=1,..I$ firms:

$$R_{id} = \alpha_i + \beta_i R_{md} + \varepsilon_{id} \quad (11)$$

In (11) R_{id} is the continuously compounded rate of return on security i for day d, R_{md} is the return on the CRSP value-weighted index on day d and α_i and β_i are firm-specific parameters of the market model. This model is based on the assumption that in the absence of unexpected information, the relationship between returns to the firm and returns on the market index should be unchanged and the expected value of ε_{id} is zero. Market returns on the event day are then used to forecast the normal return for the firm. An abnormal return, or prediction error PE_{id} $(=\varepsilon_{id})$, for firm i is generated on a given event-related day d, when unexpected information affects the return for the firm (R_{id}) without affecting the market return (R_{md}). It is computed for the *ith* firm by subtracting the return predicted by the market model from its observed return.

The model in (11) is estimated separately for each of the years, 1989 to 1994, for each of the I firms. The day of release of TRI data in each of the years (day 0) is treated as the event date. Data for a 100 day period beginning with 110 trading days prior to the day of release of the TRI and ending 10 days before that day were used to estimate the market model in (11). Ordinary least squares (OLS) estimates of the parameters α_i and β_i for the *ith* firm in each of these years are used to compute the abnormal returns for each firm for the 0-5 day window after the event. The cumulative prediction error for firm *i* over the interval of event related days $d=d_1$ to $d=d_2$ is defined as $CPE_{id_1d_2} = \sum_{d=d_1}^{d_2} PE_{id}$. Average cumulative prediction error for a sample of I firms is defined as: $MCPE_{d_1d_2} = 1/I(\sum_{i=1}^{I} CPE_{id_1d_2})$. The test statistic for the $MCPE$ is defined as the mean standardized cumulative prediction error and is distributed unit normal in the absence of abnormal performance. It is obtained by standardizing the abnormal return for each firm (by dividing it by its estimated standard deviation over the 100 days) and then averaging the standardized abnormal returns across all firms[6] (Dodd and Warner [5]).

Our empirical analysis shows that on day –1 and day 0, the average stock market returns for firms in our sample were negative, but not statistically significant in any of the years. Lack of significance on day –1 implies that there was no leakage of information to investors the day before the information was fully revealed to the public. Lack of significance on day 0, could be due to the time needed by the majority of the investors to analyze and aggregate the large volume of chemical-specific and facility-specific data contained in the TRI. It may also be that investors react after they find information about the TRI in the media on the day after its release. On day 1, however, the average abnormal returns were negative and statistically significant in the years 1990-94, but statistically insignificant in 1989 (Table 2). These average abnormal returns on day 1 varied between 0.16 percent to 0.46 percent over the period 1989-94. Average returns over the 0-1 day interval were also negative and statistically significant for the years 1990-94. In 1993, for example, these negative average abnormal returns, over the 0-1 day interval, translated into an average loss in market value of $83.4 million. Over the 0-5 day window, however, the abnormal returns were significant only in 1992 and 1994, indicating that the average market values of these firms returned close to the levels expected on the basis of the market model within a few days of the release of the TRI.

The empirical results showing a lack of significance of the negative returns obtained by our sample of firms in 1989 differ from the results obtained by Hamilton [7] and by Konar and Cohen [10]. This difference is due to a difference in the sample of firms analyzed in these studies. Hamilton [7] studies a sample of 436 firms in the manufacturing sector of which 12 percent were in the chemical industry. Konar and Cohen [10] on the other hand, analyze a sample of 130 publicly traded firms that belonged to several manufacturing industries. Firms in our study were from the chemical industry and generally known to be large polluters, relative to firms in other industries, on the basis of other sources of environmental information about these firms, such as the number of Superfund sites for which they were listed as potentially responsible. The disclosure of the TRI for the first time in 1989 provided information on the magnitude of toxic releases by firms. Since this information may have already been anticipated by investors it did not cause them to react significantly (although the average reaction was negative). The first year's data, however, established benchmarks about the toxic pollution levels generated by each of these firms. It is possible that with the repeated provision of TRI data, investors examined changes in a firm's toxic releases and its rank relative to that in the previous year. They may then have reacted to these changes and this could have generated the statistically significant reaction in subsequent years.

In order to examine whether this was the case we now compare investor reactions to firms whose performance improved (relative to that previously as well as relative to other firms) with their reactions to firms whose performance worsened. Assuming that investors anticipate next years emissions to be lower than current levels, we would expect that firms with $Z_{it} \geq Z_{it-1}$ would suffer significantly negative reductions in market value while those with $Z_{it} < Z_{it-1}$ would benefit from an increase in market value. Investors might react more negatively towards firms that do not improve their environmental performance at the same rate as other firms. Firms with $R_{it} \leq R_{it-1}$ might therefore suffer larger negative returns on average than firms with $R_{it} > R_{it-1}$.

