PUBLIC DISCLOSURE OF PRIVATE INFORMATION AS A TOOL FOR REGULATING ENVIRONMENTAL EMISSIONS: FIRM-LEVEL RESPONSES BY PETROLEUM REFINERIES TO THE TOXICS RELEASE INVENTORY

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(June 2005)

*Brandeis University, Department of Economics. The author gratefully acknowledges support from the NSF (SES-0096896). Martino de Stefano and Ken Zhu provided invaluable research assistance. The author would also like to thank Theodore S. Sims, Ernst Berndt, Wayne Gray, Ann Wolverton, and seminar participants at Yale University for their comments and suggestions. The staff at the Boston Research Data Center, in particular, James Davis, provided access to confidential Census Bureau data, helped assemble and interpret their contents. The research in this paper was conducted while the author was a Census Bureau Research Associate at the Boston Research Data Center. Research results and conclusions are those of the author and do not necessarily indicate concurrence by the U.S. Census Bureau. This paper has been screened to ensure that no confidential data are revealed.

PUBLIC DISCLOSURE OF PRIVATE INFORMATION AS A TOOL FOR REGULATING ENVIRONMENTAL EMISSIONS: FIRM-LEVEL RESPONSES BY PETROLEUM REFINERIES TO THE TOXICS RELEASE INVENTORY

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Abstract

I investigate whether, as is commonly believed -- and if so how -- firm disclosure of so-called "toxic" releases, required since 1987 by the federal "Toxics Release Inventory ("TRI"), has brought about the reductions in toxic releases that have occurred since that time. Existing literature, consisting principally of event studies of stock market returns, suggest that dirty firms experience abnormal negative returns. Using a micro-level data set that links TRI releases to plant level Census data for petroleum refineries, I study plant-level behavior, exploiting state variation in toxics regulations, and exploring the relationship between TRI releases and concomitant regulation of non-toxic pollutants.

I find that, although TRI induced public disclosure may have contributed to the decline in reported toxic releases, that alone has not been the cause of those reductions: the evidence is strong that changes in toxic emission intensity are a byproduct of more traditional command and control regulation of emissions of *non*-toxic pollutants. I find that (1) since 1987, refineries have become substantially cleaner in terms of over-all toxic releases; (2) the clean-up has not occurred through substitution away from TRI listed substances as inputs or alteration in the mix of outputs; and (3) refineries in states with more stringent supplemental regulation of toxics (*e.g.* with specific state-wide goals for toxic reductions) have significantly lower toxic emission intensity levels than refineries in other states. I find also that (4) TRI air releases are highly correlated with levels of criteria air pollution; (5) both toxic pollution levels and intensity fall with increases in pollution abatement (operating and maintenance) expenditures for non-toxic air pollution; and (6) TRI air releases are affected by being in more stringent regulatory regions for the criteria air pollutants.

Finally, I link my data-set with CRSP data to re-evaluate the effect of TRI reporting on company stock market valuation, correcting for a methodological shortcoming (stemming from the fact that all reporting firms face a common event window) of prior event studies of the impact of the TRI. Correcting for that shortcoming, I find that (7) the evidence of negative abnormal returns around TRI reporting dates for petroleum companies is not significant. My findings suggest that the most probable mechanism through which TRI reporting may induce firms to clean up is local and state governmental use of TRI disclosures. They suggest also not only that the perceived effectiveness of TRI regulation has been overstated, but perhaps more importantly that the benefits of command and control regulation of non-toxic pollutants have been underestimated.

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Public Disclosure of Private Information as a Tool for Regulating Environmental Emissions: Firm-Level Responses by Petroleum Refineries to the Toxics Release Inventory

I. Introduction.

This paper is a micro-level study of firm response to the United States Toxics Release Inventory (TRI). Enacted as part of the Emergency Planning Community Right to Know Act of 1986 (EPCRA), the TRI is an exercise in informal, "informational" regulation of toxic releases by manufacturing plants: its premise is that economic behavior -- specifically the emission of toxic substances by manufacturers -- can be influenced by the simple expedient of requiring them to disclose to the public those emissions.[1] "Toxics" differ from other environmental contaminants in that even low levels of exposure may be hazardous to human health. And though the transportation, storage, and handling of toxic substances are all heavily regulated, formal regulation of toxic emissions as such does not exist.[2] Until 1987, moreover, there was not even any tracking of toxic emissions in the United States. Under the TRI, manufacturing plants with ten or more full time employees that either use or manufacture more than a threshold level of any TRI-listed substance must now report their toxic releases for that substance to the U.S. Environmental Protection Agency (EPA) for inclusion in a public database.

The TRI has been judged by many a striking success. In an October 1996 report to the Clinton Administration, the EPA reported that "The Right-to-Know program is widely acknowledged to be one of our nation's most common-sense, cost-effective tools for protecting public health and the environment." Between 1988 and 1994, reported toxic releases fell by more than 45%. During that period, according to the 1994 TRI Executive Summary, 22 states reported total reductions in reported releases of more than 50 percent, and five of more than 70 percent; only 3 (plus the District of Columbia) reported an increase in releases since 1988 (see pg. ES-19).[3] The apparent success of the TRI in reducing toxic releases has contributed to the adoption of even more comprehensive state level community right-to-know laws. By

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[1] In contrast, most regulation of so-called criteria pollutants takes the form of "command and control," prescribing methods of abatement, emissions targets to be achieved, or both.

[2] The lack of regulation of toxic emissions may be the result of the historic approach that the EPA has taken to setting environmental quality standards. By law, the EPA must set standards based strictly on health criteria, without consideration of cost. The nature of toxic emissions is such, however, that threshold concentration levels for such substances would have to be set low -- in practical application at zero. The resulting costs would be enormous. To avoid setting zero tolerance levels for toxic emissions, no formal regulation of toxics has been undertaken at all.

[3] Over 300 toxic substances were initially listed in 1987, expanded to include over 600 substances by 1995. The chemical industry (SIC 28) is responsible for the highest level of reported releases and the most substantial reported declines. Other large toxic emitters include primary metals (SIC 33), paper (SIC 26), transportation equipment (SIC 37), plastics (SIC 30), fabricated metals (SIC 34), petroleum (SIC 29), furniture (SIC 25), and printing (SIC 27).

2004 some 35 states had in place some form of expanded right-to-know law relating to toxic pollutants.

In this paper I study firm-level response to the TRI, in an effort to address (1) how effective the approach taken by the TRI really has been at reducing toxic releases; and (2) if it has, why have firms responded to such essentially "voluntary" regulation? Despite an evidently widespread contrary belief, it is not obvious a priori why reported toxic releases should have declined. And because there was no monitoring of toxic releases prior to TRI-mandated reporting, there can be no direct test of how (or whether) emitting firms responded to the advent of the TRI (and other community right-to-know laws). The reductions might have come about as a response to TRI reporting, but they might have been induced by factors independent of community right-to-know laws. The literature to date has ignored the latter possibility. Instead, its focus has been on understanding the mechanism through which TRI reporting has induced firms to curtail toxic releases. In particular, stock market event studies of abnormal returns associated with releases of TRI data have looked at whether TRI reporting affects firm profitability. Such studies have found that more "toxic" firms experience statistically significant negative abnormal returns around the times when TRI information is publicly released, suggesting that TRI reporting affects firm value, providing an incentive for firms to reduce their toxic releases. They suffer, however, a hitherto unnoticed methodological flaw. None thus far has taken account of the fact that the event under study -- the date on which the data are publicly released -- is the same for all companies. Because of that the events are not, in contrast with the usual assumption in the event study literature, independent across firms. As a result the variances on abnormal returns have not been calculated correctly, possibly compromising the significance of the findings of negative abnormal returns.

Given such shortcomings it remains to be determined both how and why polluters reduced reported toxic releases, matters that are crucial to evaluating the success of TRI, and community right-to-know laws more broadly, in controlling toxic releases. In this paper I undertake to address those issues in the context of a study of petroleum refineries. Refineries are well suited for a study of this sort because of their limited number, their stable and well-understood production technology, and their limited ability to substitute away from TRI-listed to unlisted inputs. Refineries are also among the major producers of toxic by-products, and have reported among the most dramatic reductions in TRI releases.

For the study, I construct a micro-level data set that links TRI releases to plant level operating data drawn from the Census, EPA and Census data on abatement of non-toxic pollutants, and data on state-level regulatory stringency.[4] The resulting data set allows me to look directly at both plant level inputs

[4] The data are described more particularly in Part III.

and outputs, to exploit variation in TRI-like regulations across states, and to explore the relationship between TRI releases and regulation of non-toxic pollutants, as well as differences in regulatory stringency across counties for non-toxic pollutants. I also use data from the Center for Research in Securities Prices (CRSP) to re-evaluate the effect of TRI reporting on company stock market valuation, taking into account the common event window shared by all reporting facilities.

I find that, while there is evidence that TRI-induced public disclosure has contributed to a real decline in reported toxic releases, that alone has not been the reason for the reported reductions; the evidence is strong that changes in toxic pollution intensity are a byproduct of the more formal command and control regulation deployed to deal with emissions of *non*-toxic pollutants. I find that (1) since 1987, petroleum refineries have become substantially cleaner in terms of over-all toxic releases; (2) the clean-up has not occurred through substitution away from TRI listed substances as inputs or changes in the level or composition of output; and (3) refineries located in states with the most stringent additional TRI-related regulations (e.g. with specific state-wide toxic reduction goals) have significantly lower toxic pollution intensity levels relative to refineries in other states. I find also that (4) TRI air releases are highly correlated with levels of criteria air pollution, and (5) both toxic pollution levels and intensity fall with increases in pollution abatement (operating and maintenance) expenditures for non-toxic air pollution. Furthermore (6) TRI air releases are affected by being in more stringent regulatory regions for the criteria air pollutants. Finally, in contrast with earlier studies, I find that (7) there is virtually no statistically significant evidence of abnormal returns (of either sign) on or around TRI announcement dates for petroleum companies. Indeed, when estimated in a manner that is appropriate given a common event window (the TRI announcement date) across companies, returns for TRI-reporting and non-reporting companies are both unremarkable and not readily distinguishable from one another.

Taken together, my findings suggest that the most probable mechanism by which TRI reporting has induced firms to clean up is state and local governmental use of TRI data to implement more stringent state regulation of toxics. At a more basic level my findings suggest that the effectiveness of the TRI in inducing reductions in toxic releases has been overstated; and, that the benefits of command and control abatement of non-toxic pollutants have by a parity of reasoning been underestimated.

The balance of the paper is organized as follows. Section II briefly summarizes the background and literature, and section III describes the data. Sections IV-VII describe estimation methods and results, bearing on four questions: (i) How did petroleum refiners respond? (ii) How robust are prior findings of negative returns to toxic firms? And, what roles were played by (iii) state regulators and (iv) mpm-toxic pollution abatement expenditures, respectively, in causing firms to clean up? Section VIII concludes.

II. Background and Literature.

The premise of the TRI is that behavior will change if polluters are required to disclose their toxic emissions to the public. Public disclosure of private information is not especially novel as a regulatory approach. Examples of disclosure regulation include mandatory food labeling, package inserts for medicines and drugs, and listing of workplace hazards under the Occupational Safety and Health Act (OSHA). It also includes the public dissemination of information required by the securities laws. But there are important differences between pollution disclosure and the types of disclosure that we have seen in the past, differences that make successful regulation of toxic emitters more complex.

For informational regulation to affect firm polluting behavior, market outcomes must somehow be influenced by the information disclosed. In the case of food labeling or medical package inserts, the information is made available to the prospective consumer at the point of purchase or consumption; it discloses the possible impact of the prospective item of consumption on them; it is therefore assumed (not unreasonably) that consumers can and some consumers will make informed decisions to substitute away from products for which mandated disclosures identify undesirable traits. They can avoid food with too much fat or too many calories, or carbohydrates, or drugs with contraindications or undesirable side-effects; workers can hold out for higher wages at abnormally risky sites. In such cases negative information can reduce firm profitability -- through reduced demand, lower prices, or higher wages -- providing incentives for firms to alter their conduct. In the case of the securities laws, disclosure as such is the objective, and what firms are required to disclose are precisely those things deemed to be "material" to firm value, and hence to investors' decisions.

