MANDATORY DISCLOSURE OF PLANTS' EMISSIONS INTO THE ENVIRONMENT AND WORKERS' CHEMICAL EXPOSURE INSIDE PLANTS

Stephen R. Finger

and

Shanti Gamper-Rabindran

Version 3/15/2012

Acknowledgement: Authors are listed alphabetically. Stephen R. Finger, Assistant Professor, Moore School of Business, University of South Carolina, 1705 College Street, Columbia, SC 29208 (stephen.finger@moore.sc.edu) and Shanti Gamper-Rabindran, Assistant Professor, Graduate School of Public and International Affairs, University of Pittsburgh, 3205 Posvar Hall, 230 S. Bouquet St., Pittsburgh PA 15217 (shanti@gspia.pitt.edu). Corresponding author: Gamper-Rabindran. We gratefully acknowledge funding from the National Science Foundation (SES 1127223), University of Pittsburgh's Central Research Development Fund, University Center for Social and Urban Research, University Center for International Studies and the European Union Center of Excellence. Errors are our own.

MANDATORY DISCLOSURE OF PLANTS' EMISSIONS INTO THE ENVIRONMENT AND WORKERS' CHEMICAL EXPOSURE INSIDE PLANTS

Abstract (186 words)

Our study is the first to test if mandatory pollution disclosure programs, exemplified by the Toxics Release Inventory (TRI) program, reduce workers' chemical exposure. Plant managers report their preparation of inventories of chemical use and production processes, used to estimate their TRI emissions, reveal opportunities for source reduction that reduce both emissions and exposure. We examine newly available ***actual*** exposure data collected during 1,644 inspections in the US chemical manufacturing sector between 1984 and 2009. We find the maximum ratio of exposure to the legal limits per inspection declined substantially by 10% after the inception of the TRI program. These results present the first evidence for a decline in plant-level pollution-related measures at a time coinciding with the inception of the TRI program, as no other such data exist in the pre-TRI program period. However, we are not able to attribute these declines in worker exposure definitively to the TRI program. We do not find statistically significant evidence of greater reductions in worker exposure in plants that are affected to a greater degree by the TRI program, as measured by larger plant-level or industry-level emission reductions.

JEL codes: Q58, Q53, L65, L51, I18

Key words: right-to-know programs, information-based regulation, pollution disclosure programs, occupational exposure, exposure limits, worker safety

1. Introduction

Mandatory pollution disclosure programs require industrial plants to report their annual emissions into the environment and this information is then disseminated to the public (Hamilton, 2005; Kraft et al., 2011). Beginning with the 1987 Toxics Release Inventory (TRI) program in the United States (US), these programs now operate at the regional level, including the North American Pollutant Release and Transfer Registry (PRTR) and the European PRTR and at the national level in Japan and Australia (Antweiler and Harrison, 2003; Cañón de Francia et al., 2008; Henriques, 2010). Because strategies to reduce emissions and occupational exposure are interlinked (EPA, 1987; EPA-OSHA-NIOSH, 1999), the US Environmental Protection Agency (EPA) and other international agencies have initiated discussions on the potential role of these programs in occupational health policy (EPA, 1996; UNITAR, 1998; IFCS-WHO, 2000). The potential for disclosure programs to generate the co-benefit of reducing workers' chemical exposure is a key policy issue because worker exposure ranks as one of the highest risk areas for human health, with costs of occupational diseases amounting to $58 billion per year in the US alone (EPA, 1987; EPA-SAB, 1990; Leigh, 2011).

Our study is the ***first*** to examine if mandatory pollution disclosure programs, exemplified by the TRI program, affect workers' chemical exposure. Several authors (Porter, 1991; Hart and Ahuja, 1996; Ambec and Lanoie, 2008) have argued that external pressure can prompt plants to learn about their inputs and production processes, leading to source reduction.[1] Indeed, according to plant managers, the most important benefit from the TRI program is their discovery of opportunities for source reduction as they prepare their inventories of inputs and production processes in order to estimate their TRI emissions (Lynn and Kartez, 1994; Kraft et al., 2011).

[1] "Source reduction, also called pollution prevention, includes chemical substitution, process modification, and substitute technologies that intervene in the industrial process itself to eliminate or reduce hazards" (Roelofs and Ellenbecker, 2003).

Plants' source reduction can potentially reduce both emissions into the environment and worker exposure to chemicals. As noted in Roelofs and Ellenbecker (2003), source reduction, motivated by environmental protection goals, "… have had a *significant* impact on … reducing workers' hazardous chemical exposure in the work environment." Nevertheless, no information exists on the share of plants that have adopted source reduction that reduce worker exposure in response to the TRI program.

We examine ***actual personal*** air contaminant exposure data collected during 1,644 plant-level inspections between 1984 and 2009 for 29 states. We focus on the US chemical manufacturing sector, which ranks among the top sectors in air emissions reported to the TRI program (EPA, 1998) and violations of worker exposure limits to air contaminants (OSHA, 2011). We use the Chemical Exposure and Health Data (CEHD), which has only recently been made widely available to researchers.[2] The CEHD, the largest and most detailed worker exposure database worldwide (Yassin et al., 2005), compiles data on chemical samples collected during plant-level inspections (Gray and Jones, 1991). Crucially, the information on plants' names, addresses, and industries allow us to link three databases, the CEHD, the TRI database and the Occupational Safety and Health Administration's (OSHA) inspection and compliance database.

Our findings are two-fold. First, we find that worker exposure has declined at a time coinciding with the TRI program implementation, accounting for the time trend and other confounding factors such as plants' inspection and compliance history, and state fixed effects. The counts of chemical test results that exceed the legal exposure limits per inspection declined by 31% from 1.02 to 0.70 per inspection in the post-TRI program period, while the maximum

[2] Gray and Jones' (1991) seminal study on inspections and worker exposure secured the use of the CEHD when its dissemination was restricted.

ratio of test results to the legal limits declined by 10% in the post-TRI program period, both estimates of the decline in worker exposure are statistically significant at the 10% level. These results present the first evidence for a decline in plant-level pollution-related measures at a time coinciding with the inception of the TRI program (Hamilton, 2005), as no other such data exist in the pre-TRI program period (Gray, pers. comm.). Our description of the decline in *actual* worker exposure, measured with personal sampling devices and recorded by the regulator, is an important innovation over studies that are forced to rely on plants' *self-reported* emissions to describe plants' responses to environmental policies (Arora and Cason, 1999; Gamper-Rabindran, 2006).

Second, while our results indicate that worker exposure declined at a time coinciding with the inception of the TRI program, we are not able to attribute this decline to the TRI program per se. To definitively attribute the decline to the TRI program we believe the evidence should indicate that worker exposure declined to a greater extent in plants that were affected to a greater degree by the program. However, we do not find statistically significant evidence of greater declines in worker exposure either in plants with greater emission reductions or in plants operating in industries with greater emission reductions. While the existence of only three years of exposure data prior to the inception of the TRI program poses a limitation to our study, this data is the best available. Data from earlier years have not been stored.[3]

Our study makes two policy contributions (see section 7 for details). First, we conclude that for the *average* plant, the potential learning opportunity from the preparation of inventories of chemical use and production processes has not translated into substantial adoption of source reduction that reduce worker exposure. Our second conclusion that worker exposure declined at

[3]Email from OSHA/Directorate of Information Technology to Gamper-Rabindran in response to a Freedom of Information Act request.

a time coinciding with the inception of the TRI program is of policy interest. While the preparation of inventories can reveal opportunities for source reduction, case studies indicate that technical assistance have been crucial in enabling plants to adopt source reduction that reduce both emissions and exposure (Roelofs and Ellenbecker, 2003; Massey, 2011; Armenti et al., 2011). Future work should examine the role of technical assistance programs, that work in conjunction with disclosure programs (Geiser, 1993), on worker exposure.

Section 2 reviews the literature on the potential link between pollution disclosure programs and reductions in worker exposure. Section 3 describes our estimation strategy and data. Section 4 presents our results, with conclusions and policy implications in Section 5.

2. Mandatory pollution disclosure programs and worker exposure within plants

Pollution disclosure programs exemplify the information-based approach to regulation (Tietenberg, 1998; Weil et al., 2006). The 1986 Emergency Planning and Community Right-to-Know Act (EPCRA), which establishes the TRI program, mandates all plants in the manufacturing sector, which use or emit chemicals beyond a threshold, to report emissions annually to the EPA. The EPA, state environmental agencies and non-governmental groups, notably, Scorecard and the Right-to-Know Network then disseminates this information (Fung and O'Rourke, 2000; Scorse, 2000; Bae et al., 2010). While the limitations of the TRI data have been noted,[4] several studies indicate that plants have responded to the TRI program to varying degrees[5] (Hamilton, 2005; Shapiro, 2005; Kraft et al., 2011). Hamilton (1999) and Konar and Cohen (1997) demonstrate that plants with stronger incentives to reduce TRI emissions, because of their larger liability from emissions or their greater abnormal stock market declines, have

[4]The limitations include changes in reporting requirements (Natan and Miller, 1998) and the accuracy of the reported data (de Marchi and Hamilton, 2006).
[5] These studies examine plants' response to the TRI program, within the context of other liability and regulatory concerns and information use (Hamilton, 2005).

indeed, made larger reductions. Bui (2005) finds petroleum refineries *reduced* TRI emissions, despite increases in the use of inputs that contribute to TRI emissions. Case studies indicate that some plants have reduced emissions in response to requests from concerned citizens and because of the threat of public scrutiny (Fung and O'Rourke, 2000; Hamilton, 2005).