These two hypothesis are examined by dividing the firms in our sample into two groups for each of the years as shown in Tables 3 and 4 and comparing the abnormal returns of the two groups. Table 3 shows that for most of the years, the average negative returns over the 0-1 day period for firms whose releases increased relative to the previous year were significantly negative but those for firms whose releases decreased relative to the previous year were not. Table 4 shows that firms whose rank rose relative to the previous year (because their pollution levels rose relative to other firms) experienced statistically significant negative average returns during the event window unlike the other group of firms whose rank fell. These results support the view that with repeated provision of information investors did benchmark the environmental performance of firms, and this caused their reactions to be significant in the years 1990-94 even for firms initially known to be large polluters.

4.2 Determinants of Abnormal Returns Following the Release of the TRI

As discussed in Section 2.1, some of the factors that are expected to influence the magnitude of the abnormal returns experienced by firms following the release of the TRI include indicators of environmental performance as well as financial performance. Indicators of environmental performance available from the TRI are the magnitude of on-site toxic releases and off-site transfers as well as the number of different chemicals emitted. Investors may react more negatively to larger levels of toxic releases because they indicate low productive efficiency and potentially high pollution control costs and environmental liabilities. As shown above, investors may also compare performance over time and across firms and react negatively to firms whose performance is worsening relative to that of other firms. Additionally, the larger the number of different chemicals released by a firm the greater the attention that firm is likely to receive from investors scanning the database and the larger the potential costs of switching to alternative, less toxic, chemicals. According to the assumptions underlying the event study methodology, abnormal stock market returns are only likely to be observed in response to unanticipated events. Therefore, prior information about the environmental performance of a firm derived from sources other than the TRI, such as the list of firms named as PRPs for Superfund sites, could offset some of the negative reaction of investors to information provided by the TRI.

Other firm-specific characteristics and indictors of financial performance variables that might influence investor reaction to unanticipated environmental information include sales, number of employees, debt-equity ratio and expenditures on R&D. Larger firms, as indicated by the volume of sales and number of employees, are likely to draw greater attention from investors and therefore incur larger negative changes in market value. A higher debt-equity ratio may cause investors to view a firm unfavorably, not only because it indicates that the firm is more risky, but also because such firms may be less willing to undertake costly expenditures to clean-up pollution or invest in long term solutions to prevent pollution in the future. Higher R&D expenditures increase a firm's ability to innovate and is likely to give innovators a competitive advantage due to the "technological treadmill" effect that allows them to earn above average profits, while other firms lag in imitating the new technology (Cochrane [4]). Thus firms that are currently spending larger amounts on R&D are likely to increase productivity and profitability of the company in the future and are likely to be viewed more favorably by investors than firms with smaller R&D expenditures. This view is likely to be strengthened by the belief that R&D expenditures may also reduce waste generation and thus abatement costs and liabilities and increase profitability further.

In order to undertake an empirical analysis of the determinants of the dollar value of abnormal returns experienced on an event related day in each of the *t* years, $t=1989,...,1994$, we first estimated the abnormal change in market value (ΔV_{it}) for each of the firms on an event related day in each of the *t* years. This is calculated as a product of the prediction error for the firm on the event day, the stock price for the firm in year *t* on day *-1* of the event, and the number of shares outstanding for the firm in year *t*. A loss in market value following release of the TRI indicates $\Delta V_{it}<0$. The availability of panel data for 1989-94 provided multiple observations on each firm in the sample and allowed us to take the heterogeneity across individual cross sectional units and through time into account by estimating a variable intercept model (Hsiao [8]):

$$\Delta V_{it} = \delta_i + \gamma_t + \theta' \boldsymbol{H}_{it} + \xi_{it}, \quad i=1...I; \; t=1,....T \qquad (12)$$

where $\boldsymbol{H}_{it}$ is a $Kx1$ vector of explanatory variables for the *ith* firm at time *t*, θ' is a $1xK$ vector of parameters, δ_i is a scalar constant representing the effects of omitted variables that are specific to the *ith* firm and constant over the *T* years, and γ_t represents the effects of omitted variables that vary with time but are constant across firms. The error term ξ_{it} represents the effects of omitted variables that are peculiar to both the individual units and time periods. It is assumed that ξ_{it} is an independently and identically distributed random variable with mean zero and variance σ^2_ξ .