For the TRI to be effective it must in some fashion provide new information to some economic agents who (1) value the information and (2) will use it in a way that affects the polluting firms' behavior. But, in contrast with the instances just mentioned, the relationship between the conduct of agents to whom the information is made available and firm profitability and behavior, if it exists, is less clear. Agents who might in the abstract respond to TRI disclosures include homeowners (communities) neighboring a polluting plant, consumers who purchase its output, and investors in, and competitors of, a polluting firm required to disclose. For consumers, what is disclosed pursuant to the TRI will not typically influence their consumption decisions as such: in the usual case it does not bear on the utility of the firm's products to them. Only to the extent that consumers prefer "green" goods, on that account, would we expect TRI disclosures to influence demand for the firm's output. As for the impact of TRI disclosures on surrounding communities, it is possible that TRI-mandated disclosures could influence neighboring housing prices, which might adjust to a perceived change in an environmental amenity in a way that reflects how nearby communities value the amenity.[5] And competitors might draw inferences about a firm's cost structure and efficiency from TRI disclosures. In contrast to the other examples of mandated disclosure identified above, it is not immediately clear *which* market outcomes should or will change in response to information on toxic releases, or how (if at all) disclosing firms should optimally respond to the resulting effects. Given that uncertainty it is, in contrast with the information generally required to be disclosed pursuant to the securities laws, unclear how investors' expectations about firm performance or value should respond to the information disclosed pursuant to the TRI.

A second major difference between the TRI and other disclosure regulations is that the TRI is self-reported; the data are provided to the public "as is." There is no uniformity of standards for reporting and, until Reporting Year 1996, there was no assurance of quality: the data are basically unverifiable by the public and extremely difficult to verify by the government. (Quality assurance surveys are conducting on small samples of reporters -- approximately 50 plants from various industries.) It is widely accepted that the first year's data, collected in 1987, is unreliable. Furthermore, reported releases are constantly being revised (or "updated") by reporting firms. A casual look at the data discloses that they are riddled with errors, ranging from the merely typographical to some that may be indicative of more serious problems.[6] The (in)accuracy of the data are an important consideration to take into account when evaluating the (potential) effectiveness of the regulation. If the public has no confidence in the accuracy of the data and the government cannot assure the public of its accuracy, disclosure will to that extent be ineffective.

The evidence on the effects of the TRI falls into three groups. The first consists of event studies asking if, and to what extent, TRI data is capitalized in either the stock or the housing market. Such studies provide evidence on whether the TRI provided new information to the public. Hamilton [1995] and Konar and Cohen [1997] look at the entire cohort of publicly traded TRI reporters in event studies of whether there are negative abnormal stock market returns associated with the announcement effects of the TRI, both finding significant abnormal returns on the announcement day. Khanna et al [1998] focus on the chemical industry (SIC 28) and the repeated disclosure of information that the TRI provides. They conclude that a one-time announcement may not affect investors, but with repeated TRI reporting, investors are able to "benchmark" a firm's environmental performance over time. They find that

[5] A fall in neighboring house prices conceivably might benefit a polluting plant, providing exactly the wrong incentive for a plant to reduce its emissions. See Bui and Mayer, 2002.

[6] Errors in names, addresses, zip codes, SIC codes, parent company, and even location are typical. Occasionally, reported total TRI releases are smaller than the sum of the releases from the constituent pollution sources (e.g. air, water, land, underground injection) by a reporting firm.

significant negative abnormal returns are associated with repeated announcements of TRI performance. Khanna et al also estimate a linear relationship between on-site releases, off-site transfers, and total toxic wastes with lagged abnormal stock market returns for TRI announcements. Their study suggests that both positive and negative announcement effects lead to statistically significant increases in firm abatement behavior, as measured by off-site transfers by both groups, and by on-site reductions in releases in addition by firms that suffer from negative investor reaction. Together, these studies would suggest that the TRI did, indeed, provide new information. However, Bui and Mayer [2002] find very different results when they look at whether TRI information is capitalized in house prices in Massachusetts. They use repeat-sales data and estimate a first-difference equation of reported releases on house prices and other community characteristics. Unlike the hedonic studies on air pollution, Bui and Mayer do not find any statistically significant effects of TRI reported releases on house prices at the zip code level.

The second and third group of TRI studies are similar in that they try to determine what characteristics may explain declines in reported TRI releases. One group investigates whether there have been differential responses to TRI regulation across communities. One example is the work by Arora and Cason [1999] which is part of the environmental justice literature and studies whether reported toxic releases are influenced by community characteristics. The other group looks at the "33/50" program that exists within the TRI. That is a program under which firms voluntary agreed to reduce their toxic releases of a certain number specified set of listed substances by 33% by 1992 and 50% by 1995, in each case from 1988 base levels. Khanna and Damon [1999] study the relationship between participation in the 33/50 program and economic performance of firms in the chemical industry, and Arora and Cason [1996] look at which firms choose to participate in this program.

III. THE DATA.

I draw on several different data sets for this study. The base set of petroleum refineries is taken from the Department of Energy's (DOE) annual list of refineries, published by the Energy Information Administration in Volume I of the Petroleum Supply Annual for 1987-1995. I construct a plant-level data set for those refineries, specialized to the project at hand. The data are drawn from several sources. Toxic emissions are as reported under the TRI, from 1987-1997. Emissions of criteria air pollutants (sulfurous and nitrous oxides, particulates, volatile organic compounds, and carbon monoxide) are as reported by the EPA from 1990-1999. I obtain various plant-level characteristics from the U.S. Census of Manufactures (COM) (for Census years 1977-1997), the Annual Survey of Manufacturers (ASM) for non-census years, the Longitudinal Research Database (LRD), and the Pollution Abatement and Control Expenditure (PACE) data from 1987-1997.[7] Data from the various sets are linked either by plant-name, permanent plant number, or by location (county or state).

There are two complications to using the TRI data. The first is that the set of listed substances and the reporting thresholds change over time. This may make comparisons in over-all releases more difficult. Approximately 7-10 new chemicals were added to the official list in 1990 and 1991, 30 in 1994, and over 200 in 1995. A small number of chemicals were also de-listed during this time period. Of those chemicals that were added, only 2 are relevant to petroleum refining (N-Hexane, N-Methyl-2-Pyrrolidone, both added in 1995). Of those chemicals that were de-listed, only one is relevant to petroleum refining (sodium sulfate, solution: 1987 was the only year it was reported by our sample). No changes in reporting thresholds affected the major TRI chemicals reported by petroleum refineries. All regression results in this paper are robust to the elimination of all three of these chemicals from the aggregated levels of TRI.

The second complication is that there is no explicit toxicity index that allows users of the data to evaluate chemical releases in terms of their risk to human health and welfare. (Post-1994 TRI data, however, includes information on whether a substance is deemed carcinogenic or may have reproductive/developmental risks.) In this paper, I simply aggregate total pounds of releases, regardless of chemical, explicitly ignoring differences in potential toxicity across substances. It can be argued that the effectiveness of the TRI should be evaluated in terms of its reduction in releases that are “less toxic”. Nevertheless, *all* TRI substances are considered to be dangerous to human health and welfare at low levels of exposure. Given the difficulty of quantifying what is “more” or “less” toxic, I make no attempt to take account of relative toxicity: my study uses the straightforward measure, aggregate toxic releases.

Summary statistics are provided in Table 1 for the TRI-DOE-LRD linked sample of refiners for 1987-1995. During the period, mean (plant) TRI releases were just over 940,000 lbs. The average operating capacity of a plant was approximately 97,000 barrels/day (with an average idle capacity of 1,804 barrels/day), and daily shipments valued on average at $8.6M. Mean annual toxic pollution intensity, normalized by operating capacity (see below), was 8.69 lbs/barrel/day, mostly from toxic air releases (which are substantially larger than toxic water releases). On average, during the period under study,

[7] The COM is drawn every five years (those ending in 2 and 7); the ASM is drawn annually in non-census years, and consists of a proper subset of the COM in terms of information obtained. In addition, the ASM samples the population of manufacturing plants: it includes large plants (250 or more employees) with certainty, while rotating smaller plants out of the sample at five year intervals. Establishment data from the ASM, the COM, and other surveys of manufactures are linked through the LRD. Two unbalanced panels were drawn from Census data: the PACE data, which is linked to the ASM; and the COM. The PACE data set reports abatement investment and operating costs by the medium abated (air, water, hazardous wastes, etc.)

annual toxic releases fell by over 384,000 lbs/plant, or 2.45 lbs/barrel/day).[8]

Between 1988 and 1995, as just noted, releases, as measured both by (plant level) toxic pollution levels ("TPL": TRI-listed substances in pounds), and by (plant level) toxic pollution intensity ("TPI": toxic pollution releases normalized by operating capacity in barrels/day) fell substantially.[9] (See Figure 1.) In levels, toxic air emissions fell by approximately 40% (39% in terms of intensity), whereas toxic water releases *rose* by almost 54% (57% in terms of intensity).[10] So in terms of over-all releases and air releases, petroleum refineries appear at first look to have gotten significantly cleaner over this period. And it is clear that the reductions in releases were not due simply to reduction in output: refinery production went up during this time period. The production of toxic water pollution, however, increased significantly during this time, both in levels and intensity.[11]

To investigate the possible effect of variation in regulatory stringency on TRI emissions, I construct a data set on state level regulatory activity pertaining to pollution prevention programs and TRI-related Community Right-to-Know laws from the Right-to-Know Planning Guide (1997, The Bureau of National Affairs, 0-87179-931-1/97) and from the 1999 State TRI Program Assessment. Information from these sources includes levels of state activity supporting the national TRI, accounts of state pollution reduction programs (including whether they prescribe pollution reduction targets), educational programs, grants, tax incentives, or other forms of state government support for pollution reduction activities. Regulatory stringency is partitioned into three categories. STR1 denotes states that do not supplement the TRI. This baseline level of regulatory "stringency" consists of the TRI itself. STR2 states supplement the TRI with additional pollution prevention programs or laws, but do not prescribe state-wide quantitative

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[8] The figures given in text are unweighted. Weighted over refineries by capacity, average pollution intensity was 9.69 lbs/barrel/day, and fell by 3.96 lbs/barrel/day.

[9] Optimally, normalization should be done by units of output. However, because refineries are multi-product production processes, it is not obvious what is the correct unit of output. Here, I present results for a normalization by operating capacity, but have also calculated all of these results normalizing by total value of shipments. The results of the analysis are robust to the choice of normalization.

[10] Air and water TRI releases do not exhaust the possibilities; some toxics, for example, are injected directly into the ground (*e.g.* landfills). [[Taking all categories into account, overall toxic releases fell by nearly 80% between 1988 and 1995, a substantial aspect of which was a decline in toxic land releases of over 95 percent.]] Releases for 1987, the first year of TRI reporting, are often omitted because of concerns about accuracy. With 1987 data included, over-all TRI reductions are about 90%, air reductions approximately 40%, and water reductions at [[82%]].

[11] The divergence between changes in toxic air and water pollution could be taken as suggesting substitution between toxic pollution media, perhaps induced by the fact that, during the period under study, regulation of *non*-toxic air pollution has been far more stringent than of non-toxic water pollution. The likelihood of large-scale substitution is blunted, however, by the relative magnitudes of the changes: toxic air emissions fell by some 42 million pounds, whereas toxic water emissions rose by less than 3 million pounds.

objectives for the reduction of toxic emissions. Programs in STR2 states may include reporting (such as for additional facilities or substances) beyond that required by TRI itself, technical assistance, educational programs, data clearinghouses, tax incentives, and government grants to help firms reduce waste. STR3 denotes states that have established statewide quantitative goals for reductions in TRI-listed substances. The target reductions range from 10% to 70%, to be met over varying periods of time. (Regulatory stringency for all jurisdictions was sampled as of 1999.)