2.1 Disclosure programs, source reduction and worker exposure

While earlier studies focus on evaluating the TRI program's goal of reducing pollution, more recent work has explored the potential for pollution reduction programs, through source reduction, to generate the co-benefit of reducing worker exposure (Armenti et al., 2011; Massey, 2011). The management literature notes that external pressure from environmental policies can prompt plants to identify source reduction opportunities (Hart and Ahuja, 1996; Ambec and Lanoie, 2008). Porter (1991) and Porter and van der Linde (1995) argue that pollution represents inefficiency, and source reduction, which reduces inputs and emissions, can potentially yield profits. However, in the absence of external pressure, managers are biased towards accepting existing production methods, instead of encouraging innovation for several reasons. First, the costs of innovating production processes are incurred in the present, while benefits arrive in the future (Ambec et al., 2011). Second, managers are risk averse in adopting new production processes (Ambec and Lanoie, 2008). Third, managers' expectation of few opportunities for source reduction combined with high costs of searching for these opportunities can lead to fewer searches and thus, unexploited opportunities (King and Lenox, 2002). The requirement to report to the TRI program, combined with pressure from regulators and liability for emissions and worker exposure, can provide the impetus for plants to identify and implement source reduction.

Surveys of plant managers provide further support for the TRI program's potential to spur the adoption of source reduction. Managers report that their most frequent use of TRI data is for source reduction efforts (Lynn and Kartez, 1994, reporting on a 1990 survey). In particular, "the TRI program allowed them to identify the needs and opportunities for source reduction" (Kraft et. al., 2011, reporting on a 2005 survey). Managers learned about their own plants' emissions for the first time when the TRI program was implemented as this information had not been previously tracked (Graham, 2002; Hamilton, 2005). These views are compatible with the technical literature on the benefits from the preparation of pollution inventories. Natan (1997) describes how the data required to estimate TRI emissions, using techniques of materials accounting, process modeling or applying emissions factors, can alert managers to inputs and production processes at their plants. Moreover, managers may use worker exposure data to estimate TRI emissions, making them aware of the linkages among production processes, emissions and worker exposure (UNITAR, 1998). Benefits from source reduction become evident when managers track the potential reductions in material use (Shen, 1998).

A growing literature documents the ability for source reduction in the manufacturing sector to reduce both emissions and exposure. As noted by Roelofs and Ellenbecker (2003), "many of the technological breakthroughs that have occurred in chemistry, process engineering, and industrial equipment in response to demand for reducing the environmental impact of production have had the added benefit of reducing workers' hazardous chemical exposure." Several case studies document how source reduction has reduced both emissions and worker exposure. These examples include process changes and input substitution that eliminated methylene chloride (Roelofs and Ellenbecker, 2003), the substitution from organic solvents to aqueous cleaners (Lavoué, et al., 2003) or vegetable-oil based cleaners (Bartlett at al., 1999). Changes also include input substitution and process changes to reduce the use of toxic chemicals (Armenti et al., 2011) or eliminate the use of toxics (Massey, 2011), and process changes that integrate worker and environmental protection (Enander et al., 2003). The twin reduction of pollution and exposure occur when plants aim to improve their overall production process, and consider the potential problems from waste generation and worker exposure (Roelofs and Ellenbecker, 2003). Indeed management practices such as Lean Six Sigma focus on both reducing pollution and the handling of toxic substances, among other process improvement goals such as energy efficiency, process safety, and product quality (Massey, 2011).

Nevertheless, whether the TRI program contributes to statistically significant reductions in worker exposure is an empirical question. The program's net effect depends on the share of plants that undertook source reduction activities that reduce worker exposure. In turn, plants' decision to adopt source reduction depends on the costs of these technologies and plants' knowledge about these options (Shen, 1998). Some plants may decide not to reduce emissions or to reduce emissions by installing end-of-pipe control technologies which do not result in reduced worker exposure.

2.3 Workers' chemical exposure in manufacturing plants

Reducing workers' chemical exposure is a key policy issue. "Chemical exposures in the workplace occur at much higher frequency, intensity, and duration than those that occur in the ambient environment" (Wilson et al., 2006). Occupational exposures yearly lead to at least 50,000 new cases and 25,000 deaths from cancer; 30,000 new cases and 1,800 deaths from chronic obstructive pulmonary disease; and 7,300 new cases and 1,000 deaths from coronary and cerebrovascular diseases (Wilson et al., 2006; citing Leigh et al., 2000).

OSHA sets environmental health and safety (EHS) regulations, including legal exposure limits, and conducts inspections to enforce these regulations (Mendeloff, 1988; Weil, 1996; Gray and Scholz, 1993; Mendeloff and Gray, 2005). During health inspections, OSHA inspectors collect personal samples of air contaminants to establish violations of the legal exposure limits (Lofgren, 1996). We focus on these samples, which are collected using personal sampling devices worn by workers (Yassin et al., 2005; Lofgren et al., 2010). Almost all the chemicals sampled by OSHA are reportable to the TRI program.

OSHA's programmed inspections target industries that rank highly based on their rates of violations of OSHA's health regulations, in particular, violations that are serious, willful or repeated (Lofgren, 1996). These inspections are then randomly assigned among plants within a target industry (Gray and Jones, 1991). OSHA's non-programmed inspections are undertaken as follow-ups to previous inspections, in response to referrals from other government agencies or workers' complaints, or in relation to an accident investigation (Lofgren, 1996). The violations of EHS regulations experienced by plants in our sample include the failure to provide adequate respiratory protection, the failure to meet hazard communication requirements, and exposure to flammable or explosive liquids.

Declining regulatory budgets (Weil, 2004) and the recognition that source reduction can reduce both emissions and exposure (EPA, 1987; EPA-OSHA-NIOSH, 1999; and more recently, Armenti et al, 2011: Massey, 2011) have led to discussions on the potential for disclosure programs to generate the co-benefit of reducing exposure (EPA, 1996; UNITAR, 1998; IFCS-WHO, 2000). As described above (section 2.1-2.2), while disclosure programs can potentially reduce both emissions and exposure, their net impact on worker exposure is ultimately an empirical question.

3. Research questions, estimation strategy and data

Our sample consists of plants in 27 different industries at the 4 digit Standard Industrial Classification (SIC-4) within the chemical manufacturing sector. The main industries are SIC

2851- Paints, Varnishes, Lacquers, and Enamels (16.8% of observations); SIC 2821 - Plastics Materials and Synthetic Resins (12.3%); SIC 2899 - Chemicals, not elsewhere classified (n.e.c.) (10.0%); 2819 - Industrial Inorganic Chemicals, n.e.c. (9.5%), and 2869 - Industrial Organic Chemicals, n.e.c. (8.7%).

OSHA's health inspections have collected similar types of air contaminants in the chemical manufacturing sector in the periods before and after the implementation of the TRI program. The main chemicals in our analysis are toluene (9.4% of all sample results); lead (5.6%); beryllium (4.14%) and manganese fume (3.36%). Toluene is the most sampled chemical in both the pre- and post-TRI program periods, and lead is the second most sampled chemical in both periods. Beryllium is the fourth and third most sampled chemicals in the pre and post-TRI program period, respectively; while manganese fume is the sixth and fifth most sampled chemicals in the pre and post-TRI period, respectively. The consistent set of chemicals sampled in these two periods indicates that our finding of declines in worker exposure at a time coinciding with the TRI program (see section 4.2) is not due to changes in the composition of chemicals sampled by OSHA's inspections between these two periods.

3.1 Question 1: Has worker exposure declined after the implementation of the TRI program?

Our first research question is: has worker exposure declined in the period after the implementation of the TRI program? This descriptive exercise compares worker exposure in the period before and after the TRI program implementation, controlling for a constant time trend and other factors that influence exposure such as plants' inspection and violation history. This comparison would identify the causal impact of the TRI program only if the time trend and observed covariates fully capture systematic differences in exposure between the two periods, and thus, the remaining variation in exposure between these periods can be attributed to the TRI program. However, if unobserved events that affect worker exposure occur contemporaneously with the inception of the TRI programs, for example, the innovation of less hazardous solvents, this comparison would overstate the effect of the TRI program in reducing worker exposure.

We examine plant-level worker exposure from 1,644 inspections at 1,333 unique plants between 1984 and 2009. These are all the inspections with personal air samples in the chemical sector that are archived in the CEHD. Our assumption, that these inspected plants are mandated to reported to the TRI, is justifiable as OSHA inspects larger plants (Gray and Scholz, 1993) and the TRI program mandates reporting by plants whose chemical use exceeds a threshold, which tend to be larger plants (Hamilton, 2005).

The model, whose results are presented in Table 2, is:

$$Y = \beta_1 I\,(\textit{post-TRI program period}) + \beta_2 X + \beta_3 T + \sigma \quad \text{- Model 1}$$

Observations are inspections. To measure adverse worker exposure, we compare each chemical sample of exposure to air contaminants to its permissible exposure limits (PEL) which are the legal limits.[6] This strategy, which allows us to summarize workers' adverse exposure across different chemicals,[7] has been implemented in other studies (Gray and Jones, 1991; Lofgren et al., 2010).

We analyze two measures of worker exposure. Our first dependent variable is the counts of exceedance among test results in an inspection. We use a Negative Binomial model because many inspections have large counts of exceedance. Moreover, dispersion parameters in our

[6]PELs can be expressed as 8-hour time weighted averages (TWA), 15-minute short-term exposure (STEL), or single ceiling exposure.
[7] We do not analyze exposure to each chemical because the number of observations is insufficient to ensure statistical power.

Negative Binomial models are statistically significant, indicating that the Negative Binomial models are preferred over the Poisson models (Cameron and Trivedi, 1986).

Our second dependent variable captures the intensity of worker exposure. This variable is defined as the log (max {T/PEL} + 1), where T/PEL is the ratio of the test result to the legal exposure limit. We use the maximum T/PEL among the test results in a given inspection. The addition of the number 1 within the log expression ensures that natural log is defined. We apply Ordinary Least Squares (OLS) to estimate the model with the log of the ratio of test results to PELs. The dummy variable, *I (post-TRI program period)*, indicates that the inspection occurred after the implementation of the TRI program, with β_1 the coefficient of interest. The model also includes control variables, *X*, a time trend, *T*, and an error term, σ.