When the effects of omitted individual and time specific variables captured in δ_i and γ_t are correlated with the explanatory variables $\boldsymbol{H}_{it}$, a fixed effects model, which treats δ_i as a fixed constant over time and γ_t as fixed across individuals, is appropriate. Alternately when δ_i and γ_t are random and uncorrelated with $\boldsymbol{H}_{it}$, a random effects model is appropriate. The efficient estimator in the case of a fixed effects model is the OLS estimator, while in the case of a random-effects model it is the feasible generalized least squares (FGLS) estimator, since the variance of the composite disturbance term, $\delta_i+\gamma_t+\xi_{it}$, is unknown. We first test for the appropriateness of using a varying intercept model instead of a classical regression model using a likelihood ratio (LR) test statistic. We then use Hausman's chi-squared statistic to choose between a random effects and a fixed effects model.

Since abnormal returns, following the release of the TRI, were significant during the day *0* to day *1* interval we analyze the determinants of the dollar value of changes in market value experienced by firms during this interval. Three alternative specifications are estimated. Model 1 examines the determinants of abnormal changes incurred during the 0-1 day interval over the period 1989-94. Model 2 excludes data for the first year, 1989, since there were some doubts about the accuracy of that data. Model 3 includes a firm's rank as an explanatory variable to examine the impact of a firm's relative performance on the magnitude of abnormal returns.

The results of the estimation of the three models are presented in Table 5. Since the LR chi-squared test statistic favors the classical regression model instead of the model with firm and time-specific effects for all three models, we use the OLS method for estimating these models. In all three models an increase in the number of records and in the magnitude of off-site transfers led to a statistically significant increase in the abnormal losses experienced by firms. With the exclusion of the 1989 data in Model 2, the volume of on-site releases also has a significantly negative effect on the magnitude of abnormal returns. This suggests that doubts about the accuracy of the on-site releases reported by firms in the 1989 TRI may have prevented investors from considering them seriously. Results obtained in this study differ from those obtained by Hamilton [7] for 1989. His analysis indicates that investor reactions depended primarily on the extent to which firms were known to be polluters and that the level of wastes generated is not a significant explanatory variable. The empirical results obtained here show that with repeated provision of TRI data investors do focus on the specific levels of toxic wastes generated by firms.

The parameters estimated in Model 2 show that an additional million pounds of toxic wastes transferred off-site, with other determinants held constant, led to an increment of about $2.1 million in the losses incurred during the 0-1 day interval following release of the TRI. For an additional million pounds of on-site releases the corresponding loss was $1.35 million. Model 3 shows that a firm's rank has a significant effect on its abnormal returns. Firms that have low ranks because they generate smaller levels of toxic wastes than others experience less negative abnormal returns. The estimated parameters imply, for example, that an increase in rank from 11 to 10 leads to an increase of $2.4 million in the abnormal losses. These results indicate that firms with a larger magnitude of on-site releases and off-site transfers experienced larger abnormal losses because investors expected such firms to have lower profitability in the future and consequently bid their stock prices down. Furthermore they indicate that investors compared the performance of a firm relative to that of other firms[7].

In all three models, the coefficient of the number of Superfund sites for which a firm was likely to be held liable is significantly positive. This result is similar to that obtained by Hamilton (7) and indicates that the impact of the magnitude of on-site releases and off-site transfers on the abnormal returns incurred by firms was offset to some extent by prior information that investors had about a firm's environmental performance, for example through the number of Superfund sites for which it was potentially liable. In other words, investors reacted less negatively toward firms that were known to be large polluters by the number of Superfund sites for which they were potentially responsible. The magnitude of the coefficient of the number of Superfund sites indicates that being a PRP at an additional Superfund site decreased the dollar value of losses on day 1 by $3.5 million (Model 1).

Larger firms, measured by the volume of sales and number of employees, had more negative returns than smaller firms. The magnitude of expenditures on R&D also had a statistically significant positive effect on abnormal returns. This indicates that investors reacted less negatively towards innovative firms, expecting such firms to be in a better position to increase input-use efficiency, to find cost-effective solutions to environmental regulations and prevent waste generation at source, and thus increase profits in the long run.

4.3 Impact of Abnormal Returns on Subsequent Toxic Waste Generation

The demand function for an input is typically specified as a function of its own price, the prices of other inputs and the output level. We focus here on examining the determinants of the level of toxic wastes discharged and abated by a firm, which as shown by the framework developed in Section 2.2 can be considered as inputs to the production process.

The first order conditions (8) and (9) show that the demand for these inputs is a function of their prices, the efficiency of input-use, the expected abnormal changes in market value, the expected liability payments for Superfund sites and the level of output. In the empirical model (13-15 below), we proxy the amount of waste discharged by the total on-site releases to the environment. The amount of waste abated by a firm is proxied by total off-site transfers reported to the TRI. We also consider the total toxic waste generated, defined as the sum of on-site releases and off-site transfers, as an endogenous variable.