I use plant location in a region that has not satisfied national ambient air quality standards for criteria pollutants (so-called "non-attainment" regions) as a second measure of regulatory stringency.[12] County-level data for attainment/non-attainment status for the set of criteria air pollutants between 1985-1995 were provided by Randy Becker of the U.S. Environmental Protection Agency. Several studies have shown that non-attainment status successfully captures differences in regulatory stringency for (non-toxic) air pollutants, and is an important factor in firm-level environmental behavior.

Finally, to determine whether the TRI provides new information that is viewed as affecting profitability, and therefore firm behavior, I compile data on stock market performance of publicly traded petroleum refiners. For all SIC 2911 (petroleum refining) TRI-reporting facilities, ownership data are compiled for "ultimate" corporate parents using company annual reports, Hoover's on-line, internet searches, and direct contact with firms via telephone survey. Stock market data for publicly traded companies that are listed on the AMEX, NYSE, and Nasdaq are drawn from CRSP. Ultimate parent companies determined in the TRI search were matched with ticker symbols and then to CRSP data for the period January 1, 1988 through December 31, 1997. The CRSP files provide indices of both equal and value weighted market returns, as well as daily return data for individual firms. My control group consists of companies classified by CRSP as petroleum based that did not report to the TRI.

IV. How did Refineries Get Cleaner? Evidence from Inputs, Outputs, and Productivity

It is clear that petroleum refineries became cleaner between 1987-1995, in terms both of toxic pollution levels and intensity (see Table 1 and Figure 1). What might account for these changes? There are basically three possibilities: changes in plant level inputs, changes in (level and/or mix of) plant level outputs, or changes in production technology (which may include the addition of abatement equipment or changes in process). I use evidence from the COM and LRD to investigate each possibility.

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[12] "Non-attainment" status is typically determined at the county level and occurs when an area does not meet the national ambient air quality standards set for any of the criteria air pollutants. The consequence of being in a non-attainment area is having to face far more stringent air pollution regulations, which typically includes the mandatory adoption of specified abatement technologies and restrictions on plant renovations and expansions.

Changes in Inputs Changes in inputs may reduce TRI releases in one of two ways. First, a polluting firm might simply substitute away from a TRI listed substance to an unlisted substance, reducing its use and hence its level of releases. (From the standpoint of the regulator, this outcome may be either good or bad, depending on the relative impact on human health and welfare of the unlisted and listed substances.) It is virtually impossible to determine the extent to which firms engage in this sort of behavior[13] so a benefit to limiting this study to refineries is that in the refining process there is limited scope for input substitution. (Domestic and foreign crude oil make up over 90% of all refinery inputs, with the remaining 10% consisting of a fairly limited set of chemical catalysts.)

Therefore, I look into a second way in which changes in inputs may lead to a reduction in TRI releases, namely, by using less of a given toxic input because they are making more efficient use of that substance in their production process. To explore this possibility, I make use of the materials files from the Census of Manufactures that I match to the TRI-DOE data set described earlier. Data on inputs (materials) of the production process are collected in census years on form MC-2901 (item 17) for the petroleum refining industry.[14] On this form, materials are classified by 7-digit material codes and both quantity and cost (including delivery) information is requested. In theory, all materials should be included on this form. For the sample of plants used in this study, between 1982 and 1997, approximately 100 different inputs were used in the production process.

To investigate the use of TRI listed substances in petroleum refining, I focus on 3 different material "groups", as defined by Census material code: benzol (291107 1), toluene and xylene (286519 4), and sulfuric acid, excluding spent (281931 6). These three chemical groups constitute the largest toxic contributors to TRI releases, making up approximately 20-25% of their annual TRI releases (by weight) for petroleum refineries.[15] For each plant, and each material group, I calculate the difference in use between census years (1982, 1987, 1992) and then calculate the average difference across reporting plants. For example, for material group j, Census years 1992 and 1987, over plants $i = 1,...,N$, I calculate:

$$\frac{1}{N} \sum_{i}^{N} \left(Q_{ij,1992} - Q_{ij,1987} \right)$$

[13] In theory, one might be able to exploit the materials files to determine whether there have been systematic adoptions of new inputs that correspond to the observed reductions in TRI-listed materials, although in the general case this would be very difficult.

[14] This is the form name for the 1997 collection.

[15] The other TRI reported substances constituted much smaller amounts. There were also no reliable census data for materials on the these other chemicals.

For each of material groups, the average quantity consumed at the plant level fell between 1982-1987, the years immediately preceding the TRI. Consistent with subsequent increases in refinery output, however, refinery consumption of these materials grew between 1987-1992, the first five years of TRI reporting. Although we cannot observe TRI releases between 1982-1987, we do observe that TRI releases for the three groups *declined* by between 1.7% - 22% between 1987-1992. (The latter pattern also holds for 1992-1997, when average refinery consumption grew, but TRI releases fell between 1992-1996; 1997 TRI data were not available at the time of the analysis.) These results do not change if aggregated to the state level. (See Table 2.) So, for these TRI substances, the data show that plants used more toxic inputs but produced fewer toxic releases: during the period under study, petroleum refiners became more efficient at using these toxic materials as inputs, and hence produced fewer toxic releases.

Changes in Output: Perhaps the simplest way to reduce toxic releases is to reduce output. But refinery output increased between 1987-1995, even as the number of operating refineries fell. Total output (across all products) grew from 14,626 (thousand barrels/day) in 1987 to 15,994 (thousand barrels/day) in 1995. Capacity utilization rose from 82.9% in 1987 to 92% in 1995. (EIA: Annual Energy Review 2003.) So the reduction in reported TRI releases cannot be attributed to a decline in over-all output levels.

A change in output *mix*, however, could influence the level of toxic releases. Although, given the costly nature of doing so, it is unlikely that a plant would alter its mix of outputs solely in response to TRI reporting, variation in the price of outputs may lead to changes in the composition of output over time, and different products might contribute differently to the magnitude of toxic releases. In fact, between 1987 and 1995 there was a substantial change in refiner margins across various refined petroleum products. For example, margins for motor gasoline widened from 16.3% to 21.6%, those for jet fuel from 11.2% to 12.9%, and residential fuel oil from -4.1% to -4.8%. Refinery output of these products correspondingly changed substantially: motor gasoline production increased by 9% and jet fuel by 5%, while residential fuel oil fell by 11%. (EIA, Annual Energy Review, 2003.)

To investigate the possibility that these changes affected toxic release levels, I consider the relationship between TRI releases and a set of refined petroleum products. Specifically, I look at the ten major products summarized in Table 3. Data on refinery products are taken from Form MC-2901 (item 18b) of the Census of Manufactures and linked to the TRI-DOE data set for this analysis. (Approximately 199 different products were produced between 1977-1992.)

Results are summarized in Table 3. Columns 1 and 3 report regression results that include all 10 products, where Columns 2 and 4 report regression results that exclude aviation gasoline, no. 4 type light fuel oil, lubricating oils, and lubricating greases (each of which makes up between 0.78 and 4% of all observations). Consistent across specifications, TRI releases are positively and significantly correlated with increased production of motor gasoline and jet fuel (kerosene type), and negatively correlated with heavy fuel oils. In other words, while TRI releases are *increasing* in the production of motor gasoline and jet fuel, and the production of both *increased* between 1987-1995, TRI releases nevertheless fell. That is inconsistent with the hypothesis that the reduction in TRI releases by refineries was the result of fortuitous changes in their production mix. In fact, actual changes in the composition of refiners' output, with everything else held constant, would have increased their levels of TRI releases. In sum, while both output increased and the production mix changed in a way that worked against a reduction in toxic emissions, toxic releases nevertheless fell.

TRI releases and plant productivity. Add-on abatement technologies, changes in production processes, and recycling may all be adopted to reduce pollution emissions. There is a general consensus that pollution abatement expenditures are costly and do not contribute to output, That is, abatement reduces total factor productivity. If productivity is decreasing in abatement, it should be increasing in TRI releases, and we should expect to find a positive relationship between TRI levels and TFP.

Figure 2 displays the pattern of TRI pollution intensity and average plant-level TFP (as measured by total revenue/total cost) between 1988-1995. Both trend generally downward over the sample period: TFP falls as petroleum refineries become cleaner, as predicted. In addition to depicting movements of TPI and TFP, I estimate a relationship between TRI releases and productivity using of the general form:

(1) $$TFP_{it} = \alpha + \gamma_i + \psi_t + \beta\, TPI_{it} + \epsilon_{it}$$

where TPI_{it} is the toxic pollution intensity of plant $i = 1,...,N_t$ at time $t = 1,...,T$, γ_i (if included) are either plant or state fixed effects, and ψ_t are year fixed effects. I estimate (1) both in levels (of *TPI*) and first differences.[16]

The results of that estimation are summarized in Table 4. Here I find that, as would be expected a priori, TPI is positively, and statistically significantly, correlated with TFP. That is, and though the magnitude of the effect is small, "dirtier" plants (those with higher TRI pollution intensity) also have higher measures of TFP. From column 1 of Table 4, we can observe that a 1 lb/barrel/day difference in TPI between two plants would lead to a 0.00087 difference in TFP between them, a difference that is as expected but small. For a single plant, a one-standard deviation decline in TPI (15.9 lbs/barrel/day) would

[16] Note that in the estimation of (1) in first-differences, the time invariant constants drop out and the interpretation of the coefficients are somewhat different.

lead to a decline in TFP of 0.014 units (from column 3, Table 4). Average plant-TFP in the sample is approximately 1.15, so this would be approximately a 1.2% change in average TFP.

Taken together, the data surveyed in this section show that firms did reduce their toxic releases in the aggregate *and* in terms of emissions per unit of output. They accomplished those reductions not simply by substituting unlisted for listed substances as inputs, or by reducing (or altering the composition of) their output, but through changes that were costly in terms of plant factor productivity, albeit only marginally so. That evidence may be encouraging to environmental regulators, as it suggests that firm polluting behavior has improved substantially, but without imposing excessive costs on the affected plants.

I turn next to the question *why* firms might have undertaken reductions in toxic releases.

V. Stock Market Response to the TRI.

The basic premise behind the TRI is that by forcing public disclosure of firms' polluting behavior, they will be induced to clean up: the asymmetric information between polluters and victims will be corrected, and no further regulatory intervention will required. In that spirit, researchers have devoted much of their effort to determining how households (or consumers or investors) may have used TRI information to influence firm behavior. Most prevalently, event studies have been used to analyze the effect of TRI announcements on firm value. The general consensus of the literature is that such announcements have had a significant negative impact on stock market valuation. Larger, negative (abnormal) returns are associated with persistently dirty firms.

In this section I re-examine the stock market evidence, using movements of petroleum refiners' stock to explore whether (1) the TRI provided new information to shareholders on the toxic polluting behavior of petroleum companies and (2) whether (unexpected) changes in toxic polluting behavior were capitalized in stock market valuations. The latter would provide evidence of an incentive for polluting firms to reduce their toxic releases.

Methodology: The methodology is based on McKinley [1998]. Individual stock market returns are typically estimated using a so-called "market model," in which daily returns are assumed to be a simple linear function of the market return on that day:[17]

(2) $$r_{it} = \alpha_i + \beta_i r_{mt} + \epsilon_{it},$$

[17] Note that the market model may be modified to include company and/or plant-specific variables as well. For example, information on the number of Superfund sites for which the company is listed as a potentially responsible party, the number of EPA violations incurred in a given year, lagged TFP measures, etc. These additional explanatory variables may play an important role in the estimation of the market model by reducing the variance on the estimators. See McKinley, 1998.

where r_{mt} is the market rate of return on day t, r_{it} is the daily rate of return for stock i on date t, and ε_{it} is a random disturbance.