3.2 Question 2: Can the decline in worker exposure be attributed to the TRI program?

Our second question asks if the decline in worker exposure can be attributed directly to the TRI program. We test the causal link between the TRI program and worker exposure using a difference-in-difference approach (Shadish, Cook and Campbell, 2002; Wooldridge, 2010). We argue that if worker exposure declined in response to the TRI program, the extent of the decline would be related to the degree to which plants are affected by the TRI program. Our main and secondary analysis utilizes variation in industry-level and plant-level emission reductions, respectively, to capture the degree to which plants are affected by the TRI program.

3.2.1 Industry-level variation in emission reductions

Our main analysis uses *industry-level* variation in emission reduction to identify the TRI program's effect. This analysis examines plant-level worker exposure from 1,644 inspections at 1,333 unique plants between 1984 and 2009. If the TRI program affects worker exposure, we expect the extent of the reductions in worker exposure after the inception of the TRI program to correspond with the degree to which the *industries* are affected by the TRI program. We use the change in the industry emissions in the early period of the TRI program as a direct measure of the extent to which the TRI program affects an industry. As a second measure, we use the average industry emissions.[8]

The model, whose results are presented in Table 3 and 4, is:

$$Y = \beta_1 \, I \, (\textit{post-TRI program period}) + \beta_2 X + \beta_3 T + \beta_4 \, \textit{Industry Relative Emissions} + \beta_5 \, I \, (\textit{post-TRI program period}) \times \textit{Industry Relative Emissions} + \sigma$$ - Model 2.1

Observations are inspections. The dependent variable, *Y*, control variables *X*, and the time trend *T*, are as defined above. *Industry Relative Emissions* captures the degree to which the TRI program affects a given plant. As described above, an industry's change in emissions in the early years following the inception of the TRI program serves as a direct measure of the impact of the TRI program on that industry. We also expect plants in industries with larger emissions to be affected to a greater degree by the TRI program. The interaction term of interest is, *I (post-TRI program period) x Industry Relative Emissions.* The coefficient on this interaction term allows us to infer if the decline in worker exposure in the post-TRI program period can be attributed to the TRI program. We use two alternative static measures for the *Industry Relative Emissions.* First, we use the log of the de-meaned average change in the TRI emissions between 1988 and 1990 (or between 1988 and 1993) for a given industry.[9] Second, we use the log of the de-meaned

---

[8] We construct the TRI emissions at the SIC-4 level for 1988-1993 using our data analyzed in (Gamper-Rabindran and Finger, 2010). These are plants that report to the TRI database that also reported number of employees to Dun and Bradstreet in the years 1988 to 2001. We link the SIC-4 industry emissions to plant-level exposure data using the plant's primary SIC-4 code.

[9] The de-meaned average emissions for a SIC-4 industry is defined as the average emissions for that SIC-4 industry minus the average emissions for the chemical sector. The de-meaned average change in emissions for a SIC-4 industry is defined as the average change in emissions for that SIC-4 industry minus the average change in emissions for the chemical sector. The de-meaned average emissions average change in emissions for a given plant is defined analogously. (Check this, sounds repetitive)

average TRI emissions for that industry from 1988 to 1990. We de-mean each of the interaction variables so that β_1 captures the average change in exposure in the post-TRI period. We exclude the less reliable 1987 emissions data (Hamilton, 2005). As an alternative measure to industry emissions, we examine industry emissions intensity, which is defined as the ratio of emissions to the value of shipments in a given industry.[10] In this specification, the extent to which an industry is affected by the TRI program is captured by the change in emissions intensity, as opposed to the change in the level of emissions per se.

Hypothesis testing: Results that $\beta_1 < 0$ indicates that worker exposure are, on average, lower in the post-TRI period, after controlling for confounding variables and a constant time trend. While these results would indicate that worker exposure declined at the inception of the TRI program, they do not allow us to distinguish between the effects of the TRI program on worker exposure and the effects of other contemporaneous events on worker exposure. Results that $\beta_4 > 0$ would indicate the plant-level exposure is positively related to the *Industry Relative Emissions*. If plants reduce worker exposure in response to the TRI program, we expect that the extent of reductions will correspond to the degree to which the industries' emissions are affected by the TRI program. The coefficient β_5 captures how changes in worker exposure after the introduction of the TRI program vary with the *Industry Relative Emissions* variables. In particular, we expect β_5 to be positive for the interaction term on the average change in industry emissions and we expect β_5 to be negative for the interaction term on average industry emissions.

3.2.2 Plant-level variation in emission reductions

[10] This ratio captures the cross-industry variation in industry emissions intensity, even though the numerator and denominator for this ratio comes from two different data sources that are likely to cover two samples of plants which do not completely overlap. Value of shipments is from NBER-CES Manufacturing Industry Database (Bartelsman, Becker and Gray, 2000).

Our secondary analysis uses *plant-level variation* in emission reductions to identify the TRI program effect. We examine plant-level worker exposure from 426 inspections at 330 unique plants between 1984 and 2009. Our resources permit us to link inspections from 1,644 inspections to our sample of larger plants that report to the TRI between 1988 and 2001. This time-intensive linkage exercise yielded 426 inspections at 330 plants for which we have both plant-level exposure data (between 1984 and 2009) and plant-level emissions data (between 1988 and 1993). If the TRI program affects worker exposure, we expect the extent of the reductions in worker exposure after the inception of the TRI program to correspond with the degree to which the *plants* are affected by the TRI program. We use the change in the plants' emissions in the early period of the TRI program as a direct measure of the extent to which the TRI program affects a plant. As a second measure, we use the average plant emissions. Plants with larger average emissions are likely to face greater pressures to reduce emissions. Annual worst polluter lists have been created by government agencies, the media, and non-governmental organizations (Fung and O'Rourke, 2000; Scorse, 2000). The media and non-governmental organizations pay the maximum attention to those plants with the minimum environmental performances, as indicated by large emissions (Fung and O'Rourke, 2000).

The model, whose results are presented in Table 5, is:

$$Y = \beta_1 I\ (\textit{post-TRI program period}) + \beta_2 X + \beta_3 T + \beta_4\ \textit{Plant Relative Emissions} +$$

$$\beta_5 I\ (\textit{post-TRI program period})\ x\ \textit{Plant Relative Emissions} + \sigma \quad \text{- Model 2.2}$$

Observations are inspections. A plant's relative emissions are defined in two ways: (1) the de-meaned average change in emissions between 1988 and 1990 (or between 1988 and 1993) and (2) the de-meaned average emissions at the plant. Other variables are as defined above. The interpretation of the coefficients in Model 2 is analogous to that in Model 1.

3.2.3 Control variables

Control variables included all three models are described below. We include the log of the number of test results per inspections (Gray and Jones, 1991) because larger number of test samples per inspections may lead to greater counts of exceedance. Dummy variables are included for the type of inspections (accident, referral, follow-up, complaint and other; programmed inspections is the omitted category). We also include regulatory pressure variables, i.e., the number of inspections in the previous year and the number of inspections in the prior two to five years. We include measures of previous violations, i.e., the log of the number of violations in the previous year and in the prior two to five years. We restrict our comparison to plants within the same state, by including state-level fixed effects in the models. While we restrict our analysis to the 29 states in which Federal OSHA implements the law, there is still variation across states in worker exposure policies (Thompson and Scicchitano, 1985).

3.3 Estimation issues

We analyze exposure data which are collected during inspections. Regulators are more likely to select plants to inspect which are expected to have a greater likelihood of exceeding the legal exposure limits. In several specifications, we use industry and state fixed effects, restricting our comparisons to plants within the same industry and state and thereby addressing the targeting of inspections based on industry-ranking of rates of violations of health inspections (see section 2.3). Our analysis has not corrected for other sources of sample selection, particularly, those arising from plant-level unobservable factors. As in other studies of inspection-generated data (Gray and Jones, 1991), we do not have a persuasive instrument that is correlated to the likelihood of inspection at a given plant, but not correlated with exposure at the plant. Other key studies have similarly used the CEHD data to describe time trends in worker exposure without correcting for sample selection (Froines et al., 1986; Froines et al., 1990; Yassin 2005).

While our estimated level of exposures are likely to be higher than that for the population of plants in the chemical sector, our estimates of the effect of the TRI program on exposure remains informative for policy inference. Crucially, our "difference-in-difference" approach to estimate the effect of the TRI program in worker exposure is less prone to bias arising from sample selection than cross-sectional studies of inspection data. For our study to be biased, OSHA would have to change its inspection strategy in the post-TRI period in such a way to affect the counts of exceedance in plants in those industries that are more affected by the TRI program relative to the counts of exceedance in plants in those industries that are less affected by the TRI program. However, our extensive review of OSHA's inspection strategy does not yield any evidence of OSHA using the TRI data to prioritize its inspection. Lofgren's (1996) exhaustive report on OSHA's targeting of inspections does not identify OSHA's use of the TRI data. Similarly, Hamilton's (2005) detailed study of the use of the TRI data does not identify OSHA's use of TRI data to target inspections. One practical reason for OSHA not using the TRI data to target plant-level inspections is that, to-date, the OSHA and TRI plant-level databases have not been linked by OSHA or EPA, but only by a handful of researchers (Deily and Gray, 1996, for the steel industry, and this study for the chemical industry). Instead, as described in section 2.3., OSHA's health inspections are based on industries' violations of health regulations, or are undertaken in response to complaints from workers, referrals from other government agencies and in response to accidents (Lofgren, 1996).