$$\textit{On-site Releases}_{it}=F_1(\textit{Sales}_{it},\ R\&D_{it-5},\ \Delta V_{it-2},\ \textit{No. of Superfund sites}_{it},\ \textit{Average Cogs}_{it})+\mu_{1it} \quad (13)$$

$$\textit{Off-site Transfers}_{it}=F_2(\textit{Sales}_{it},\ R\&D_{it-5},\ \Delta V_{it-2},\ \textit{No. of Superfund sites}_{it},\ \textit{Average Cogs}_{it})+\mu_{2it} \quad (14)$$

$$\textit{Total Toxic Wastes}_{it}=F_3(\textit{Sales}_{it},\ R\&D_{it-5},\ \Delta V_{it-2},\ \textit{No. of Superfund sites}_{it},\ \textit{Average Cogs}_{it})+\mu_{3it} \quad (15)$$

We hypothesize that the volume of on-site releases and off-site transfers at time *t* are a function of the volume of sales at time *t*, the lagged value of abnormal returns experienced by the firm, the lagged value of expenditures on R&D, the cumulated number of Superfund sites for which firms are PRPs at time *t*, and the average cost of goods sold at time *t*. The assumptions surrounding cost minimization behavior by firms include the assumption that the level of output is predetermined, and that it is not a contemporaneous endogenous variable chosen by the firm. Abnormal returns experienced in the past are used as a proxy for the expected changes in market value due to current toxic releases. Konar and Cohen [10] considered a three year time lag between the time that abnormal returns are experienced by firms and they have an impact on their toxic releases and off-site transfers. We considered both two and three year lagged abnormal returns as explanatory variables. Since the direction and statistical significance of the results did not change with the choice of the two alternative lags, only the results with the two year lagged value of abnormal returns are reported in Table 6. Given the available TRI data (at the time of the study) and the two year lag in the impact of abnormal returns on wastes generated, we are able to analyze the impact of abnormal returns incurred over the period 1989-91 on the on-site releases and off-site transfers during the reporting years 1991-93. Using off-site transfers over the period 1991-93 as a proxy for waste abated is therefore reasonable, since over 96 percent of these off-site transfers, after 1991, were to recycling, energy recovery and treatment facilities (EPA [15]).

Among the other explanatory variables, expenditures on R&D (with a lag of five years) are assumed to influence current levels of toxic waste, through their effect on the efficiency of input-use. The use of R&D expenditures in 1986-88 to explain the levels of on-site releases and off-site transfers in the reporting years 1991-93 enables us to treat R&D as an exogenous variable that is not endogeneously determined by abnormal returns, since the latter were experienced only after 1989. Additionally, the cumulated number of Superfund sites for which the firm is a PRP at time t is used as an explanatory variable to examine the impact of potential liabilities for environmental damages on current toxic releases[8].

Since data on prices of other inputs used in production and on the per unit costs of abatement and environmental discharges are not available for this study, we use data on average costs of goods sold (AVERAGE COGS) for each firm at time t to control for the effects of input prices and other costs on the level of wastes abated/discharged by firms. AVERAGE COGS for each firm at time t is obtain by dividing the data on COGS for each firm at time t by its SALES at time t. We assume that the firm is operating at its long run minimum average cost which is exogenously fixed at time t and therefore independent of the other explanatory variables. The random errors μ_{1it}, μ_{2it} and μ_{3it} measure the impact of omitted and unobservable variables.

A log-linear relationship is hypothesized for each of these three equations. We use panel data estimation methods described above to estimate each equation while allowing for the presence of heterogeneity among firms and/or across time. Two alternative models were estimated with each of these three endogenous variable specifications. In Model I, like Konar and Cohen [10], we focus only on those sample firms that incurred negative abnormal returns during 1989-91. The theoretical model in Section 2.2, however, suggests that positive investor reactions should also create incentives for firms to reduce their on-site discharges and off-site transfers. Therefore in Model 2 we include all firms in our sample and take the absolute magnitude of the change in market value of a firm as an explanatory variable. Model 2 examines whether both the positive and negative reactions by investors have an impact on the magnitude of subsequent toxic releases and off-site transfers generated by firms.

Out of the 273 pooled observations for this part of the study, 163 had negative abnormal returns, during the one day period following release of TRI data, in the years 1989-91. In the case of all six regressions, the chi-squared LR test rejects the validity of a classical regression model and indicates the presence of fixed/random effects (Table 6). Following the results of the Hausman test we estimate a fixed effects model for all the regressions in Table 6 except for those with off-site transfers as the dependent variable, for which a random effects model is estimated[9].

The empirical results indicate that for firms that experienced negative returns, the larger the abnormal losses the greater the reduction in the magnitude of their on-site releases. However, in Model 2, absolute changes in the market value of firms did not have a statistically significant negative impact on the on-site releases of firms. This indicates that while negative investor reactions provided a strong incentive to reduce on-site releases, positive investor reactions created a negative but insignificant incentive to reduce on-site discharges. Abnormal returns, however, led to statistically significant increases in off-site transfers in both Models 1 and 2. This implies that both the negative and the positive investor reactions led firms to increase abatement.