For an event on day t, estimates for α and β from (2) may be found by using daily market returns for some period prior to the event date, t. We estimate the abnormal return of stock i on event day t as the difference between the actual and predicted daily return for that stock:

(3) $$AR_{it} = r_{it} - \left(\hat{\alpha}_i + \hat{\beta}_i r_{mt} \right).$$

The variance on the abnormal return for a given stock on a given day is made up of two components, the variance of the daily return, and the variance of the predicted daily return and may be written as:

(4) $$\sigma^2_{AR} = \sigma^2_r + \sigma^2_{\hat{\alpha}} + r^2_m \sigma^2_{\hat{\beta}} + 2 r_m COV(\hat{\alpha}, \hat{\beta}).$$

When estimated daily abnormal returns from an event are averaged over occurrences involving different stocks, the variance of the averaged abnormal returns under the assumption that the abnormal returns to the constituent companies have zero covariance is given by:

(5) $$Var(\bar{AR}) = \frac{1}{N^2} \sum_i^N \sigma^2_{AR}.$$

Then, under the null hypothesis of no abnormal returns associated with the event date:

(6) $$\frac{\bar{AR}}{\sqrt{(VAR(\bar{AR}))}} \sim N(0,1).$$

Event Study Results: The companies that were chosen for the event study come from two sources. The first consists of all SIC 2911 firms that reported TRI releases. For those facilities, TRI releases are aggregated up to the ultimate parent company. (The allocation of TRI releases to the parent, when a refinery merges with (or is taken over by) a different parent during a TRI reporting period, depends upon the timing of the change in ownership.) When the ultimate parent has TRI-reporting facilities that do NOT include SIC 2911 as their primary code, I nevertheless incorporate those releases into measured total TRI releases for the parent. The second set of companies (the control group) consist of those with petroleum interests as given by CRSP that reported no TRI releases. In total, over the entire sample period, approximately 106 different companies are included in the sample.

Because of the roughly 18 month lag between each TRI reporting year and announcement of the year's results, announcement dates for TRI releases between 1987-1995 fell between 1989-1997. Announcement dates for all but the initial TRI announcement were determined through newspaper searches.

Returns are calculated based on Equation (2). I estimate the model using for the market rate of return both the value weighted index return and the equal weighted index return as given by CRSP. For the initial TRI announcement, data from January 1, 1989, through June 14, 1989, the third trading day prior to the initial TRI announcement (on June 19, 1989) are used to estimate the market model. For subsequent announcements, the market model is estimated using data from the third trading day following the previous year's announcement through the second trading day prior to the last trading day preceding the next announcement date. Thus, the event window is defined to begin two trading days before the announcement and to end two trading days after the announcement (5 trading days in all). So, for the initial TRI announcement on June 19, 1989, the estimation window is given by the trading days between (January 1, 1989 - June 14, 1989) and the event window is given by (June 15, 1989 - June 21, 1989). The abnormal return is defined as the difference between the actual return and the predicted return (see Equation (3)).

In any year, there were between 47 and 53 TRI reporting firms and between 30 and 35 non-reporting firms in the sample. Table 5 and 6 summarize abnormal returns for the TRI reporting and non-reporting companies for the two days before and after the public release of the 1987-1995 TRI data. For the first TRI announcement in 1989, TRI-reporting companies had announcement day average abnormal returns of approximately -0.7% (standard error of 0.3%), whereas non-reporters had abnormal returns that, although negative, were not significantly different from zero. (Positive abnormal returns were found for the TRI announcement in 1990, but the announcement date was also the date on which OPEC announced a price increase.) Over-all, however, the evidence that TRI announcements had much effect on the stock market returns for petroleum-based companies is weak. The ten-year average abnormal return on the event date for TRI reporting companies is negative, but significant only at the 10% level, and that is true for non-reporting companies as well. A test for whether the average abnormal returns between reporting and non-reporting companies are significantly different from one another for each day (two before, two after, and the announcement date, itself) and for each announcement exhibited no statistically significant results. [Details are not reported here, but are available on request from the author.]

The results just reported are weaker than, although qualitatively consistent with, findings from previous studies. There is, however, one potentially serious problem with the results just reported that also affects the results found by Hamilton [1995] and Konar and Cohen [1997]. The variance calculation in Equation (5) assumes that the event windows are uncorrelated across companies. The TRI events, however, are *identical* for each company in each year: that is, there is a single event date for all companies. The assumption of zero covariance across abnormal returns is therefore almost surely violated.

In an attempt to mitigate the covariance problem, I report two sets of alternative results. First, in Tables 7 and 8, I report the results for abnormal returns around the event window for two portfolios of companies, TRI reporting and non-reporting companies. Those results offer little evidence that TRI announcements had any negative effect on market returns, and there is no statistical support for the hypothesis that abnormal returns for reporting and non-reporting companies are significantly different from one another. For only four of the 50 event days during the period under study did abnormal returns for the portfolio of TRI reporting companies differ from zero at the 5% level. Of those four days, two exhibited positive and two exhibited negative abnormal returns.[18]

Finally, in Tables 9 and 10 I report abnormal returns for companies grouped by whether they are thought to be reporting "bad news" versus "good news." Companies are classified as reporting bad news if their TRI releases are larger in the current year than in the previous year. Only companies that are in the data set for all reporting years are included in this analysis. All companies are classified as reporting bad news in the first year of TRI reporting. Once again, there is virtually no evidence that companies reporting "bad news" had statistically significant negative abnormal returns during the event window, or had returns that were statistically significantly different from firms reporting "good news."

The event study results are consistent across all specifications. From them it seems clear, for petroleum companies at least, that TRI announcements either provided no new information to the public, or that the level of toxic emissions reported were not expected to affect firm value. In either case, I find no evidence to support the belief that TRI reporting provided an incentive to firms to reduce toxic emissions.

In light of that finding, I turn possible alternative explanations for the reductions in releases.

VI. Plant Level Response to Variations in Regulatory Stringency.

In response to the apparent success of TRI reporting at the federal level, some 35 states adopted expanded legislation, intended to enhance both the scope and effectiveness of the TRI. (Several others have expressed the intent to do so in the near future.) Such state programs run the gamut from supplemental reporting to specific statewide target reductions in toxic releases. Here I use state-to-state variation in regulatory "stringency" to test whether such differences have an effect on plant-level response to TRI.

As described in Section III, states are grouped into one of three categories, depending upon the

[18] None were significant at the 10% level. The pattern for the portfolio of non-TRI reporters (Table 8) was similar: four days exhibited abnormal returns at the 5 percent confidence level, two positive and two negative (the non-reporters also exhibited abnormal returns significant at the 10% level on another 5 event days), Two days exhibited significant abnormal returns in both portfolios, Event day 1 in 1990 (negative) and 1994 (positive), casting further doubt that the abnormal returns were attributable to TRI announcements.

level of additional state regulation, with STR1 states having the lowest (*i.e.*, only baseline *TRI*) regulatory stringency, and STR3 states having the highest. Table 11 provides summary statistics broken down by state level of regulatory stringency. Although average plant releases did not differ greatly across the three different categories (averaged over the sample period), plants located in STR3 states did exhibit significantly higher initial TPI's, at 53.4 lbs/barrel/day, compared to 24.6 and 31.5 lbs/barrel/day for STR2 and STR1 states, respectively.

To start, I investigate whether STR2 and STR3 states differ from STR1 states in their determination of plant level toxic pollution intensity (controlling for initial level of toxic intensity). The basic regression that I estimate is of the form:

(7) $$TRI_{it} = \alpha + \beta_1 STR2 + \beta_2 STR3 + \beta_3 Initial\,TRI_i + \beta_3 year_t + \epsilon_{it}$$

where *STR2* and *STR3* are dummy variables set to 1 if the refinery is located in an STR2 or STR3 state, as characterized in 1999 (the resulting possibility of endogeneity is addressed below). The results are summarized in Table 12, panel 1. Refineries located in STR2 states are not significantly different in terms of toxic pollution intensity than refineries located in STR1 states. However, refineries located in STR3 states have significantly lower toxic pollution intensities -- on the order of 7.7 lbs/barrel/day. For the over-all sample, the average TPI was only 8.8 lbs/barrel/day, so the impact of being in an STR3 state is large.

Because STR2 and STR1 states differed only in either the level of reporting required or in the quantity of state-sponsored TRI support for reporters, and because the data did not support the hypothesis that refineries in STR2 states differed from refineries located in STR1 states, I consider an alternative specification that focuses on the effect of *instituting* a state policy with a specified toxic reduction goal in effect (STR3B). (STR3B takes on the value of 1 for refineries located in STR3 states, but only for years after adoption of the statewide toxic reduction goal.) These results are summarized in Table 12, panel 1, columns 2 and 3.

Compared to refineries located elsewhere, and to refineries located in the same state but prior to adoption of the statewide toxic reduction goal, refineries in STR3 states after a policy of toxic reduction has been adopted are significantly cleaner than other refineries, by on the order of between 10 and 14 lbs/barrel/day. The results suggest that taking an average plant in an STR1 state and moving it to an STR3 state would lead to a reduction in TPI of not less than about 10 lbs/barrel/day – an 86% reduction from its STR1 toxic pollution intensity (holding everything else constant).

Because state regulatory stringency is sampled as of 1999, there is a possible endogeneity between the *STR* explanatory variables and TRI emissions on the left-hand side in earlier years. To address the possibility of a resulting bias in the above regressions, I used state-level expenditures on education and natural resources in 1988, as well as over-all TRI releases *excluding* petroleum in 1988, to instrument for the level of state regulatory stringency. The null hypothesis of no endogeneity in the resulting Hausman test could not be rejected at any reasonable level of significance, so I report the results from the OLS regressions (rather than the IV estimates) here.

I also consider a slightly different question regarding state stringency: In STR3 states, do refineries look different *after* the state adopts a toxic release reduction policy with specific numeric objectives? These results are presented in Table 12, panel 2. What I find is that yes, refineries look significantly cleaner after the state in which they are located has adopted a specific target for toxic reductions (conditioned on being in a state that is known to adopt a strict toxics policy). On average, refineries are 14 lbs/barrel/day cleaner *after* the adoption of a statewide goal than refineries prior to adoption of the policy. The adoption of statewide toxic reduction goals clearly has an important effect on polluting behavior. Hence, one path by which the TRI-disclosures may have influenced polluting behaviour entails intermediation by state regulators: by inducing the latter to resort to more traditional forms of regulation, they (in the case of refineries at least) induced polluters to alter their behaviour.

VI. The Relationship Between Toxics and Regulation of Non-Toxic Pollutants.

Another possible explanation for the reduction in TRI releases is that they may in part be attributable to the formal regulation of more traditional, non-toxic pollutants, primarily criteria air pollutants. To explore that possibility, I turn to an examination of the relationship between TRI releases, criteria air pollution emissions, and pollution abatement expenditures.

TRI Air Releases and the Criteria Air Pollutants: SIC 2911 facility-level emissions for the criteria air pollutants (1990-1999) are available from the Emissions Factor and Inventory Group of the EPA. The data for 1990, 1996, and 1999 are collected directly from polluting facilities. All other years are estimated emissions based on emissions factors, inputs, and other economic variables. For this analysis, the data are aggregated to the state level and compared with state level TRI air releases for TRI reporting facilities in SIC 2911.[19]

During the 1990s, 4 of the criteria air pollutants (NO_x, SO_2, VOC, PM_{10}) showed a general downward trend in over-all level of emissions by petroleum refineries. (The exception was carbon monoxide, which was increasing during a large fraction of this period.) (See Figure 3.) Corresponding

[19] Plant-level matching of these data may be possible, but have not yet been done.

with this period was the passage of the 1990 Clean Air Act Amendments, which strengthened many of the regulations affecting these pollutants. From Figures 4 and 5 it can be seen that, apart from carbon monoxide, the patterns of emissions were broadly similar, with the decline in TRI air releases and sulfur dioxide emissions most strikingly similar, suggesting that their declines might be related.