We note that two potentially sharper identification strategies are not feasible in practice. First, because almost all chemicals sampled by OSHA are reportable to the TRI program, we are not able to compare worker exposure to chemicals that are reportable and that are not reportable to the TRI program. Second, in theory, it would be useful to compare industries that have undertaken more source reduction activities than other industries. Unfortunately, such data is available only after 1991 and data quality is an issue particularly in first few years of that database.[11]

3.4 Data

The CEHD provides information on worker exposure including the chemical sampled, test results, and a code for personal airborne samples. We link the exposure data to OSHA's Integrated Management and Inspection System (IMIS), which provides information on plant characteristics (i.e., the plant's SIC-4 code, name and address), the type and date of inspections, the plant's history of EHS inspections and violations. OSHA's PELs are from Tables Z-1, Z-2, and Z-3 of the OSHA General Industry Air Contaminants Standard (29 CFR 1910.1000). The TRI emissions data is from the EPA. For our main analysis, we link the CEHD plants to industry-level emissions using the plants' SIC-4 industries. For our secondary analysis, we link the CEHD and TRI database based on plants' names and addresses using Fellegi and Sunter's (1969) matching techniques. For matches that are border-line in quality, we undertake further library research to determine if there is a true match.

4. Results

4.1 Summary statistics

The inspections in our main sample generally occur at different plants. In the pre-program period, 340 inspections occurred at 310 unique plants and in the post-program period, 1,098 inspections occurred at 1,304 unique plants. During our study period, 1,110 plants

[11] The 1990 Pollution Prevention Act requires plants to report source reduction activity each year, beginning in 1991, as part of the reporting requirements of the TRI program. The Act, however, does not mandate plants to undertake source reduction activities (EPA, 1990).

experience one inspection, 167 plants experience two inspections, and 56 plants experience three or more inspections. Only 98 plants experience inspections in the periods before and after the inception of the TRI program, limiting our ability to include plant fixed effects in the analysis. Among the 1,644 inspections in our sample, 20.9% of inspections have at least one exceedance. Inspections with at least one exceedance have, on average, 3.46 exceedance per inspection. Therefore, examining the counts of exceedance is more informative than examining simply the presence or absence of exceedance.

Comparison of the raw means suggests that worker exposure has declined in the period after the implementation of the TRI program (Table 1, column 3 and 4). The likelihood of at least one exceedance per inspection declines from 27.9% in the pre-program period to 19.0% in the post-program period. Similarly, the average number of exceedance per inspection declines from 0.953 in the pre-program period to 0.663 exceedance per inspection in the post-program period. Nevertheless, the maximum ratio of test results to PELs per inspection declines only slightly from 0.553 in the pre-program period to 0.518 in the post-program period. (A ratio above 1 indicates exceedance of the PEL). The higher worker exposure in the pre-program period is also evident from the means at the level of test results. The 1,644 inspections collected 25,156 test results. The ratio of test results to PELs averaged over all test results in the pre-program period is 0.515 while this ratio for the post-program period is 0.390.

Next we consider control variables for inclusion in the regression models (Table 1, column 6 and 7). We include the number of test results per inspection as a control variable because the inspections with exceedance have more test results per inspection and the pre-program period has more test results per inspection. Our regression analysis also incorporates the inspection and violation history at the plants because exceedance is more likely to occur at those plants with more frequent inspections and violations. Our models control for the types of inspections because referral and follow-up inspections make up a greater share of those inspections that detect exceedance, while complaint inspections make up a lower share of such inspections. Exceedance is also more likely to occur in industries with larger emissions.

Unsurprisingly, the ratio of test results to PELs, on average, is higher for those inspections that detect at least one exceedance than for those inspections without any exceedance (Table 1, column 6 and 7). We examine the maximum ratio of test results to PELs among test results in a given inspection. The average of this value for inspections with at least one exceedance is 2.279, which is much higher than the 0.063 figure from the inspections without any exceedance. We also examine the ratio of test results to PELs averaged over all test results. The average of this value for inspections with an exceedance is 0.993, which is much higher than the corresponding 0.045 figure from inspections without an exceedance.

In our smaller sample of 426 inspections for which we have plant-level emissions, inspections occur at 330 unique plants. During our study period, 247 plants experience one inspection, 54 plants experience two inspections, and 29 plants experience three or more inspections. Only 37 plants experience inspections in the periods before and after the inception of the TRI program. Plants in the smaller sample are more frequently inspected than plants in our main sample. The average counts of exceedance per inspection are slightly higher in the smaller sample, but the difference is not statistically significant. (Details are available from authors.)

4.2 Question 1: Has worker exposure declined?

The estimated coefficients from the Negative Binomial models which examine the counts of exceedance per inspection are in Table 2, columns 1-5. These results provide evidence that the counts of exceedance declined in the post-program period, accounting for the time trend. The coefficient on the post-program dummy is negative and statistically significant in several specifications (Table 2, columns 1-3). Table 2, column 1 reports the results for our baseline model, which controls for state and industry fixed effects, the type of inspections and the time trend. The coefficient is negative and statistically significant at the 10% level. While it is appropriate to include a time trend in the model, we run a specification without a time trend and continue to find a negative and statistically significant coefficient on the post-program dummy (Table 2, column 2). Our results are robust to additional control variables on past inspections and past violations at the plant (Table 2, column 3).[12] In column 4, we drop the industry fixed effects and use industry emissions in 1988 to control for variations across industries. The coefficient on the post-program dummy continues to be negative and is similar in magnitude to previous estimates, but it is less precisely estimated.

Using the smaller estimated coefficient on the post-program dummy (Table 2, column 1), we calculate the Average Treatment on the Treated (ATT) estimates. We conclude that there is some evidence that worker exposure declined in the post-program period. The expected number of exceedances declined from 1.02 to 0.70 exceedances per inspection, corresponding to a 31% decline. Corresponding ATT estimates from the probit model (available from authors) indicate that the likelihood of at least one exceedance in an inspection declined from 24.6% to 19.3%.

Results from the OLS model, which examine the maximum ratio of test results to the PELs, are in Table 2, columns 6-9. These results mirror our earlier results on the counts of exceedance. The results in Table 2, columns 6-7 provide evidence of the decline in worker exposure. The maximum ratio of test results to PELs decline by 10% or 11% in the post-TRI period, and these estimates are statistically significant at the 10% level. As in our earlier results

[12] For our study to be valid, we need to control for the association between these variables and worker exposure. However,we do not need to isolate the causal effect of past inspections or violations on worker exposure.

(Table 2, column 4), the specification with industry emissions, instead of industry fixed effects, yields a negative coefficient of similar magnitude, but the coefficient is not statistically significant (Table 2, column 8).

In additional specifications, we break the post-program period into the periods 1987-1990 and post-1990 (Table 2, columns 5 and 9). The coefficients on both time periods are negative but significant only for the post-1990 period. In additional specifications (available from authors), we break the post-program period into smaller time periods and find negative estimates for these time periods, though these coefficients are imprecisely measured. We proceed by using one post-period dummy, i.e., post-1987, for the rest of the paper. We also replicated results from Table 2 using a shorter time period from 1984-1995 and find a negative time trend and a negative coefficient on the post-program dummy, though they are imprecisely estimated. We proceed to analyze our full sample from 1984 to 2009 in the rest of the paper.

4.3 Question 2: Can the decline in worker exposure be attributed to the TRI program?

While we find evidence that worker exposure declined in the post-program period, results from Tables 3-5 make it difficult to definitively attribute this decline to the TRI program.

4.31 Industry-level variation in emission reductions

In Table 3 and 4, we estimate whether the impact on worker exposure in the post-TRI period varies with the average industry emissions (columns 1-4), the industry-level change in emissions between 1988 and 1990 (columns 5-8), and the industry-level change in emissions between 1988 and 1993 (columns 9-12). Table 3 reports the coefficients from the Negative Binomial models, which examine the outcome of the counts of exceedance per inspection. Applying industry fixed effects and a full set of control variables, we find a negative and statistically significant coefficient on the dummy for post-program years (Table 3, columns 2, 6 and 10). Industries with larger average emissions (Table 3, columns 3-4) or larger emissions in 1988 (Table 3, columns 7-8, 11-12) have more exceedance per inspection in the pre-program years.

The coefficients on the interaction terms capture how the change in worker exposure varies with measures of *Industry Relative Emissions.* Across several specifications, the signs of these coefficients are consistent with greater declines in worker exposure in industries that are more affected by the TRI program; but these coefficients are not statistically significant at conventional levels (Table 3, columns 1-4 and 9-12). The interaction term on average industry emissions is negative, indicating that plants in higher emitting industries reduce worker exposure to a greater degree after the inception of the TRI program (Table 3, columns 1-4). Correspondingly, the interaction term on the change in emissions between 1988 and 1993 is positive, indicating that industries with larger reductions in emissions in the five years following the inception of the TRI program reduce worker exposure to a greater extent (Table 3, columns 9-12). The point estimates are sizable relative to the estimated trend of declining exposure, i.e., 0.057 fewer counts of exceedance per inspection per year (see below, Table 5). Relative to plants in other industries, those with a one standard deviation greater reduction in the log of industry emissions between 1988 and 1993 have 0.049 fewer counts of exceedance per inspection in the post-TRI program period (Table 3, column 9). Similarly, plants in industries with one standard deviation higher log emissions have 0.019 fewer counts of exceedance per inspection in the post-TRI program period (Table 3, column 1). However, because none of the interaction coefficients are statistically significant at conventional levels (Table 3, columns 1-4 and 9-12), we are not able to attribute the declines in worker exposure definitively to the TRI program.

Additional specifications (available from authors) using different years to calculate the average industry emissions yield qualitatively similar results. We note that the sign is positive on the interaction term on the change in emissions between 1988 and 1993 (Table 3, columns 9-12), while the sign is negative on the interaction term on the change in emissions between 1988 and 1990 (Table 3, columns 5-8). It is plausible that a longer period is required for plants to implement changes in production processes, and the longer five year period may better capture industries' response to the TRI program. Even so, the positive sign on the interaction term (Table 3, columns 9-12) is not statistically different from zero.