Despite the negative reaction by investors to unanticipated levels of off-site transfers (as indicated in Table 5) firms may have been induced to increase off-site transfers because they viewed the resulting reduction in their market value as being smaller than the costs of reducing off-site transfers either by reducing waste generation at source or by increasing on-site discharges which are likely to have been associated with larger expected cost of liabilities. The parameters estimated in Model 1 imply that the elasticity of on-site releases with respect to abnormal losses in market value is (-) 16 percent, while that of off-site transfers is 21.7 percent, when abnormal losses equal $1 million. As the magnitude of abnormal losses increases the absolute values of these elasticities decrease.

Unlike Konar and Cohen [10], however, we find that the impact of abnormal returns on total toxic wastes generated by firms is insignificant (Table 6, columns C and F). This implies that the abnormal losses experienced by firms caused them to substitute off-site transfers for on-site discharges. Nevertheless, this change in the composition of toxic releases may have net benefits for society since on-site releases go directly into air or water and are likely to be riskier for human health than off-site transfers which were primarily for recycling and treatment. A reduction in the proportion of releases discharged on-site and the increase in the proportion of waste abated could thus have important implications for social welfare and make the provision of TRI information an effective tool for reducing the net risks associated with toxic waste generation. However, one must also consider the increased risks of contamination while transporting hazardous wastes off-sites, since many of these wastes are shipped to great distances.

The volume of sales has a significantly positive impact on the volume of on-site releases, off-site transfers, and total toxic wastes. This is consistent with the findings by the EPA which showed that 70 percent of the facilities they sampled cited a change in production levels as one of the most important factors in influencing the changes in toxic releases reported to the TRI (GAO [17]). The number of Superfund sites for which firms are PRPs has a statistically significant positive effect on off-site transfers in columns (B and E) and a significant negative influence on the volume of on-site releases in column (D). It did not have a significant effect on total toxic waste generation in either model. This implies that potential magnitude of litigation costs as well as possible clean-up and damage costs provide incentives for firms to reduce discharges and increase abatement activities. Previously incurred R&D expenditures have a significant negative impact on on-site toxic releases but not on off-site transfers.

5. CONCLUSIONS

Public provision of environmental information is one of the key initiatives by the EPA for engaging the private sector in sharing the responsibility of environmental regulation of firms with the government. This study examines the impact of public provision of environmental information about known polluter firms on their stock market returns as well as the effectiveness of information as an instrument for environmental protection in the long run. It shows that in the case of firms known to be polluters, a one-time provision of environmental information may not generate significant reactions among investors, but that repeated provision of environmental information does lead to statistically significant negative abnormal returns. Repeated provision of information allows investors to benchmark a firm's environmental performance and make comparisons of performance over time as well as across firms. It is this feature of the TRI that enables stockholders to react to the changes in a firm's environmental performance over time.

The magnitude of abnormal losses is affected by the magnitude of on-site releases and off-site transfers as well as by a firm's performance relative to other firms. However, these losses were offset to some extent by prior information available to investors about the pollution-generating behavior of firms and by indicators that firms were engaging in R&D.

The study also shows that while the R&D expenditures of firms have a significantly negative impact on the magnitude of on-site releases, potential liabilities for Superfund sites provide strong incentives for increasing off-site transfers, a large part of which were to recycling and treatment facilities. More importantly, it shows that provision of environmental information is an effective policy tool for inducing firms to reduce on-site releases and increase off-site transfers. Although it does not cause firms to reduce total toxic waste generation, the substitution of off-site transfers for on-site discharges could reduce the net risks associated with toxic waste generation and lead to positive net benefits for society.

[1] The Chemical Manufacturers' Association initiated the Responsible Care Program in 1988 to encourage its members to continuously improve performance through responsible management of chemicals.

[2] Since we are assuming that time is a continuous variable, the time dependent variables should be denoted as $X(t)$. However, for the ease of exposition we are denoting them as X_t.

[3] This law states that the mass of all material inputs from the environment (energy and raw materials) to the economy must equal the mass of final products plus the mass of residuals discharged to the environment minus the mass of materials recycled (Ayres and Kneese [1]).

[4]The laws that address hazardous and/or toxic chemicals are the National Emission Standards for Hazardous Air Pollutants, that regulate six specific chemicals, and the Clean Water Act, that regulates 126 priority pollutants. However, so far very few chemical specific performance standards have been specified for these toxic chemicals because of lack of numeric criteria on which to base the standards (GAO [17]). Instead there are technology-based regulations on pollutants in the waste stream. Additionally, RCRA and the Superfund Act regulate hazardous waste streams destined for disposal on land and impose costs of installing best practice technologies and of obtaining discharge permits as well as costs of monitoring waste streams and meeting technical standards for disposal.