To capture the (descriptive) nature of the relationship between toxic and non-toxic air releases, I estimate the following equation:

(8)
$$TRI\text{-}Air_{it} = \alpha + \beta_1 CO_{it} + \beta_2 NOx_{it} + \beta_3 PM10_{it} + \beta_4 SO2_{it} + \beta_5 VOC_{it} + \beta_6 Year + \beta_7 N\text{-}A_{it} + \epsilon_{it},$$

where *Year* is a trend variable, and $N\text{-}A_{it}$ is a dummy variable set to 1 when plant *i* is located in a non-attainment region. (As with Equation (7) I estimate Equation (8) using both *TPI* and *TPL* on the left-hand side.) Results from the descriptive regression are summarized in Table 13.

In levels, TRI air releases are significantly correlated with all 5 criteria air pollutants at either the 5% or 10% significance level, although not necessarily in obvious ways. In particular, I find that higher levels of SO_2 and NO_x emissions -- the two major air pollutants resulting from combustion of fossil fuels -- are statistically significantly associated with higher *levels* of toxic air releases, but higher levels of CO, PM10, and VOCs are associated with *lower* levels of toxic air releases. That trend does not, however, persist when I use *TPI* rather than *TPL* on the left-hand side. Here, only CO, PM10, and VOC emissions are found to be statistically significant (and positive), depending upon the specification.

TRI Releases and Non-Toxic Pollution Abatement Activities: Given the suggestive evidence that TRI releases may be related to emissions of non-toxic pollutants, I address next whether TRI reductions are affected by pollution abatement activities for the regulated, non-toxic, pollutants. Here, I make use of the PACE survey data for 1982-1994,[20] which I match to TRI data by plant name, permanent plant number, and location, for 1988-1994.

To investigate the relationship between TRI and PACE more closely, I estimate the reduced form equation:

(9)
$$TRI_{it} = \alpha + \gamma_i + \psi_t + \beta_1 P\text{-}OM_{it} + \beta_2 Initial\,TPI\text{-}Air_i + \epsilon_{it}$$

where $P\text{-}OM_{it}$ are pollution abatement operating and maintenance costs[21] for plant *i* at time *t*, and I use

[20] I exclude 1983, 1987 and 1995, years for which the PACE data were not considered of adequate quality.

[21] PACE capital expenditures were not included in the estimation due to lumpiness of the investment data. There is some question as to when a large capital outlay should translate into a measurable change in pollution levels.

TPI on the left-hand side. Year (ψ_t) and state (γ_i) fixed effects are sometimes included in the estimation of Equation (9). Separate regressions are estimated for air and water releases. In estimating (9) I maintain the assumption that PACE expenditures are exogeneous to the TRI. [[This requires that polluting plants *not* undertake additional abatement of conventional pollutants (increasing PACE expenditures) to reduce TRI releases. (As collected in the PACE survey, pollution abatement control expenditures are intended to capture those arising directly in response to pollution regulation, and therefore, in principle and consistent with the assumption maintained here, should not include expenditures that relate to the TRI.)]]

Table 14 provides a summary of the regression results for TRI air releases. I find that larger expenditures on *air* pollution abatement operating and maintenance activities lead to reduced intensity of TRI air releases, even controlling for the initial TPI. This is indicative of the existence of positive externalities, in terms of reduced toxic pollution intensity, from air pollution abatement expenditures unrelated to the TRI. A one standard deviation increase in operating and maintenance expenditures ($12,067.79) leads to between a 0.24 and 0.48 lbs/barrel/day *decline* in air TPI (depending upon the precise specification). This is a decline of between 2.7% and 7.5% from the average level of air TPI for the entire sample. (Adding lagged capital expenditures does not alter the results.)

Table 15 provides the summary regression results for water TPI. The most surprising result from these regressions is that *higher* levels of PACE operating and maintenance expenditures for non-toxic water pollution lead to *higher* levels of water *TPI*. The effect is not statistically significant and the estimate is consistently small: a one standard deviation increase in water operating and maintenance expenditures ($4,556) leads to approximately a 2% increase in water TPI (from an average level of 1.7 lbs/barrel/day). But the effect is consistent across specifications. This may be suggestive that there are negative externalities associated with non-toxic water pollution abatement expenditures, and might be consistent with substitution between (unregulated) toxic and (regulated) non-toxic water pollution. The finding warrants further investigation.

Attainment and Non-Attainment Status: Given the evidence that TRI air releases are linked to levels of non-toxic air pollution, I now consider whether differences in regulatory stringency for the *criteria* air pollutants has an effect on the level or change in TRI air releases.[22] To do this, I make use of county-level data on attainment/non-attainment status for criteria air pollutants, trading on the fact that plants located in non-attainment regions face far more stringent (criteria) air pollution regulations that

[22] For this study, the classification of non-attainment status is given if a county is found to be in non-attainment for *any* of the criteria air pollutants.

include such requirements as mandatory use of specified abatement technologies. (Note that the designation of attainment/non-attainment status is independent of toxic release levels so that no endogeneity problem exists here.)

When looking at the relationship between TRI air pollution (both in levels and intensity) and the levels of the criteria air pollutants (Table 13, columns 3 and 4), facilities located in non-attainment areas were found to have lower TRI releases (in terms of both TPL and TPI) that are statistically significant. In Table 13 I report the results of estimating the relationship between TRI releases and non-attainment status for:

(5) $$TPI_{it} = \alpha + \psi_t + \beta_1 N\text{-}A_{it} + \beta_2 Initial\,TPI_i + \epsilon_{it}$$

After controlling for initial TPI, I find that refineries located in non-attainment regions[23] are *lower* in overall TPI by 2.62 lbs/barrel/day (average plant TPI is 8.7 lbs/barrel/day in the sample); for air TPI, the difference is -1.24 lbs/barrel/day, compared with a sample average of 5.8 lbs/barrel/day. Differences in regulatory stringency, associated with being in a non-attainment region for non-toxic air pollution, has a strong, negative effect on air TPI and also on overall TPI.

The implication, at least for toxic air releases, is that being in a county that is subject to more stringent *formal* air pollution regulation leads to lower levels of *toxic* pollution intensity. That is consistent with the finding that higher pollution abatement expenditures for the control of non-toxic air pollution leads to lower toxic pollution intensity.

VIII. Conclusions

There may never be definitive evidence to confirm or refute the effectiveness of regulation of toxics by disclosure alone, the foundational premise of the TRI. Where toxic emissions by petroleum refineries are concerned, however, four basic conclusions emerge with some clarity from this study. First, since the inception of TRI reporting, the observed improvement in toxic releases by refineries has been real. The decline in releases has come about not through reductions in (or favorable changes in the composition of) output, or substitution away from TRI-listed substances as inputs, but through real changes in firm polluting behavior. While it appears as though these changes have had some effect on firm productivity, the cost in lost total factor productivity does not appear to have been substantial.

What is less clear is why these changes have come about. A second conclusion to the work re-

[23] A facility is considered to be in a non-attainment region if that region is in non-attainment for *any* of SO_x, NO_x, *CO*, *VOC*, or *PM10.* I don't include air borne lead here.

ported here is that prior event studies, suggesting abnormal negative firms to "dirty" TRI reporters, are less convincing than they at first might have appeared. While I am able to replicate the results of those studies, when their methodology is modified to correct for prior failures to take account of the correlation of the event under study across firms, the finding of significant negative abnormal returns disappears, undermining the basis for the belief that information provided by the TRI has affected firm value (and provided an incentive for firms to "clean up"). Returns to TRI reporters and non-reporters are not readily distinguishable on TRI announcement dates, neither exhibiting any systematic abnormality.

That leaves to be resolved just why it is that firm behavior changed. Two basic explanations emerge from the findings above. One is that disclosure did *indirectly* bring about changes in firm conduct, but through the intervention of state regulators taking more positive steps. My findings indicate clearly that the formal promulgation of a statewide target for the reduction of toxic releases had a pronounced, statistically significant, impact on toxic releases by refiners. In an important sense this can be viewed as a consequence of the public disclosure mandated by the TRI, but it is not a response to disclosure as such. Rather, disclosure appears to have provoked state regulators to take more positive steps that had the effect of inducing refiners to abate. That is the third major conclusion suggested by the evidence here.

My final conclusion is that there is strong evidence that TRI releases are affected by pollution and abatement control expenditures undertaken to abate non-toxic pollutants, which face heavy regulation via command and control strategies. Expenditures on non-toxic air pollution control have a strong, positive spill-over benefit in the control of toxic air releases (though the opposite may hold true for water pollution). These last findings are of importance, quite beyond what they say about the abatement of toxic releases following the advent of the TRI. For one thing they suggest that there may be substitutions between pollution media (air and water) and pollution types (toxics and non-toxics) that are not as yet technically well understood. They suggest also that the TRI may have been responsible for less of the observed reductions in toxic releases than its devotees are inclined to believe. Just as importantly, it suggests that command and control regulation of non-toxic pollutants has been having hitherto unnoticed collateral benefits that have been ignored in the comparative evaluation of different strategies for the control of environmental contaminants. While disclosure may have had its effects, it may very well be that the benefits of disclosure as a regulatory strategy have been overestimated, and those of more traditional strategies underestimated. That important possibility warrants further study.

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Table 1. Summary Statistics: Petroleum Refineries 1987-1995

Variable	N	Mean	Std. Deviation
TPL (lbs)	1332	948526.2	3266657
TPI (lbs/barrel/day)	1332	8.686507	18.12564
TPI Air (lbs/barrel/day)	1332	5.847965	10.96213
TPI Water (lbs/barrel/day)	1332	1.703056	12.96763
Air O&M (000s $)	656	7934.92	12067.79
Air O&M _OC (000s $/barrel/day)	656	0.053849	0.068283
Water O&M (000s $)	656	2732.609	4556.381
Water O&M _OC (000s $/barrel/day)	656	0.0200426	0.02713
Δ TPL	1137	-374532.7	3098662
Δ TPI	1137	-2.448282	15.9055
ΔTPL Air	1137	-34435.27	315318.1
Δ TPI Air	1137	-0.325918	5.290195
Δ TPL Water	1137	-274699.2	2959802
Δ TPI Water	1137	-1.654425	13.95698
Δ Air O&M	481	77.38544	5709.26
Δ Air O&M_OC	481	0.0002423	0.03824
Δ Water O&M	481	133.0172	3888.796
Δ Water O&M_OC	481	0.0007621	0.0250767
Operating Capacity (barrels/day)	1295	97167.28	92159.38
Idle Capacity (barrels/day)	1295	1804.04	9769.913
Total Value of Shipments (000s $)	1295	860895.2	865046.4

Notes: All $s are real, 1982.
_OC: normalized by operating capacity
O&M: PACE operating and maintenance costs
Δ: first difference
Mins and maxes could not be reported due to confidentiality of the data.

Table 2: Average Plant-Level Change in Materials and TRI releases for Three Major Toxic Inputs

Chemical	Δ 1982-1987		Δ 1987-1992		Δ 1992-1997	
	Inputs	TRI	Inputs	TRI	Inputs	TRI*
Benzol	-	NA	+	+	+	+
Toluene and Xylene	-	NA	+	+	+	+
Sulfuric Acid	-	NA	+	+	+	+

* TRI values are for 1992-1996, as 1997 values were not available at the time of the study.

Table 3: Regression of TRI releases on Product Mix for Matched TRI- Census Years 1987, 1992

	TRI[1]	TRI[1]	TRI[2]	TRI[2]
Aviation Gasoline	188.75		1.22	
	(518.91)		(19.00)	
Motor Gasoline	189.24*	193.66*	8.21*	8.44*
	(80.60)	(79.27)	(3.42)	(3.35)
Jet Fuel	-115.67	-140.6223	-3.60	-4.65
	(588.80)	(591.01)	(25.81)	(25.80)
Kerosene	775.91*	935.64*	34.46*	39.69*
	(238.60)	(229.64)	(11.27)	(10.78)
Distillate Light	314.13	211.96	22.32	13.26
	(1099.70)	(919.60)	(53.16)	(43.94)
No. 4 Light Fuel	-335.24	-338.11**	-16.57*	-16.73*
	(183.86)	(183.36)	(8.46)	(8.39)
Heavy Fuel Oils	-379.04		-19.46	
	(616.69)		(31.95)	
Heavy Diesel	-403.00	-481.38*	-25.19	-29.42**
	(240.00)	(235.90)	(16.31)	(16.11)
Lubricating Oils	2514.62*		47.44**	
	(1023.02)		(24.76)	
Lubricating Greases	-4549.88		-101.11	
	(17344.13)		(351.39)	
Constant	73178.67	200861	1144100	237599.6
	(1061952)	(1061236)	(1074469)	(1067907)
N	298	298	298	298
R^2	0.1626	0.1438	0.1494	0.1375

Notes:

1. Materials are measured in quantity (000s of barrels).
2. Materials are measured in $value of shipments. These results are robust to using $value of shipments normalized by TVS.
   * significant at the 5% level
   ** significant at the 10% level.