Results on the log of the maximum ratio of test results to PELs for a given inspection, reported in Table 4, correspond with our results on the counts of exceedance. The coefficients on the interaction term for average emissions are negative (Table 4, columns 1-4), while the coefficients on the interaction term for the change in emissions between 1988 and 1993 are positive (Table 4, columns 9-12). These results correspond with the view that plants operating in industries with greater reductions in emissions or in industries that face greater pressure for emissions reductions (indicated by larger average emissions) reduce worker exposure to a greater extent, following the inception of the TRI program. The point estimates are sizable relative to the estimated trend of declining exposure of 2% per year, measured by the maximum ratio of test results to PELs (see below, Table 5). In comparison to plants in other industries, those with one standard deviation greater reduction in the log of industry emissions between 1988 and 1993 reduce exposure by 2.7% in the post-TRI program period (Table 4, column 10). Similarly, those plants in industries with one standard deviation higher log emissions reduce exposure by 3% more in the post-TRI program period (Table 4, column 2). However, because none of the interaction coefficients are statistically significant at conventional levels (Table 4, columns 1-4 and 9-12), we are not able to attribute the declines in worker exposure definitively to the TRI program. The sign on the interaction term for the change in emissions between 1988 and 1993 is positive (Table 4, columns 9-12), while the sign on the interaction term for the change in emissions between 1988 and 1990 is negative (Table 4, columns 5-8), contrary to expectation. We place greater weight on the model with the change in emissions over a 5 year period (Table 4, column 9-12), because it is likely that the longer period is required for plants to implement changes in production processes.

Consistent with our earlier results, we find industries with larger average emissions (Table 4, column 3-4) or larger emissions in 1988 (Table 4, columns 7-8 and 11-12) have a higher ratio of test results to PELs in the pre-program years. We also find a negative coefficient on the post-program dummy in our specification with industry fixed effects and a complete set of control variables (Table 4, columns 2, 6 and 10). The time trend is negative across specifications, but statistically significant only in two specifications (Table 4, columns 3 and 7).

We repeat our analysis in Table 2-4 using industry-level emissions intensity, defined as the ratio of emissions to value of shipments. These results (available from authors), like our models with industry-level emissions, do not allow us to attribute the decline in worker exposure definitively to the TRI program.

4.32 Plant-level variation in emission reductions

Next we turn to the smaller sample of inspections for which we have plant-level emissions (Table 5). Results for the counts of exceedance and the ratio of test results to PELs are in columns 1-6 and 7-12, respectively. We find a negative and statistically significant time trend across our specifications (Table 5, columns 1-12). These results indicate a decline of 0.057 exceedances per inspection per year (Table 5, column 6) or a 2% decline in the ratio of test results to PELs per year (Table 5, column 12).[13] The coefficients on the interaction term for average emissions are negative (Table 5, columns 1-2 and 7-8), while the coefficients on the interaction term for the change in emissions between 1988 and 1990 (Table 5, columns 3-4 and 9-10) and between 1988 and 1993 (Table 5, columns 5-6 and 11-12) are positive. These results correspond with the view that plants that face greater pressure to reduce emissions, or plants that have reduced emissions by a greater amount, have also reduced worker exposure to a greater degree following the inception of the TRI program.

Relative to other plants, those with one standard deviation greater reduction in the log of TRI emissions between 1988 and 1993 have 0.037 fewer counts of exceedance per inspection (Table 5, column 6) or 0.9% lower maximum ratio of test results to PELs in the post-TRI program period (Table 5, column 11). Similarly, plants with one standard deviation higher log emissions have 0.22 fewer counts of exceedance per inspection (Table 5, column 2) or 2% lower ratio of test results to PELs in the post-TRI program period (Table 5, column 8). However, as with our industry specifications, the coefficients on the interactions terms are not statistically significant (Table 5, columns 1-12), precluding us from attributing the decline in exposure to the TRI program per se.

4.4 Further robustness checks

All our results, presented in Tables 2, 3, 4 and 5 are robust to allowing year trends to vary by SIC-4 industry or state. The signs and significance of the coefficients from these models are consistent with those reported for baseline models. The magnitudes of the coefficients change only slightly, allowing us to draw qualitatively similar inferences from these specifications.

Next we consider anticipation effects. If plants anticipate the TRI program and reduce

[13] Similar to the estimate in Table 5, column 6, those from columns 2 and 4 indicate declines of 0.047 and 0.050 exceedances per inspection per year, respectively. Likewise, the estimates from columns 8 and 10 are similar to that from column 12.

emissions before 1987, (and that action resulted in concurrent reductions in worker exposure), one may be concerned that our study would be biased towards underestimating the impact of the TRI program in reducing worker exposure. Our results are robust to the use of 1986, one year prior to the TRI program, as the “effective” program year. We are limited in how much earlier we can set the “effective” program year in our analysis because only 3 years of worker exposure data exist prior to the TRI program implementation.

5. Conclusion and policy implications

This first test of the impact of pollution disclosure programs on worker exposure uses a newly available plant-level database on worker exposure, which we have linked to the TRI database and OSHA’s inspection database. We provide the first evidence that worker exposure declined at a time coinciding with the inception of the TRI program, after accounting for the time trend and other confounding factors, such as plants’ inspection and violation history. The counts of exceedance declined by 31% from 1.02 to 0.70 per inspection, while the maximum ratio of test results to the legal limits declined by 10% in the post-TRI period, with both estimates statistically significant at the 10% level. However, we are not able to attribute this decline in worker exposure to the TRI program per se. We do not find statistically significant evidence of greater reductions in worker exposure in plants that are affected to a greater degree by the TRI program, as measured by larger plant-level or industry-level emission reductions. Our conclusions are robust to the use of several measures of worker exposure and other measures of the extent to which industries or plants are affected by the TRI program. While the use of three years of worker exposure data prior to the implementation of the TRI program places an important caveat on our study, this data is the best that exists (see footnote 3).

Our study provides two policy lessons. First, as reviewed in section 2, the TRI program could potentially reduce worker exposure, given the evidence that (i) strategies to reduce emissions and worker exposure are interlinked, and (ii) plant managers report that the preparation of inventories of chemical use and production processes, used to estimate their TRI emissions, reveal opportunities for source reduction that reduce both emissions and worker exposure. However, our results indicate that that for the *average* plant, the potential learning opportunity alone from the TRI program has not translated into significant adoption of source reductions that reduce worker exposure. Our results are consistent with the findings in the few available plant surveys of low adoption rates of source reduction that reduce worker exposure. One survey indicates that only 23% of plants adopted source reduction to reduce TRI emissions (Graham and Miller, 2001). Two other surveys (not in relation to the TRI program) indicate that among plants that adopted source reduction, only half report that these techniques reduce worker exposure (Roelofs et al., 2000; Massey, 2011).

Second, our documentation that worker exposure has declined in the period coinciding with the TRI program implementation raises the question as to why this decline has occurred. Our pioneering study on pollution disclosure programs and worker exposure explores a straightforward link between the extent of the decline in worker exposure and the degree to which plants or industries have reduced their TRI emissions. Future work should explore potentially more complex links between disclosure programs and exposure, in particular technical assistance programs for the adoption of source reduction that operate in conjunction with TRI program in several states (Geiser, 1993). While plants' inventories of their chemical use and processes provide the first step in bringing to light opportunities for source reduction, case studies indicate that technical assistance has been crucial in enabling plants to switch to technologies that reduce both emissions and exposure (Roelofs and Ellenbecker, 2003; Massey, 2011; Armenti et al., 2011). Massey (2011) notes that technical assistance can address the barriers which 62% of surveyed plants report had prevented their adoption of source reduction. Technical assistance programs, which provide information on the range of technical options and guidance on their adoption, reduce the risk and uncertainty in adopting new technology (Anderson and Newell, 2004). The CEHD, which our study highlights, provides the opportunity to examine the impact of these programs, working in tandem with the TRI program, on worker exposure.

Bibliography

Ambec, Stefan, Mark A Cohen, Stewart Elgie and Paul Lanoie. 2011. "The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness." *RFF Discussion Paper* 11-01.

Ambec, Stefan and Paul Lanoie. 2008. "When And Why Does It Pay To Be Green?" *Academy of Management Perspectives* 2008, 23: 45-62

Anderson, Soren T. and Richard G. Newell. 2004."Information Programs for Technology Adoption: the Case of Energy-efficiency Audits" *Resource and Energy Economics* 26: 27–50

Antweiler, Werner and Kathryn Harrison. 2003. "Toxic Release Inventories and Green Consumerism: Empirical Evidence from Canada." *Canadian Journal of Economics* 36 (2). 495-520.

Antweiler, Werner and Kathryn Harrison. 2007. "Canada's Voluntary ARET Program: Limited Success Despite Industry Cosponsorship." *Journal of Policy Analysis and Management* 26 (4): 755-774.

Armenti Karla R., Rafael Moure-Eraso, Craig Slatin, and Ken Geiser. 2011. "Primary Prevention for Worker Health and Safety: Cleaner Production and Toxics Use Reduction in Massachusetts." *Journal of Cleaner Production* 19 (5): 488-497.

Arora, Seema and Timothy N. Cason. 1999. "Do Community Characteristics Influence Environmental Outcomes? Evidence from the Toxics Release Inventory." *Southern Economic Journal* 65 (4): 691-716.

Bae, Hyunhoe, Peter Wilcoxen and David Popp. 2010. "Information Disclosure Policy: Do States' Data Processing Efforts Help More than the Information Disclosure Itself?" *Journal of Policy Analysis and Management* 29(1): 163-182

Bartelsman, Eric J., Randy A. Becker, and Wayne B. Gray. 2000. June 2000 NBER-CES Manufacturing Industry Database

Bartlett I. W., A. J. P. Dalton, A. McGuinness, and H. Palmer. 1999. "Substitution of Organic Solvent Cleaning Agents in the Lithographic Printing Industry. *The Annals of Occupational Hygiene* 43 (2): 83-90.

Bui, Linda. 2005. "Public Disclosure of Private Information as a Tool for Regulating Environmental Emissions: Firm-Level Responses by Petroleum Refineries to the Toxics Release Inventory," Working Papers 05-13, Center for Economic Studies, U.S. Census Bureau.

Cameron, A. Colin, and Pravin K. Trivedi. 1986. "Econometric Models Based on Count Data: Comparisons and Applications of Some Estimators and Tests." *Journal of Applied Econometrics* January (1): 29-54.