[5] In order to report releases to the TRI, facilities were to develop their estimates of releases using readily available data or standard engineering formulas; no additional monitoring of the facilities was required. Firms often lacked accurate information about the composition of certain chemicals and in the reporting year 1987 half of the facilities had made at least one major error in estimating their releases, while some erred by a factor of 10 or more (GAO [18]). However, the GAO study found that the database for the 1988 reporting year was virtually complete. For further discussion on the extent of compliance by firms with TRI reporting requirements see Brehm and Hamilton [2]).

[6] The advantage of the standardization procedure is that it permits the entire cross-sectional distribution of cumulative prediction errors to be compared to a unit normal. However, with this procedure it is possible in principle that the mean cumulative prediction error and the z-statistic differ in sign (Dodd and Warner [5]). This occurs in a few instances in Tables 3 and 4.

[7] We did not find the annual changes in releases or in the rank of a firm to have a significant effect on the magnitude of its abnormal returns.

[8] By including abnormal returns experienced at time $t-2$ and number of Superfund sites for which a firm is a PRP at time t, we avoid including correlated contemporaneous data on these two variables (since the number of Superfund sites at time t is shown to influence the abnormal returns at time t in Table 5).

[9] The LR test shows that the specification with only firm-specific effects is preferable to one with both firm and time-specific effects in all cases. A common intercept is not specified in a fixed effects model because it cannot be identified separately from the firm-specific intercept. Firm-specific intercepts are recovered using the method in Hsiao [8]. Since, our primary interest is in the direction and significance of the response of pollution level to the specified explanatory variables, we do not discuss those here.

Table 1: Descriptive Statistics about Sample Firms (Mean values and standard errors[a])

	1989	1990	1991	1992	1993	1994
Abnormal losses on 0-1 day interval ($M)	-20.51 (28.95)	-6.07 (20.99)	-5.07 (36.04)	76.34 (64.04)	-83.38 (25.52)	64.58 (48.72)
No. of Records	140.14 (19.91)	148.27 (19.65)	144.09 (19.27)	140.63 (19.00)	135.20 (18.67)	132.92 (17.88)
D-E Ratio	48.47 (24.00)	86.96 (35.63)	23.25 (23.66)	93.85 (47.33)	59.85 (11.82)	-17.74 (60.29)
R & D.($M)	266.12 (64.39)	290.70 (67.17)	308.66 (73.11)	315.01 (74.29)	317.14 (75.34)	328.31 (84.82)
Sales ($M)	8757.64 (1884.39)	9672.67 (2052.09)	9400.09 (2009.65)	9451.36 (2060.17)	9312.4 (2057.40)	9820.14 (2198.93)
No. of Employees ('000)	40.67 (9.36)	40.48 (9.24)	38.93 (9.10)	36.85 (8.81)	35.11 (8.34)	34.46 (8.13)
No. of PRP Sites	11.81 (1.31)	14.18 (1.55)	15.20 (1.66)	16.63 (1.82)	17.23 (1.89)	17.89 (1.95)
On-site Releases* (M lbs.)	97.16 (58.24)	16.59 (4.81)	14.54 (4.62)	10.73 (2.95)	9.36 (2.96)	8.90 (2.99)
Off-site transfers (M lbs)*	4.69 (0.75)	3.82 (0.67)	2.67 (0.58)	2.08 (0.50)	10.11 (3.07)	12.06 (3.51)
% of SIC 28 Releases & Transfers**	76.67	61.6	57.03	52.6	65.14	67.5
% of total TRI Releases & Transfers**	41.16	28.7	27.45	23.19	25.07	25.2
No. of Firms	91	91	91	91	91	91

[a] Standard errors of the data are reported in parenthesis. *This refers to toxic releases and transfers generated over the period 1987-92 but contained in the TRI reports made public in 1989-94. **Comparison of sample figures with total releases and transfers by SIC 28 (the chemical industry) and by all facilities reporting to TRI are based on figures reported in annual issues of EPA [15].

Table 2. Average Abnormal Returns for Sample Firms Reporting TRI Releases

	1989	1990	1991	1992	1993	1994
Date of release of TRI	6/19/89	4/30/90	5/16/91	5/27/92	5/25/93	4/19/94
Day 0 Average Returns z-value	-0.00144 (-0.45)	-0.00055 (-0.52)	-0.0019 (-1.37)	-0.0029 (-0.89)	-0.0025 (-0.81)	-0.00039 (-1.12)
Day 1 Average Returns z-value	-0.00184 (-1.31)	-0.00334 (-1.61)*[a]	-0.0016 (-2.17)**	-0.00019 (-1.72)*	-0.0046 (-2.8)***	-0.00193 (-1.99)**
Day 0-1 Average Returns z-value	-0.00329 (-1.25)	-0.00389 (-1.50)*[a]	-0.0035 (-2.50)**	-0.0031 (-1.84)**	-0.0071 (-2.55)**	-0.00233 (-2.21)**
Day 0-5 Average Returns z-value	-0.00406 (-0.78)	-0.00496 (-1.23)	-0.0056 (-1.08)	-0.0056 (-2.53)**	-0.0062 (-0.88)	-0.00576 (-1.99)**

*** Statistically significant at the 1% level. ** Statistically significant at the 5% level; *Statistically significant at the 10% level; *[a] Statistically significant at the 15% level. All two-tailed tests.