Table 4: Regression of Total Factor Productivity on TRI Pollution Intensity in Levels and First Differences (1988-1995)

			First Differences	
	TFP	TFP	ΔTFP	ΔTFP
TPI	0.00087* (0.00024)	0.00067** (0.00039)		
ΔTPI			0.00089* (0.00038)	0.00052* (0.00019)
Plant Fixed Effects	X		X	
State Fixed Effects		X		X
Constant	1.3676* (0.1205)	1.3177* (0.1545)	0.1942 (0.1479)	-0.04011 (0.03617)
R^2	0.5462	0.0446	0.0714	0.0139
N	1135	1135	1072	1072

Notes: Robust standard errors in parentheses.
Year dummies are included in all specifications.
* significant at the 5% level
** significant at the 10% level.

Table 5: Value Weighted Abnormal Returns Around Announcement Date: TRI Reporting Companies

Year	-2	-1	0	1	2	N
1989	0.005343	-0.006029**	-0.007763*	0.002205	-0.006781*	47
	(0.003294)	(0.003294)	(0.003294)	(0.003294)	(0.003294)	
1990	-0.018910*	-0.005745**	0.012240*	-0.001340	-0.001707	48
	(0.003030)	(0.003030)	(0.003030)	(0.003030)	(0.003030)	
1991	-0.008811**	0.006717	0.005474	-0.008157**	-0.002666	48
	(0.004664)	(0.004664)	(0.004664)	(0.004664)	(0.004664)	
1992	0.005028	-0.00533	0.006166	0.006509	0.005671	49
	(0.004353)	(0.004353)	(0.004353)	(0.004353)	(0.004353)	
1993	-0.003954	0.001873	-0.004687	-0.010991*	0.000849	50
	(0.003984)	(0.003984)	(0.003984)	(0.003984)	(0.003984)	
1994	0.010867*	0.004305	-0.006823*	-0.004392	-0.010116*	53
	(0.003433)	(0.003433)	(0.003433)	(0.003433)	(0.003433)	
1995	-0.001739	0.001232	-0.000406	-0.001134	0.008260*	52
	(0.003299)	(0.003299)	(0.003299)	(0.003299)	(0.003299)	
1996	-0.002683	-0.007314	-0.004332	0.016563*	-0.000568	53
	(0.004003)	(0.004003)	(0.004003)	(0.004003)	(0.004003)	
1997	0.004507	0.004703	-0.003497	-0.005374**	-0.001246	51
	(0.003273)	(0.003273)	(0.003273)	(0.003273)	(0.003273)	
1998	0.006502**	0.006710**	-0.006902**	0.0002388	-0.003135	50
	(0.003656)	(0.003656)	(0.003656)	(0.003656)	(0.003656)	
10-Year	-0.000265	0.000151	-0.002066**	-0.000517	-0.001628	501
Average	(0.00118)	(0.00118)	(0.00118)	(0.00118)	(0.00118)	

Notes: Standard errors in parentheses.
* Significant at the 5% level
** significant at the 10% level.

Table 6: Value Weighted Abnormal Returns Around Announcement Date: Non-TRI Reporting Companies

Year	-2	-1	0	1	2	N
1989	0.004332	-0.000618	-0.000696	-0.005238	0.005276	34
	(0.005647)	(0.005647)	(0.005647)	(0.005647)	(0.005647)	
1990	-0.023305*	-0.008133	0.010850*	0.001230	0.003329	31
	(0.021072)	(0.021072)	(0.021072)	(0.021072)	(0.021072)	
1991	-0.006946	-0.002044	-0.011452	-0.001593	-0.001853	30
	(0.006054)	(0.006054)	(0.006054)	(0.006054)	(0.006054)	
1992	-0.000728	-0.006937	-0.000637	0.006951	0.001959	30
	(0.005316)	(0.005316)	(0.005316)	(0.005316)	(0.005316)	
1993	0.005780	0.003588	-0.008849	-0.011235	-0.001842	30
	(0.008669)	(0.008669)	(0.008669)	(0.008669)	(0.008669)	
1994	0.029784*	-0.000284	-0.013048*	0.002841	0.001900	32
	(0.005961)	(0.005961)	(0.005961)	(0.005961)	(0.005961)	
1995	0.006318	0.001837	0.001459	0.003915	0.016095*	34
	(0.00525)	(0.00525)	(0.00525)	(0.00525)	(0.00525)	
1996	0.000464	0.011057**	0.010814**	-0.006809	0.011269**	35
	(0.005678)	(0.005678)	(0.005678)	(0.005678)	(0.005678)	
1997	0.003909	0.004911	-0.008066**	0.002008	-0.001892	34
	(0.00478)	(0.00478)	(0.00478)	(0.00478)	(0.00478)	
1998	0.010719*	0.013665*	-0.013907*	0.002513	0.009804**	34
	(0.005202)	(0.005202)	(0.005202)	(0.005202)	(0.005202)	
10-Year	0.0032393**	0.0019662	-0.0032479**	-0.0005490	0.004536	324
Average	(0.001833)	(0.001833)	(0.001833)	(0.001833)	(0.001833)	

Notes: Standard errors in parentheses.
* Significant at the 5% level
** significant at the 10% level.

Table 7. Value Weighted Abnormal Returns Around Announcement Date: Portfolio of TRI Reporting Companies

Year	-2	-1	0	1	2
1989	0.000178	0.001452	0.0002511	0.002988	-0.001670
	(0.004465)	(0.004454)	(0.004454)	(0.004455)	(0.004455)
1990	-0.013946	-0.006429	0.012714	0.000853	-0.003380
	(0.006517)	(0.006417)	(0.006432)	(0.0064165)	(0.006418)
1991	-0.009924	0.005007	0.005509	-0.0000011	0.002453
	(0.007300)	(0.007284)	(0.007258)	(0.007248)	(0.007247)
1992	0.004374	-0.006744	0.003552	0.007418	-0.001926
	(0.006824)	(0.006825)	(0.006818)	(0.006836)	(0.006829)
1993	-0.004173	0.003185	-0.003138	-0.002667	0.002312
	(0.007453)	(0.007453)	(0.007453)	(0.007540)	(0.007472)
1994	0.012339	-0.002415	0.001653	-0.005684	-0.014042
	(0.005929)	(0.005964)	(0.005933)	(0.005938)	(0.00603)
1995	0.003064	0.001254	0.000327	-0.0023525	0.003945
	(0.004721)	(0.004752)	(0.00493)	(0.004721)	(0.004722)
1996	-0.00101	0.001709	0.004298	-0.005616	-0.00864
	(0.00634)	(0.006338)	(0.00636)	(0.00634)	(0.00635)
1997	0.001510	0.010902	-0.006215	0.002067	-0.006503
	(0.00672)	(0.00668)	(0.00670)	(0.006684)	(0.00672)
1998	0.006881	0.010684	-0.005987	-0.006386	0.001395
	(0.00798)	(0.00801)	(0.007972)	(0.00798)	(0.007972)
10-Year	-0.00008	0.001860	0.001244	-0.000936	-0.002606
Average	(0.00206)	(0.00206)	(0.00206)	(0.00206)	(0.00206)

Notes: Standard errors in parentheses.
* Significant at the 5% level
** significant at the 10% level.

Table 8. Value Weighted Abnormal Returns Around Announcement Date: Portfolio of Non-TRI Reporting Companies

Year	-2	-1	0	1	2
1989	-0.002947	0.0035335	-0.0011222	-0.001191	0.003462
	(0.007017)	(0.006998)	(0.006998)	(0.006998)	(0.006998)
1990	-0.029975	-0.001113	0.007172	0.000001	-0.005213
	(0.0086728)	(0.008540)	(0.008559)	(0.008539)	(0.008542)
1991	-0.0038041	-0.0003778	-0.001799	0.000063	-0.002655
	(0.008553)	(0.0085337)	(0.0085304)	(0.008486)	(0.008486)
1992	-0.000083	-0.000191	-0.001766	0.002394	-0.000230
	(.008203)	(0.008205)	(0.008196)	(0.008218)	(0.008209)
1993	0.002347	0.0015302	-0.004507	-0.008492	-0.006946
	(0.008070)	(0.008069)	(0.008059)	(0.008164)	(0.008089)
1994	0.039654	0.008941	-0.013633	0.002464	0.007238
	(0.008268)	(0.008335)	(0.008297)	(0.008299)	(0.008433)
1995	0.003591	0.002935	0.001855	0.003226	0.007264
	(0.005909)	(0.006954)	(0.006921)	(0.00691)	(0.006909)
1996	0.001350	0.011184	0.004089	-0.032049	0.015953
	(0.006397)	(0.006499)	(0.005621)	(0.006503)	(0.006551)
1997	0.006383	0.004936	-0.005675	0.001472	0.006302
	(0.00864)	(0.00860)	(0.00862)	(0.00860)	(0.00860)
1998	0.013255	0.016398	-0.018954	-0.006078	0.016088
	(0.00995)	(0.00997)	(0.00992)	(0.009924)	(0.00992)
10-Year	0.003067	0.004790	-0.003434	-0.003820	0.004120
Average	(0.002573)	(0.002570)	(0.002567)	(0.002570)	(0.00257)

Notes: Standard errors in parentheses.
* Significant at the 5% level
** significant at the 10% level.

Table 9. Value Weighted Abnormal Returns Around Announcement Date: Companies Reporting "Bad News"[1]

Year	-2	-1	0	1	2	N
1989	0.002606	-0.002581	-0.004007	-0.000478	0.001968	27
	(0.003184)	(0.003184)	(0.003184)	(0.003184)	(0.003184)	
1990	-0.018962	-0.007338	0.010171	0.004207	-0.003578	15
	(0.003596)	(0.003596)	(0.003596)	(0.003596)	(0.003596)	
1991	-0.0058571	0.004203	0.003077	-0.0044013	-0.003376	15
	(0.004835)	(0.004835)	(0.004835)	(0.004835)	(0.004835)	
1992	0.003842	-0.004784	0.002248	0.005501	0.001592	16
	(0.003549)	(0.003549)	(0.003549)	(0.003549)	(0.003549)	
1993	-0.007462	0.0021457	-0.005976	-0.007111	0.005976	11
	(0.004234)	(0.004234)	(0.004234)	(0.004234)	(0.004234)	
1994	0.012110	0.007242	-0.002218	0.003011	-0.023179	13
	(0.003908)	(0.003908)	(0.003908)	(0.003908)	(0.003908)	
1995	-0.001955	0.005944	0.012555	0.001486	0.010128	8
	(0.005342)	(0.005342)	(0.005342)	(0.005342)	(0.005342)	
1996	0.006535	-0.005144	0.000077	-0.006040	0.002089	8
	(0.005781)	(0.005781)	(0.005781)	(0.005781)	(0.005781)	
1997	0.003005	0.0011068	0.001520	0.002002	-0.001964	10
	(0.005567)	(0.005567)	(0.005567)	(0.005567)	(0.00567)	
1998	0.007185	0.0113956	-0.005860	-0.004363	0.000524	10
	(0.004650)	(0.004650)	(0.004650)	(0.004650)	(0.004650)	
10-Year	-0.0001997	0.0013742	0.000679	-0.000203	-0.001338	133
Average	(0.001364)	(0.001364)	(0.001364)	(0.001364)	(0.001364)	

[1] Sample consists of TRI reporting companies that are in the panel for all ten years. All companies are considered to be reporting "bad news" in the first year of reporting. "Bad news" occurs when reported TRI emissions are higher in current year relative to the previous year. Change in company level TRI emissions are included in the base regression.