Cañón de Francia, J., Garcés Ayerbe, C. and Ramirez Alesón, M. 2008. “Analysis of the effectiveness of the first European Pollutant Emission Register (EPER). Ecological Economics, 67, 83-92.

de Marchi, Scott and James T. Hamilton. 2006. “Assessing the Accuracy of Self-Reported Data: an Evaluation of the Toxics Release Inventory” *Journal of Risk and Uncertainty* 32 (1): 57-76.

Deily, Mary E. and Wayne B. Gray. 2007. "Agency Structure and Firm Culture: OSHA, EPA and the Steel Industry," *The Journal of Law, Economics, and Organization*: 685-709.

Ellenbecker, Michael. 1996. “Engineering Controls as an Intervention to Reduce Worker Exposure.” *American Journal of Industrial Medicine* 29: 303-307.

Enander, Richard T., David M. Gute, and Howard J. Cohen. 2003. “The Concordance of Pollution Prevention and Occupational Health and Safety: A Perspective on US Policy.” *Journal of Industrial Medicine* 44 (3): 312-320.

Environmental Protection Agency. 1987. Overview Report on Unfinished Business: A Comparative Assessment of Environmental Problems. Washington, DC: Environmental Protection Agency.

Environmental Protection Agency. 1990. The Pollution Prevention Act of 1990. Washington, DC: Environmental Protection Agency.

Environmental Protection Agency.1996. “Addition of Reporting Elements; Toxic Chemical Release Reporting; Community Right-to-Know; Proposed Rules.” Federal Register 61:191 (October 1, 1996), pp. 51321-51330 (to be codified at 40 CFR Part 372). Available on website: http://www.epa.gov/EPA-TRI/1996/October/Day-01/pr-59DIR/pr-59.txt.html. Accessed January 26, 2012.

Environmental Protection Agency. 1998. Toxics Release Inventory. Washington, DC: Office of Information Analysis and Access.

Environmental Protection Agency Scientific Advisory Board. 1990. Reducing Risk: Setting Priorities and Strategies for Environmental Protection SAB-EC 90-021. September 1990.

Environmental Protection Agency, National Institute for Occupational Safety and Health, and Occupational Safety and Health Administration. 1999. *Common Sense Approaches to Protecting Workers and the Environment Interagency Cooperation Towards Comprehensive Solutions.* Washington, DC: Workshop.

European Commission. 2006. Guidance Document for the Implementation of the European PRTR. European Commission: 139.

Fellegi, Ivan P. and Alan B. Sunter. 1969. “A Theory for Record Linkage.” *Journal of the American Statistical Association* 64 (328): 1183-1210.

Froines, John R., David H. Wegman, and Cornelia A. Dellenbaugh. 1986. “An Approach to the Characterization of Silica Exposures in U.S. Industry.” *American Journal of Industrial Medicine* 10: 345-361.

Froines, John R., S. Baron, David H. Wegman, and S. O'Rourke. 1990. "Characterization of the Airborne Concentrations of Lead in U.S. Industry." *American Journal of Industrial Medicine* 18 (1): 17.

Fung, Archon and Dana O'Rourke. 2000. "Reinventing Environmental Regulation From The Grassroots Up: Explaining and Expanding The Success of The Toxics Release Inventory." *Environmental Management* 25 (2): 115-127.

Gamper-Rabindran, Shanti. 2006. "Did the EPA's Voluntary Industrial Toxics Program Reduce Plants' Emissions? A GIS Analysis of Distributional Impacts and a By-media Analysis of Substitution." *Journal of Environmental Economics and Management* 52 (1): 391-410.

Gamper-Rabindran, Shanti, and Stephen Finger. 2010. "Does Industry Self-Regulation Reduce Pollution? Responsible Care Program in the Chemical Industry." Revised and resubmitted. *Journal of Regulatory Economics.*

Geiser, Kenneth. 1993. "Protecting Reproductive Health and the Environment: Toxics Use Reduction." *Environmental Health Perspectives* 101(Suppl 2): 221–225.

Graham, Mary. 2002. *Democracy by Disclosure: The Rise of Technopopulism.* Washington, DC: Brookings Institution Press.

Graham, Mary and Catherine Miller. 2001. "Disclosure of Toxic Releases in the United States." *Environment* 43 (8): 9-20.

Gray, Wayne B. and Carol A. Jones. 1991. "Longitudinal Patterns of Compliance with OSHA in the Manufacturing Sector." *Journal of Human Resources* 26 (4): 623-653.

Gray, Wayne B. and John T. Scholz. 1993. "Does Regulatory Enforcement Work? A Panel Analysis of OSHA Enforcement." *Law and Society Review* 27 (1): 177-213.

Hamilton, James T. 1999. "Exercising Property Rights to Pollute: Do Cancer Risks and Politics Affect Plant Emission Reductions?" *Journal of Risk and Uncertainty* 18 (2): 105-124.

Hamilton, James T. 2005. *Regulation through Revelation: The Origin, Politics, and Impacts of the Toxics Release Inventory Program*. Cambridge, UK: Cambridge University Press.

Hart, Stuart L. and Gautam Ahuja. 1996. "Does it Pay to be Green? An Empirical Examination of the Relationship Between Emission Reduction and Firm Performance." *Business Strategy and the Environment* 5: 30-37.

Henriques, Irene. 2010. "2010 PRTR and Greening of the North American Economy." Presented at the *Annual North American Pollutant Transfer and Commission for Environmenal Cooperation* November 3-4.

Henriques, Irene and Perry Sadorsky. 2008. "Voluntary Environmental Programs: A Canadian Perspective." *Policy Studies Journal* 36 (1): 143-166.

IFCS-WHO. 2000. Emission inventories (Pollutant Release and Transfer Registers) Third Session of the Intergovernmental Forum on Chemical Safety. Salvador da Bahia, Brazil, 15 – 20 October 2000. Intergovernmental Forum on Chemical Safety/World Health Organization.

King, Andrew and Michael Lenox. 2002. "Exploring the Locus of Profitable Pollution Reduction." *Management Science* 48 (2): 289-299.

Konar, Shameek and Mark A Cohen. 1997. "Information As Regulation: The Effect of Community Right to Know Laws on Toxic Emissions" *Journal of Environmental Economics and Management* 32 (1): 109-124.

Kraft, Michael E., Mark Stephan, and Troy D. Abel. 2011. *Coming Clean: Information Disclosure and Environmental Performance.* MIT Press.

Lavoué, Jérôme, Denis Bégin, and Michel Gérin. 2003. "Technical, Occupational, Health and Environmental Aspects of Metal Degreasing with Aqueous Cleaners." *Annals of Occupational Hygiene* 47 (6): 441-459.

Leigh, J. Paul. 2011. "Economic Burden of Occupational Injury and Illness in the United States" *Milbank Quarterly*. 89 (4): 728-772.

Leigh J. Paul, S. Markowitz, M. Fahs, P. Landrigan. 2000. *Costs of Occupational Injuries and Illnesses*. Michigan: University of Michigan Press.

Lofgren, Don J. 1996. "OSHA Compliance Issues: Targeting Industries and Work Sites for OSHA Health Inspections." *Applied Occupational and Environmental Hygiene.* 11 (5): 448-456.

Lofgren, Don J., Carolyn K. Reeb-Whitaker, and Darrin Adams. 2010. "Surveillance of Washington OSHA Exposure Data to Identify Uncharacterized or Emerging Occupational Health Hazards." *Journal of Occupational and Environmental Hygiene* (7) 7: 375-388.

Lynn, Francis M. and Jack D. Kartez. 1994. "Environmental Democracy in Action: The Toxics Release Inventory. *Environmental Management* 18 (4): 511-21.

Massey, Rachel I. 2011. "Program Assessment at the 20 Year Mark: Experiences of Massachusetts Companies and Communities with the Toxics Use Reduction Act (TURA) Program." *Journal of Cleaner Production* 19 (5): 505–516.

Mendeloff, John M. 1988. *The Dilemma of Toxic Substance Regulation*. Cambridge, MA: MIT Press.

Mendeloff, John M. and Wayne B. Gray. 2005. "Inside the Black Box: How Do OSHA Inspections Lead to Reductions in Workplace Injuries?" *Law and Policy* 27 (2): 219-237.

Natan Jr., Thomas E. 1997. "Estimating Environmental Releases for Facility PRTR Reporting: Introduction and Guide to Method." *The Hampshire Research Institute.* Alexandria, VA.

Natan, Thomas and Catherine Miller. 1998. "Are Toxic Release Inventory Reductions Real?" *Environmental Science and Technology* 32 (15): 368A-374A.

Occupation Safety and Health Agency. 2011. Website on Statistics and Data http://www.osha.gov/oshstats/index.html.

Organisation for Economic Co-Operation and Development. 2005. Framework for Selecting and Applying PRTR Release Estimation Techniques. Paris, OECD Environment.

Porter, Micheal 1991. "American Green Strategy" *Scientific American* 264: 168.

Porter, Michael and Claas van der Linde. 1995. "Towards A New Conception of Environment-Competitiveness Relationship" *Journal of Economic Perspectives* 9: 97-118.

Roelofs, Cora. 2007. "Preventing Hazards at the Source." *American Industrial Hygienists Association Press*. Fairfax, VA.

Roelofs, Cora R., Rafael Moure-Eraso, and Michael J. Ellenbecker. 2000. "Pollution Prevention and the Work Environment: The Massachusetts Experience." *Applied Occupational and Environmental Hygiene* 15 (11): 843-850.

Roelofs, Cora R. and Michael J. Ellenbecker. 2003. "Source Reduction for Prevention of Methylene Chloride Hazards: Cases from Four Industrial Sectors." *Environmental Health* 2 (9): 1-15.

Ruser, John and Richard Butler. 2010. "The Economics of Occupational Safety and Health", *Foundations and Trends in Microeconomics* 5 (5): 301-35.