Table 3. Average Abnormal Returns for Sample Firms Grouped According to Annual Changes in Toxic Releases

	1990		1991		1992		1993		1994	
	Decrease in Emissions	Increase in Emissions	Decrease in Emissions	Increase in Emissions	Decrease in Emissions	Increase in Emissions	Decrease in Emissions	Increase in Emissions	Decrease in Emissions	Increase in Emissions
Day 0-1 Av. Returns z-value	-0.0038 (-1.01)	-0.0041 (-1.22)	-0.004 (-0.75)	-0.0027 (-2.98)***	-0.0021 (0.11)	-0.0042 (-1.76)*	-0.011 (-1.98)**	-0.0046 (-1.68)*	-0.003 (-0.92)	-0.0016 (-2.22)**
Day 0-5 Av. Returns z-value	-0.0058 (-1.15)	-0.0074 (-0.48)	-0.0049 (-1.1)	-0.0065 (-0.38)	-0.0058 (-1.03)	-0.0058 (-2.0)**	-0.0089 (-0.66)	-0.0046 (-0.60)	-0.0025 (0.11)	-0.0092 (-2.99)***
Number of firms	66	25	53	38	59	32	34	57	47	44

*** Statistically significant at the 1% level; ** Statistically significant at the 5% level; * Statistically significant at the 10% level.
Note: Firms were grouped according to those whose total toxic emissions increased and decreased relative to the previous year's emissions.

Table 4. Average Abnormal Returns for Sample Firms Grouped According to Annual Changes in Rank

	1990		1991		1992		1993		1994	
	Decrease in Rank	Increase in Rank	Decrease in Rank	Increase in Rank	Decrease in Rank	Increase in Rank	Decrease in Rank	Increase in Rank	Decrease in Rank	Increase in Rank
Day 0-1 Av. Returns z-value	-0.0052 (-1.02)	-0.0029 (-1.11)	0.0007 (-0.18)	-0.0061 (-3.04)***	0.0002 (1.17)	-0.0052 (-2.17)**	-0.0063 (-1.83)*	-0.0081 (-1.78)*	-0.0052 (-1.46)	-0.0003 (-1.65)*
Day 0-5 Av. Returns z-value	-0.0003 (0.06)	-0.0085 (-1.69)*	0.0003 (-0.50)	-0.0093 (-0.99)	-0.0104 (-1.05)	-0.0024 (-1.75)*	-0.0046 (-0.53)	-0.0083 (-0.73)	-0.0059 (-0.75)	-0.0057 (-1.98)**
Number of firms	52	39	35	56	36	55	51	40	38	53

*** Statistically significant at the 1% level; ** Statistically significant at the 5% level. * Statistically significant at the 10% level.
Note: Firms were ranked according to the magnitude of their annual total toxic emissions relative to those of other firms in the sample. Changes in rank are relative to the previous year's rank. A decrease in rank implies that the firm's environmental performance improved relative to other firms.

Table. 5 Panel Data Analysis of the Abnormal Returns[a] during the 0-1 Day Interval following TRI Disclosure

Variable	**Model 1** (1989-94)	**Model 2** (1990-94)	**Model 3** (1989-1994)
Records	-0.62 (0.224)***	-0.47 (0.29)*	-0.58 (0.22)***
On-Site Releases (M lbs.)	-0.57E-03 (0.07)	-1.35 (0.72)*	0.01 (0.07)
Off-Site Transfers (M lbs.)	-2.14 (0.91)**	-2.1 (0.95)**	-1.94 (0.91)**
Debt-Equity Ratio	0.12E-02 (0.045)	0.15E-02 (0.048)	0.21E-02 (0.045)
R&D ($ M)	0.26 (0.62E-01)***	0.34 (0.71E-01)***	0.26 (0.62E-01)***
Sales ($ M)	-0.215E-02 (0.161E-02)	-0.41E-02 (0.18E-02)**	-0.21E-02 (0.16E-02)
Employees ('000)	-1.30 (0.637)**	-1.83 (0.78)**	-1.33 (0.64)**
Number of Superfund Sites	3.48 (1.94)*	4.18 (2.19)*	3.16 (1.9)*
Rank	-	-	3.099 (1.42)**
Rank Squared	-	-	-0.0357 (0.019)*
Constant	45.06 (21.9)**	42.26 (25.48)*	-
Number of observations	546	455	546
R^2	0.078	0.11	0.081
LR test statistic: χ^2 [d.f.] {p-value}	73.3 [96] {0.96}	81.7 [95] {0.83}	71.83 [96] {0.97}