Notes: Standard errors in parentheses. * Significant at the 5% level, ** significant at the 10% level.

Table 10. Value Weighted Abnormal Returns Around Announcement Date: Companies Reporting "Good News"[1]

Year	-2	-1	0	1	2	N
1990	-0.015465	0.007302	0.001759	-0.011255	-0.008232	11
	(0.0043259)	(0.0043259)	(0.0043259)	(0.0043259)	(0.0043259)	
1991	-0.013312	-0.006617	0.002440	-0.003396	-0.00363	11
	(0.004273)	(0.004273)	(0.004273)	(0.004273)	(0.004273)	
1992	0.0025317	0.0072308	-0.005563	0.007280	-0.0066423	11
	(0.006001)	(0.006001)	(0.006001)	(0.006001)	(0.006001)	
1993	-0.0079399	0.003112	-0.007574	-0.008628	-0.005781	16
	(0.004146)	(0.004146)	(0.004146)	(0.004146)	(0.004146)	
1994	0.020435	-0.003028	-0.012568	-0.014611	-0.005073	14
	(0.004096)	(0.004096)	(0.004096)	(0.004096)	(0.004096)	
1995	0.007211	0.003115	-0.002384	-0.000947	0.004565	19
	(0.003043)	(0.003043)	(0.003043)	(0.003043)	(0.003043)	
1996	-0.000308	0.003199	0.003144	-0.007034	-0.007071	19
	(0.002987)	(0.002987)	(0.002987)	(0.002987)	(0.002987)	
1997	0.011952	0.002815	-0.006408	0.002478	-0.000058	17
	(0.003566)	(0.003566)	(0.003566)	(0.003566)	(0.003566)	
1998	0.011668	0.003854	-0.009839	0.000813	0.001404	15
	(0.004108)	(0.004108)	(0.004108)	(0.004108)	(0.004108)	
10-Year	0.002820	0.001567	-0.003458	-0.003337	-0.001910	160
Average	(0.001228)	(0.001228)	(0.001228)	(0.001228)	(0.001228)	

[1] Sample consists of TRI reporting companies that are in the panel for all ten years. Change in company level TRI emissions are included in the base regression. "Good news" occurs when reported TRI emissions are lower in current year relative to the previous year. Change in company level TRI emissions are included in the base regression.

Notes: Standard errors in parentheses. * Significant at the 5% level, ** significant at the 10% level.

Table 11. Summary Statistics By State Level of Pollution Reduction Policy 1987-1995

	STR1		STR2		STR3	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
TRI Emissions (lbs)	1233894	1010000	1141611	3668516	932378	4017280
Initial Level of TPL (lbs/barrel/day)	4623740	2330000	3815211	9332946	5691886	1.08e+07
TPI (lbs/barrel/day)	11.652	47.936	10.815	30.778	9.248	34.038
Initial Level of TPI (lbs/barrel/day)	31.581	105.835	24.612	42.547	53.340	88.732
Number of plant-years	658		644		137	

Notes: Each observation is a plant-year (a single facility in a given year).

Table 12. Regression of TRI Emissions on Stringency Level of State Pollution Policies

Panel 1: All States

	TPI	TPI	TPI
STR2	0.858 (1.914)		
STR3	-7.711* (3.250)		
STR3B		-13.811* (3.881)	-9.96* (3.881)
Year			-2.204* (0.355)
Initial Level of TPI (lbs/barrel/day)	0.243* (0.011)	0.243* (0.011)	0.243* (0.011)
Constant	3.979* (1.391)	4.430* (0.990)	4393.4* (707.5)
N	1439	1439	1439
R^2	0.2495	0.2525	0.2720

Panel 2: STR3 States

	TPI
STR3B	-14.675* (6.83)
Initial Level of TPI (lbs/barrel/day)	0.118* (0.074)
Constant	11.952* (3.602)
N	137
R^2	0.1389

Notes: Robust Standard errors are reported in parentheses
* significant at the 5% level
** significant at the 10% level

Table 13. Regression of State Level TRI Air Releases on Non-Toxic Air Emissions

	TPL-Air	TPI-Air	TPL-Air	TPI_Air
CO	-11.50** (6.37)	8.66* (3.15)	-9.28 (9.30)	4.34 (3.08)
NO_x	50.66** (39.34)	-54.80 (34.05)	158.83* (38.95)	51.92 (36.75)
PM_{10}	-617.88* (158.84)	-32.52 (104.44)	41.11 (289.93)	254.89* (112.23)
SO_2	41.06* (10.79)	2.05 (10.14)	-29.13* (12.99)	-13.29 (10.57)
VOC	-75.41** (39.11)	-33.68 (24.99)	154.35* (41.47)	60.04* (23.35)
Year	-71051* (20961)	-0.22 (0.14)	-160180* (57849)	-0.24 (0.19)
Non-Attainment			-1000335* (220041)	-2.97* (0.81)
Constant	1.44e+08* (4.18e+07)	448.65** (277.91)	3.19e+08* (1.15e+08)	477.58 (376.48)
R^2	0.9875	0.8178	0.9233	0.2523
N	185	185	185	185

Notes: Specifications include state dummies for columns 1 and 2, only.
TPI regressions have both the dependent and the independent variables normalized by operating capacity.
Non-attainment variables takes on the value of 1 if there is at least one county in the state that is out of attainment for any of the criteria air pollutants with the exception of lead.
Robust standard errors are reported in parentheses.
* indicates significance at the 5% level
** indicates significance at the 10% level.

Table 14. Regression of TRI Air Releases on PACE

	Air TPI (lbs/barrel/day)		
PACE Air O&M	-0.00003** (0.000014)	-0.00002 (0.000014)	-0.00004** (0.000024)
Air TPI: Initial Level	0.73288* (0.06501)	0.729612* (0.063981)	0.77115* (0.06578)
State Dummies			X
Year Dummies		X	X
Constant	0.515812** (0.29382)	-0.530746 (0.685841)	-0.762193 (0.599164)
N	651	651	651
R^2	0.4391	0.4503	0.4638

Notes. * significant at the 5% level
** significant at the 10% level
O&M = Operating and maintenance costs in 000s ($1982)
robust standard errors in parentheses

Table 15. Regression of TRI Water Releases on PACE

	Water TPI (lbs/barrel/day)		
PACE Water O&M	4.65e-06 (4.92e-06)	6.55e-06 (4.6e-06)	6.39e-06** (3.31e-06)
Water TPI : Initial Level	0.001576* (0.000417)	0.00158* (0.00043)	0.001489* (0.00042)
State Dummies			X
Year Dummies		X	X
Constant	0.21675* (0.030367)	0.17625* (0.03360)	0.19029* (0.03988)
N	674	674	674
R^2	0.0147	0.0358	0.1132

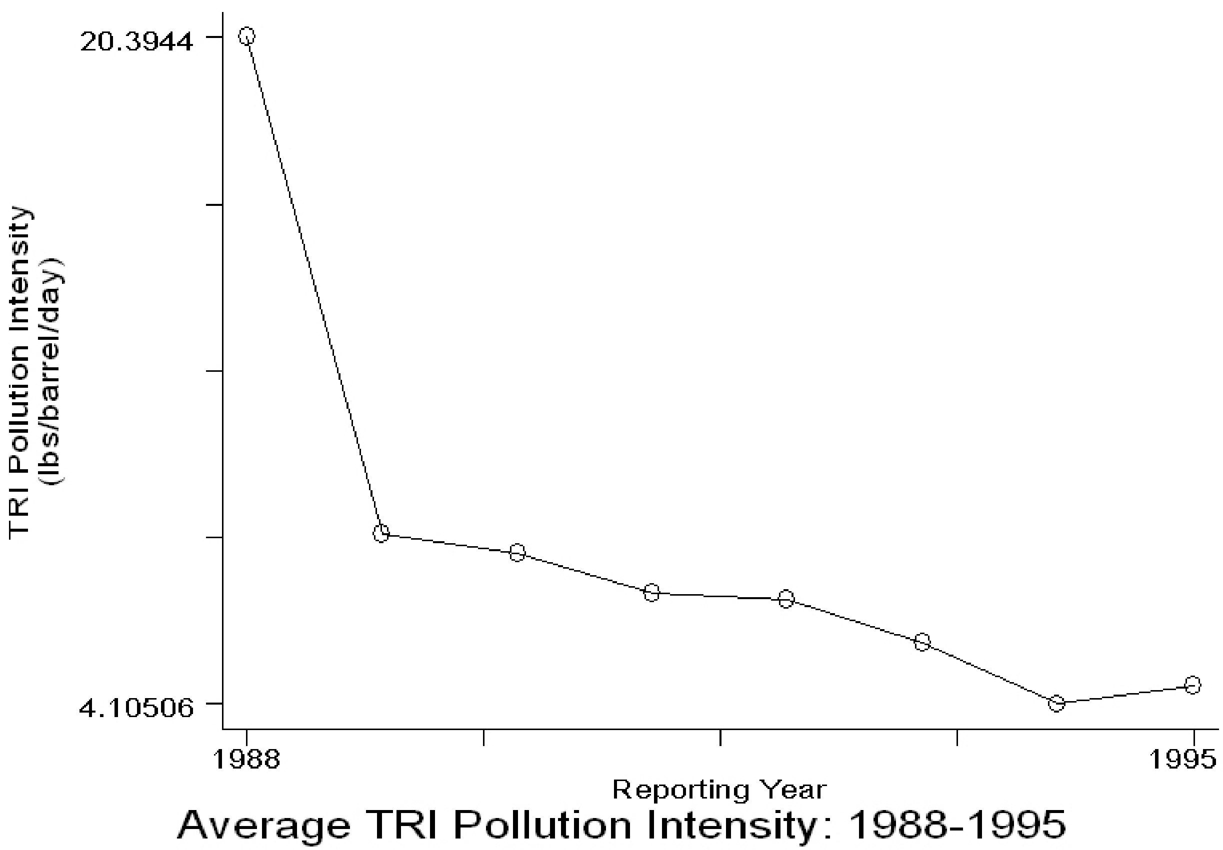
Notes. * significant at the 5% level
** significant at the 10% level
O&M = Operating and maintenance costs in 000s ($1982)
robust standard errors in parentheses

Table 16. Regression of Plant Level TRI Air Releases on Air Pollution Attainment Status

	TPI	Air-TPI
Initial Level of TPI	0.1856* (0.0464)	
Initial Level of Air TPI		0.6401* (0.0481)
Non-Attainment	-2.6249* (0.8442)	-1.2482* (0.3707)
Constant	2.0425 (1.3386)	0.4787 (0.6196)
R^2	0.2610	0.5326
N	1301	1322