Scorse, Jason. 2000. "Does Being a "Top 10" Worst Polluter Affect Facility Environmental Releases? Evidence from the U.S. Toxic Release Inventory." ARE Working Paper.

Shadish, William R., Thomas D. Cook, and Donald T. Campbell. 2002. *Experimental and Quasi-Experimental Designs for Generalized Causal Inference*. Boston: Houghton-Mifflin.

Shapiro, Marc D. 2005. "Equity and Information: Information Regulation, Environmental Justice, and Risks from Toxic Chemicals." *Journal of Policy Analysis and Management* 24 (2): 373–398.

Shen, Thomas T. 1998. *Industrial Pollution Prevention.* Berlin, Germany: Springer-Verlag.

Stafford, Sarah. 2002. "The Effect of Punishment on Firm Compliance with Hazardous Waste Regulations." *Journal of Environmental Economics and Management* 44: 290-308.

Thompson, Frank J. and Michael J. Scicchitano. 1985. "State Enforcement of Federal Regulatory Policy: The Lessons of OSHA" *Policy Studies Journal* 13(3): 591–598.

Tietenberg, Thomas. 1998. "Disclosure Strategies for Pollution Control" *Environmental and Resource Economics* 11 (3-4): 587-602

United Nations Institute for Training and Research. 1998. "Guidance for Facilities on PRTR Data Estimation and Reporting." UNITAR Series of PRTR Technical Support Materials (2).

Weil, David. 1996. "If OSHA is So Bad, Why is Compliance So Good?" *Rand Journal of Economics* 27 (3): 618-640.

Weil, David, Archon Fung, Mary Graham, and Elena Fagotto. 2006. "The Effectiveness of Regulatory Disclosure Policies." *Journal of Policy Analysis and Management* 25 (1): 155–181.

Weil, David. 2004. "Individual Rights and Collective Agents: The Role of New Workplace Institutions in the Regulation of Labor Markets." In Richard Freeman, Larry Mishel, and Joni Hersch, eds., *Emerging Labor Market Institutions for the 21st Century*. Chicago, IL: University of Chicago Press: 13-44.

Wooldridge, Jeffrey M. 2010. *Econometric Analysis of Cross Section and Panel Data, 2nd Edition.* MIT Press.

Wilson, Michael P., Daniel A. Chia and Bryan C. Ehlers. 2006. Green Chemistry in California: A Framework for Leadership in Chemicals Policy and Innovation. California Policy Research Center, University of California.

Yassin, Abdiaziz, Francis Yebesi, and Rex Tingle, 2005. "Occupational Exposure to Crystalline Silica Dust in the United States 1988-2003." *Environmental Health Perspectives* 113 (3): 255-260.

Table 1: Summary Statistics

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	All inspections		Inspections before the TRI years	Inspections during the TRI years		Inspections with ≥ 1 exceedance	Inspections with no exceedance	
	Mean	Std. Dev.			Diff			Diff
No of inspections	1,644	-	340	1,304		343	1,301	
No of unique plants that are inspected	1,333	-	310	1,098		291	1,127	
Test results per inspection	16.98	30.37	18.22	16.65		31.81	13.08	***
No of unique chemicals	242	-	155	222		146	225	
Average counts of exceedances per inspection	0.723	2.256	0.953	0.663	**	3.463	-	***
The likelihood of at least one exceedance per inspection	0.209	0.406	0.279	0.190	***	-	-	
The maximum (test result / PEL) averaged across inspections	0.525	2.686	0.553	0.518		2.279	0.063	***
The likelihood of at least one exceedance per test result	0.045	0.221	0.057	0.042	***	0.115	-	***
The (test result / PEL) averaged across test results	0.417	4.809	0.515	0.390	***	0.993	0.045	***
Inspection history at the inspected plant								
# inspections in the previous year	0.269	0.705	0.359	0.245	***	0.338	0.251	**
# inspections in the previous 5 years	1.045	1.803	1.418	0.948	***	1.213	1.001	*
# violations in the previous year	1.313	5.192	1.268	1.324		1.397	1.291	
# violations in the previous 5 years	5.038	23.713	4.241	5.246		5.306	4.968	
Inspection Type								
Referral inspection	0.200	0.400	0.174	0.207		0.248	0.188	**
Follow-up inspection	0.062	0.241	0.082	0.057	*	0.099	0.052	***
Accident inspection	0.017	0.129	0.021	0.016		0.017	0.017	
Complaint inspection	0.525	0.500	0.426	0.551	***	0.437	0.548	***
Other inspection	0.014	0.117	0.012	0.015		0.012	0.015	
Programmed inspection	0.444	0.497	0.541	0.419	***	0.534	0.420	
Industry emissions								
†Average industry emissions (1988-1990)	8.396	1.323	8.517	8.364	*	8.563	8.352	***
ǂChange in industry emissions (1988-1990)	-0.262	0.181	-0.230	-0.270	***	-0.246	-0.266	*
ǂChange in industry emissions (1988-1993)	-0.116	0.108	-0.112	-0.117		-0.130	-0.113	***
Plant-level emissions for the sample of 426 inspections in 330 plants								
Log mean plant emissions 1988-1990	8.473	2.587	8.844	8.365		8.322	8.519	
Average yearly change in plant emissions 1988-1990	-0.063	0.597	-0.077	-0.060		-0.125	-0.045	
Average yearly change in plant emissions 1988-1993	-0.068	0.384	-0.010	-0.083		-0.019	-0.083	

†Average industry emissions denotes the log of industry emissions averaged in the period 1988-1990. ǂChange in industry emissions between t1 and t2 denotes [Log (emissions in t2) minus Log (emissions in t1)]/(t2-t1). The Diff columns indicate that the relevant means are statistically different at the ***1%, **5% and * 10%.

Table 2: Plant-level worker exposures in the period before and after the TRI program implementation

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
	Model: Negative Binomial					Model: OLS			
	Dependent variable: Counts of exceedance of the legal exposure limits per inspection					Dependent variable: Log (max { ratio of the test result to the legal exposure limit} +1)			
Dummy for TRI years	-0.386*	-0.382**	-0.405*	-0.353		-0.100*	-0.110*	-0.092	
	(0.217)	(0.170)	(0.217)	(0.215)		(0.060)	(0.060)	(0.061)	
Dummy for 1987-1990					-0.320				-0.072
					(0.222)				(0.062)
Dummy for post-1990					-0.757**				-0.192**
					(0.312)				(0.080)
Time trend	0.0003		0.0005	-0.001	0.022	-0.003	-0.003	-0.005	0.002
	(0.012)		(0.013)	(0.012)	(0.018)	(0.003)	(0.003)	(0.003)	(0.005)
Log (# test results per inspection)	0.786***	0.786***	0.771***	0.746***	0.781***	0.204***	0.202***	0.207***	0.202***
	(0.064)	(0.064)	(0.065)	(0.062)	(0.064)	(0.017)	(0.017)	(0.017)	(0.017)
SIC-4 level emissions in 1988				0.266***				0.032**	
				(0.049)				(0.015)	
# inspections in t-1			-0.045	-0.020			0.022	0.033	
			(0.154)	(0.157)			(0.040)	(0.040)	
# inspections in t-2 to t-5			-0.040	-0.038			-0.033	-0.023	
			(0.073)	(0.074)			(0.020)	(0.020)	
Log (# violations in t-1)			-0.019	-0.064			-0.039	-0.049	
			(0.145)	(0.149)			(0.038)	(0.038)	
Log (# violations in t-2 to t-5)			0.155	0.155			0.075***	0.068**	
			(0.094)	(0.095)			(0.027)	(0.027)	
Inspection type: Referral	0.280	0.279	0.285	0.549**	0.270	0.176***	0.172***	0.188***	0.173***
	(0.232)	(0.229)	(0.232)	(0.228)	(0.232)	(0.063)	(0.063)	(0.063)	(0.063)
Inspection type: Followup	0.307	0.306	0.234	0.574*	0.327	0.090	0.088	0.193*	0.088
	(0.310)	(0.309)	(0.352)	(0.348)	(0.309)	(0.090)	(0.100)	(0.100)	(0.090)
Inspection type: Accidents	0.075	0.073	0.099	0.398	0.041	-0.034	-0.035	0.058	-0.033
	(0.621)	(0.617)	(0.618)	(0.590)	(0.624)	(0.153)	(0.153)	(0.154)	(0.153)
Inspection type: Complaint	-0.100	-0.101	-0.114	0.057	-0.106	-0.032	-0.037	-0.016	-0.036
	(0.202)	(0.200)	(0.203)	(0.200)	(0.202)	(0.054)	(0.054)	(0.054)	(0.054)
Inspection type: Other	0.290	0.291	0.322	0.953	0.286	0.121	0.127	0.215	0.119
	(0.587)	(0.587)	(0.585)	(0.585)	(0.588)	(0.171)	(0.171)	(0.172)	(0.171)
State fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
SIC-4 industry fixed effect	Y	Y	Y	N	Y	Y	Y	N	Y
log (dispersion parameter)	1.381***	1.381***	1.367***	1.501***	1.375***				
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)				
R-sqr						0.184	0.189	0.139	0.185

Obs. = 1,644 inspections. The TRI program was implemented in 1987. In the pre-program period (1984-6), 340 inspections took place in 310 unique plants. In the post-program period, 1,098 inspections took place in 1,304 unique plants. Statistically significant at the ***1%, **5% and *10%.