[a] Abnormal Returns are the dollar value (in millions of dollars) of the estimated change in market value of a firm and are negative when a firm experienced a loss in market value. Standard errors are given in parentheses.*** statistically significant at the 1 percent level; **statistically significant at the 5 percent level; * statistically significant at the 10 percent level. χ^2 is the likelihood ratio chi-squared test statistic to test the null hypothesis of a classical regression model vs. a model with group and time specific effects. Degrees of freedom (d.f.) are in square brackets. P-value is in curly brackets.

Table 6: Effectiveness of Abnormal Stock Market Losses as a Regulatory Instrument

	Model 1			Model 2		
Dependent variable	On-site Releases (lbs)	Off-site Transfers (lbs)	Onsite Releases & Off-site Transfers (lbs)	On-site Releases (lbs)	Off-site Transfers (lbs)	Onsite Releases & Off-site Transfers (lbs)
	A	B	C	D	E	F
Sales ($ M)	6.617 (2.176)***	3.189 (1.344)**	6.899 (2.12)***	4.016 (1.279)***	2.28 (1.15)**	3.816 (1.187)***
Sales squared	-0.435** (0.178)	-0.162 (0.927E-01)*	-0.403 (0.173)**	-0.214 (0.874E-01)**	-0.98E-01 (0.75E-01)	-0.202 (0.811E-01)**
R&D ($M)	-0.724 (0.42)*	-0.155 (0.486)	-0.176 (0.487)	-0.522 (0.3)*	0.114 (0.27)	-0.353 (0.371)
R&D squared	-0.122 (0.980E-01)	0.243E-01 (0.657E-01)	-0.150 (0.95E-01)	-0.347E-01 (0.569E-01)	0.15E-02 (0.027)	-0.0309 (0.528E-01)
Abnormal Returns[a] ($ M)	-0.162 (0.79E-01)**	0.217 (0.106)**	-0.172E-01 (0.769E-01)	-0.302E-02 (0.702E-02)	0.14E-01 (0.93E-02)*[a]	0.779E-02 (0.652E-02)
Abnormal Returns squared	0.297E-01 (0.149E-01)**	-0.219E-01 (0.191E-01)	0.817E-02 (0.145E-01)	0.333E-02 (0.692E-02)	-0.14E-01 (0.92E-02)*[a]	-0.737E-02 (0.642E-02)
No. of Superfund Sites	0.558E-01 (0.102)	0.104 (0.516E-01)**	0.695E-01 (0.998E-01)	-0.131 (0.608E-01)**	0.67E-01 (0.4E-01)*	-0.687E-01 (0.564E-01)
No. of Superfund Sites squared	-0.744E-03 (0.942E-03)	-0.814E-03 (0.647E-03)	-0.584E-03 (0.918E-03)	0.747E-03 (0.635E-03)	-0.4E-03 (0.57E-03)	0.617E-03 (0.589E-03)
Average Cost of goods sold ($)	1.705 (0.884)*	-0.561 (0.386)	1.437 (0.862)*	1.174 (0.622)*	-0.60 (0.35)	1.381 (0.577)**
Constant		-16.387 (4.597)***			0.66 (4.01)	
No. of pooled observations	163	163	163	273	273	273
R^2	0.96	0.50	0.97	0.96	0. 47	0.97
Hausman test (9 d.f.) {p-value}	28.78 {0.001}	9.59 {0.384}	23.55 {0.005}	33.56 {0}	17.01 {0.05}	24.44 {0.004}
LR test χ^2 [d.f.] {p-value}	527.2[83]{0}	546.3[83] {0}	541.6 [83]{0}	821.7 [90]{0}	792.8[90] {0}	862.2 [90]{0}

All variables except number of Superfund sites are measured in logs. Squared variables are squares of the log values. [a] In Model 1, only firms that received negative Abnormal Returns at time *t* are included. These abnormal losses are, however, measured positively in order to obtain their log values. In Model 2, all firms are included and the absolute value of abnormal returns received at time *t* are used as an explanatory variable. χ^2 is the likelihood ratio chi-squared test statistic to test the null hypothesis of a classical regression model vs. a model with group specific effects. Degrees of freedom (d.f.) are in square brackets. P-value is in curly brackets. Standard errors are given in parentheses. *** statistically significant at the 1 percent level; **statistically significant at the 5 percent level ;* statistically significant at the 10 percent level. *[a] statistically significant at the 15 percent level. All two-tailed tests.

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