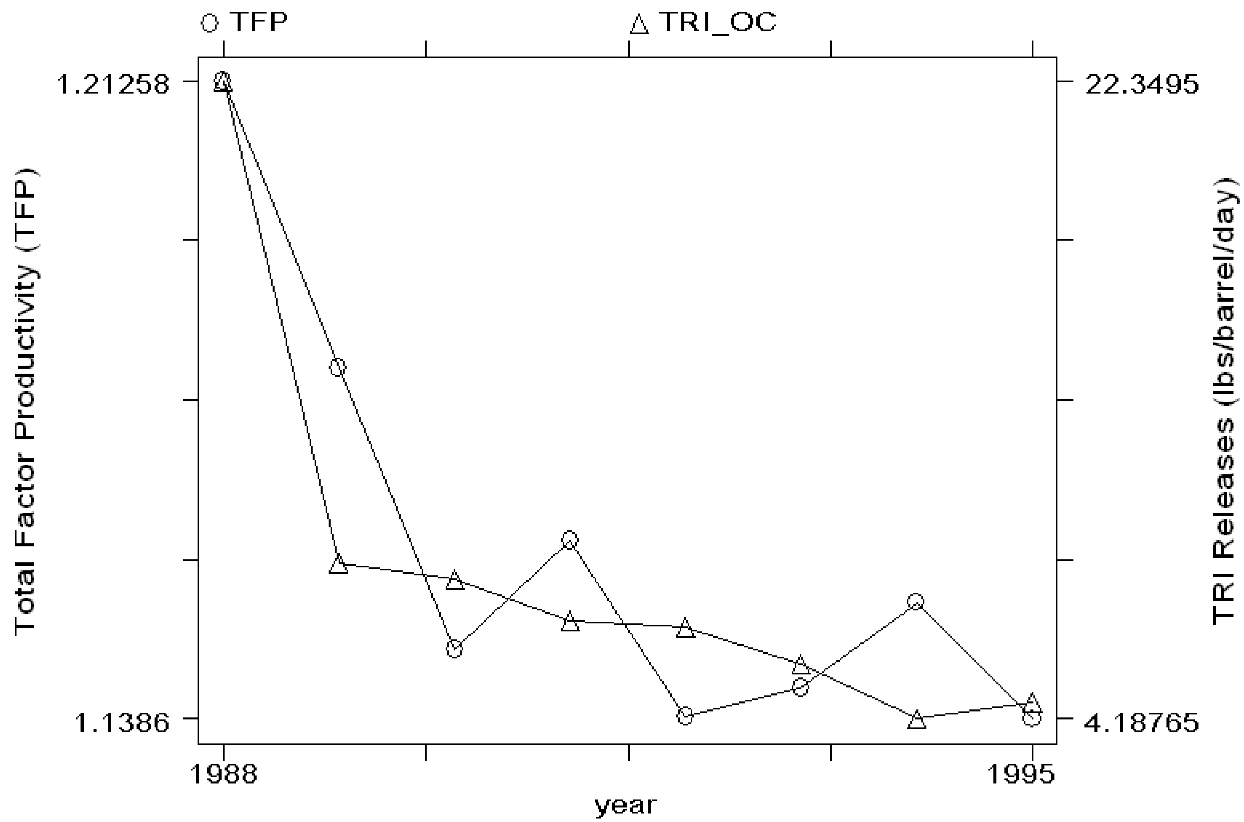
Notes: All specifications include year dummies.
Non-attainment variables takes on the value of 1 if there is at least one county in the state that is out of attainment for any of the criteria air pollutants with the exception of lead.
Robust standard errors are reported in parentheses.
* indicates significance at the 5% level
** indicates significance at the 10% level.

Figure 1.



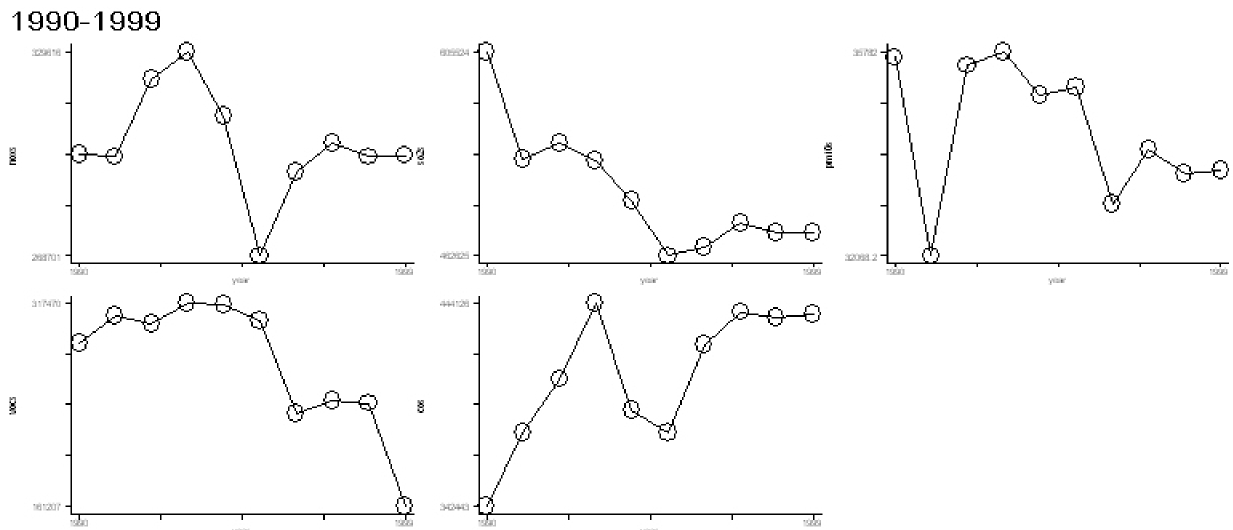
20.3944
4.10506
TRI Pollution Intensity
(lbs/barrel/day)
1988
1995
Reporting Year
Average TRI Pollution Intensity: 1988-1995

Figure 2.



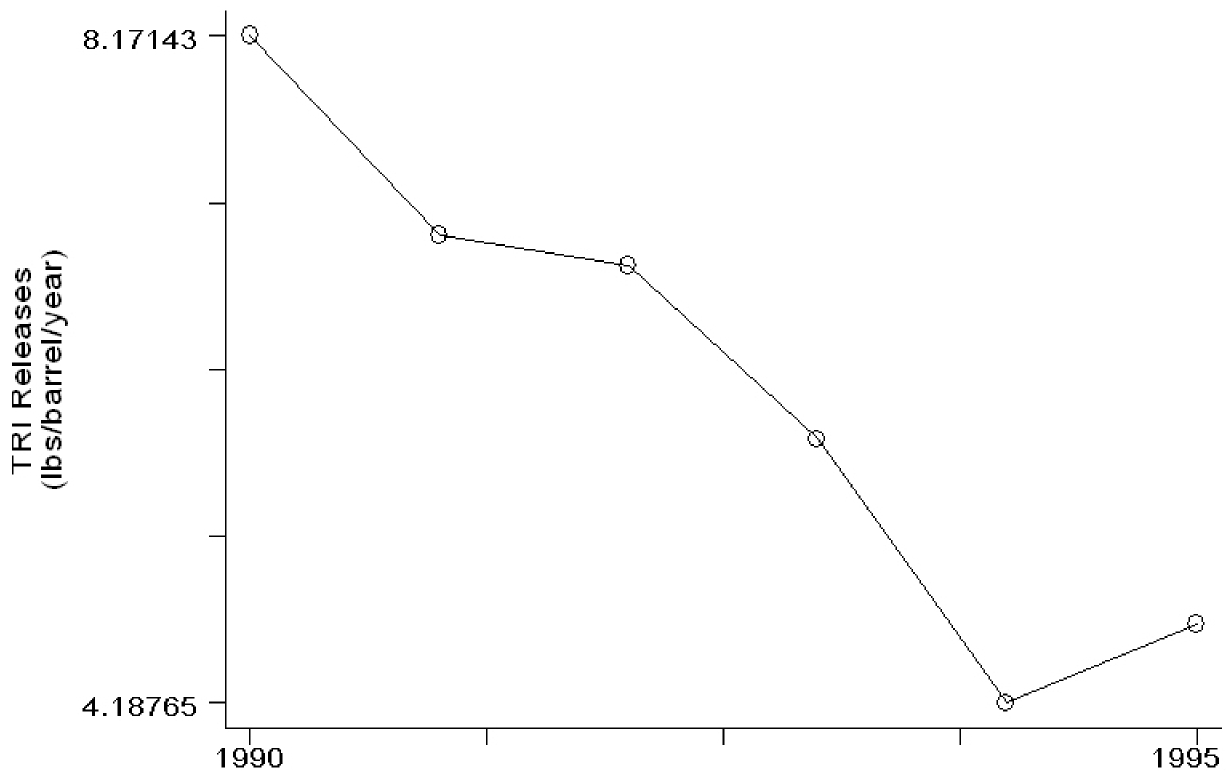
Plant Level TFP and TRI Pollution Intensity

Figure 3.



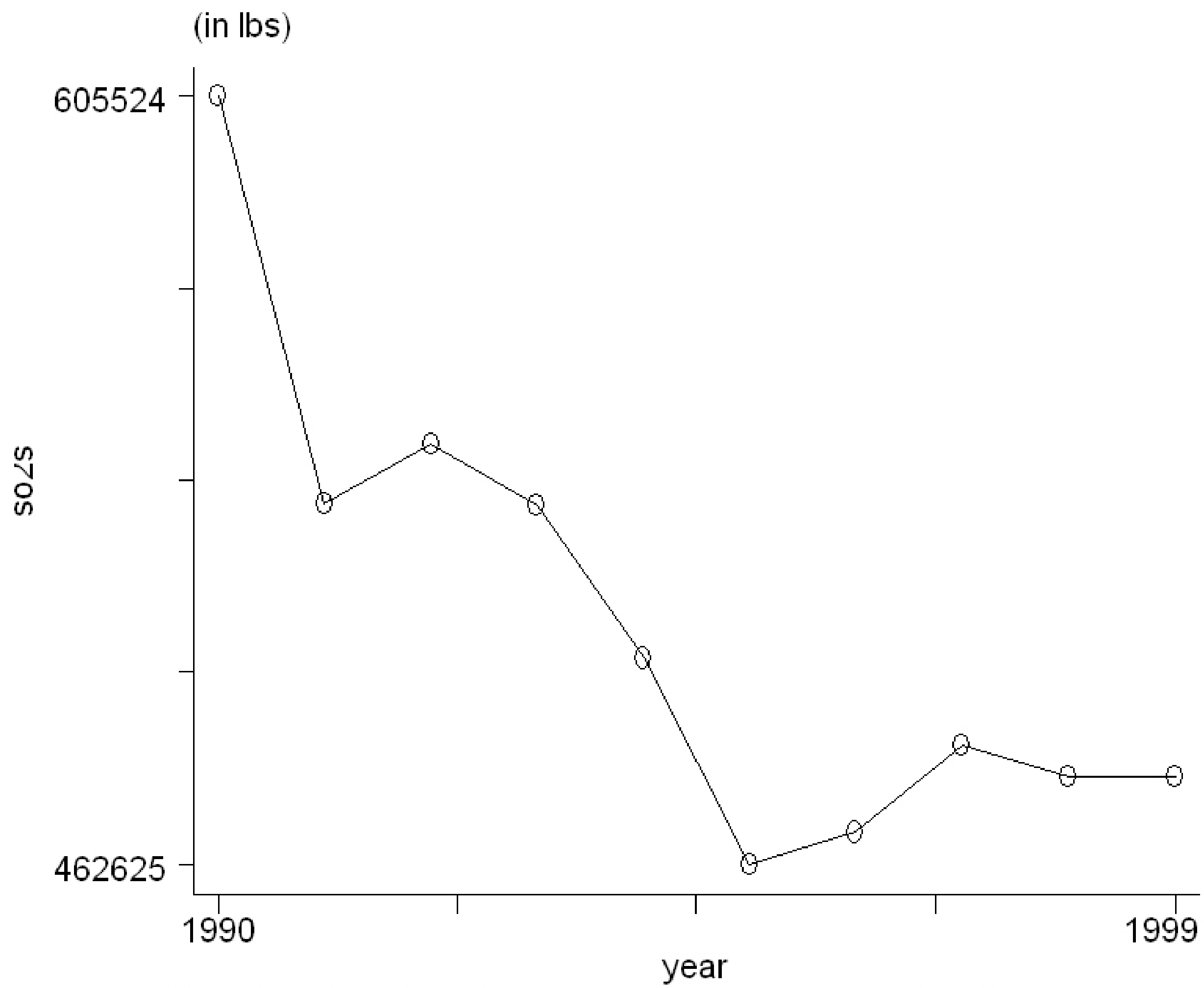
Non-Toxic Air Pollution Emissions by SIC 2911

Figure 4.



Average TRI Releases (lbs/barrel/year)

Figure 5.



Sulfur Dioxide Emissions by Petroleum Refineries