Table 3: Negative binomial model: TRI program effects on plant-level worker exposures measured as the counts of exceedances of the legal exposure limits per inspection

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
	Average Industry Emissions (1988-1990)				Change in Industry Emissions in 1988-1990				Change in Industry Emissions in 1988-1993			
TRI year dummy	-0.379*	-0.399*	-0.247	-0.27	-0.360	-0.380*	-0.244	-0.267	-0.377*	-0.395*	-0.295	-0.313
	(0.219)	(0.218)	(0.218)	(0.219)	(0.225)	(0.225)	(0.222)	(0.222)	(0.218)	(0.218)	(0.219)	(0.219)
TRI year dummy x	-0.036	-0.033	-0.094	-0.086								
Average industry emissions	(0.130)	(0.130)	(0.126)	(0.126)								
TRI year dummy x					-0.448	-0.450	-0.477	-0.446	1.061	1.332	1.148	1.426
Change in industry emissions					(1.067)	(1.067)	(1.029)	(1.030)	(1.616)	(1.614)	(1.463)	(1.477)
Industry pollution in 1988							0.130**	0.140**			0.150***	0.157***
							(0.061)	(0.061)			(0.057)	(0.057)
Average industry emissions (1988-90)			0.205*	0.204*								
			(0.112)	(0.112)								
Change in industry emissions							0.405	0.311			-2.029	-2.202*
							(0.957)	(0.961)			(1.302)	(1.311)
Time trend	0.0003	0.0005	-0.008	-0.008	0.0001	0.0003	-0.009	-0.008	0.00005	0.0002	-0.006	-0.005
	(0.012)	(0.013)	(0.012)	(0.012)	(0.012)	(0.013)	(0.012)	(0.012)	(0.012)	(0.013)	(0.012)	(0.012)
Log (# test results per inspection)	0.785***	0.770***	0.770***	0.760***	0.784***	0.769***	0.771***	0.763***	0.789***	0.774***	0.776***	0.766***
	(0.064)	(0.065)	(0.063)	(0.063)	(0.064)	(0.065)	(0.063)	(0.063)	(0.065)	(0.065)	(0.063)	(0.063)
# inspections in t-1		-0.046		0.033		-0.049		0.033		-0.053		0.010
		(0.154)		(0.160)		(0.154)		(0.160)		(0.154)		(0.160)
# inspections in t-2 to t-5		-0.039		-0.028		-0.039		-0.031		-0.040		-0.026
		(0.073)		(0.074)		(0.073)		(0.074)		(0.074)		(0.075)
Log (# violations in t-1)		-0.018		-0.100		-0.016		-0.101		-0.015		-0.088
		(0.145)		(0.151)		(0.145)		(0.151)		(0.146)		(0.152)
Log (# violations in t-2 to t-5)		0.154		0.131		0.154		0.136		0.160*		0.137
		(0.094)		(0.096)		(0.094)		(0.096)		(0.095)		(0.096)
Inspections: Referral	0.282	0.286	0.538**	0.560**	0.290	0.295	0.546**	0.564**	0.294	0.303	0.572**	0.601**
	(0.232)	(0.231)	(0.232)	(0.232)	(0.233)	(0.232)	(0.236)	(0.236)	(0.233)	(0.233)	(0.233)	(0.234)
Inspections: Followup	0.309	0.236	0.681**	0.669*	0.302	0.227	0.680**	0.670*	0.310	0.235	0.621*	0.607*
	(0.310)	(0.352)	(0.315)	(0.352)	(0.310)	(0.352)	(0.316)	(0.353)	(0.311)	(0.353)	(0.318)	(0.356)
State fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry fixed effect	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N
Log (dispersion parameter)	1.381***	1.367***	1.577***	1.566***	1.379***	1.365***	1.579***	1.568***	1.382***	1.367***	1.570***	1.559***
	(0.090)	(0.091)	(0.086)	(0.086)	(0.090)	(0.091)	(0.086)	(0.086)	(0.090)	(0.091)	(0.086)	(0.086)

Obs. = 1,644 inspections. The coefficients on "Dummy for TRI years x Average industry emissions" and "Dummy for TRI years x Change in industry emissions" capture the changes in worker exposures in industries with larger emissions or larger changes in emissions. Three dummy variables are included for accident, complaint and other inspections, respectively. Programmed inspections are the omitted category. Statistically significant at the ***1%, **5% and *10%, respectively.

Table 4: OLS model: TRI program effects on plant-level worker exposures defined as the log (max { test result to legal exposure limits} + 1) for a given inspection

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
	Average industry emissions (1988-1990)				Change in emissions 1988-1990				Change in emissions 1988-1993			
Dummy for TRI years	-0.098	-0.109*	-0.080	-0.089	-0.092	-0.103*	-0.074	-0.084	-0.099*	-0.109*	-0.088	-0.096
	(0.060)	(0.060)	(0.061)	(0.061)	(0.061)	(0.061)	(0.062)	(0.062)	(0.060)	(0.060)	(0.061)	(0.061)
Time trend	-0.003	-0.003	-0.005*	-0.005	-0.003	-0.003	-0.005*	-0.005	-0.003	-0.003	-0.005	-0.005
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Dummy for TRI years x	-0.024	-0.023	-0.032	-0.031								
Average industry emissions	(0.036)	(0.036)	(0.036)	(0.036)								
Dummy for TRI years x					-0.200	-0.190	-0.217	-0.206	0.189	0.249	0.470	0.503
Change in industry emissions					(0.296)	(0.296)	(0.293)	(0.293)	(0.450)	(0.450)	(0.445)	(0.445)
Industry emissions in 1988							0.028*	0.030*			0.034**	0.034**
							(0.016)	(0.016)			(0.015)	(0.015)
Average industry emissions			0.059*	0.059*								
			(0.033)	(0.032)								
Change in industry emissions							0.245	0.214			-0.729*	-0.722*
							(0.277)	(0.277)			(0.402)	(0.402)
Log (# test results per inspection	0.203***	0.202***	0.207***	0.205***	0.203***	0.202***	0.206***	0.205***	0.204***	0.202***	0.207***	0.206***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
# inspections in t-1		0.022		0.032		0.022		0.032		0.022		0.030
		(0.040)		(0.040)		(0.040)		(0.041)		(0.040)		(0.040)
# inspections in t-2 to t-5		-0.032		-0.022		-0.032		-0.022		-0.033		-0.023
		(0.020)		(0.020)		(0.020)		(0.020)		(0.020)		(0.020)
Log (# violations in t-1)		-0.039		-0.049		-0.038		-0.047		-0.039		-0.048
		(0.038)		(0.038)		(0.038)		(0.038)		(0.038)		(0.038)
Log (# violations in t-2 to t-5)		0.075***		0.067**		0.075***		0.067**		0.076***		0.067**
		(0.027)		(0.027)		(0.027)		(0.027)		(0.027)		(0.027)
Inspections: Referral	0.176***	0.172***	0.193***	0.190***	0.178***	0.173***	0.196***	0.192***	0.176***	0.172***	0.191***	0.188***
	(0.063)	(0.063)	(0.063)	(0.064)	(0.063)	(0.063)	(0.064)	(0.064)	(0.063)	(0.063)	(0.063)	(0.063)
Inspections: Followup	0.089	0.088	0.196**	0.193*	0.089	0.087	0.198**	0.193*	0.090	0.089	0.186**	0.186*
	(0.090)	(0.100)	(0.090)	(0.100)	(0.090)	(0.100)	(0.090)	(0.100)	(0.090)	(0.100)	(0.090)	(0.100)
State fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry fixed effect	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N
R-squared	0.184	0.189	0.135	0.14	0.184	0.189	0.134	0.139	0.184	0.189	0.136	0.141

Obs. = 1,644 inspections. The coefficients on "Dummy for TRI years x Average industry emissions" and "Dummy for TRI years x Change in industry emissions" capture the changes in worker exposure in industries with larger emissions or larger changes in emissions. Three dummies are included for accident, complaint and other inspections, respectively. Programmed inspections are the omitted category. Statistically significant at the ***1%, **5% and *10%, respectively.

Table 5: TRI program effects on plant-level worker exposures in plants with larger emissions or larger changes in emissions relative to other plants

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
	Model: Negative Binomial						Model: OLS					
	Dependent variable: Counts of Exceedance Per Inspection						Dep. var.: Log (max {ratio of test result to PEL} + 1)					
	Average Plant-level Emissions (1988-90)		Change in Plant-level Emissions 1988 to 1990		Change in Plant-level Emissions 1988 to 1993		Average Plant-level Emissions (1988-90)		Change in Plant-level Emissions 1988 to 1990		Change in Plant-level Emissions 1988 and 1993	
Dummy for TRI years	0.054	0.032	0.231	0.358	0.101	0.081	0.125	0.031	0.175	0.13	0.086	0.039
	(0.360)	(0.384)	(0.374)	(0.425)	(0.363)	(0.397)	(0.132)	(0.133)	(0.145)	(0.146)	(0.136)	(0.136)
Dummy for TRI years	-0.105	-0.104					-0.021	-0.008				
x Plant emissions	(0.117)	(0.131)					(0.040)	(0.041)				
Dummy for TRI years			0.545	0.666	0.194	0.200			0.229	0.271	0.024	-0.001
x Change in plant emissions			(0.453)	(0.543)	(0.647)	(0.718)			(0.181)	(0.185)	(0.246)	(0.246)
Plant emissions	0.088	-0.015					0.007	-0.027				
	(0.105)	(0.117)					(0.036)	(0.036)				
Change in plant emissions			-0.521	-0.666	0.691	0.293			-0.185	-0.252	0.288	0.206
			(0.360)	(0.436)	(0.496)	(0.565)			(0.156)	(0.160)	(0.200)	(0.204)
Time trend	-0.073***	-0.084***	-0.078***	-0.103***	-0.081***	-0.097***	-0.029***	-0.026***	-0.033***	-0.034***	-0.030***	-0.030***
	(0.024)	(0.024)	(0.026)	(0.027)	(0.024)	(0.025)	(0.008)	(0.008)	(0.009)	(0.009)	(0.008)	(0.008)
Log (# test results per inspection)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Dummy for types of accidents	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Inspection variables	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Violation variables	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
SIC-4 industry-level pollution	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
Log dispersion parameter	0.601***	1.218***	0.264	1.087***	0.450**	1.153***						
	(0.210)	(0.169)	(0.267)	(0.196)	(0.229)	(0.178)						
R-sqr							0.277	0.165	0.319	0.214	0.296	0.185
No obs.	436	436	347	347	412	412	436	436	347	347	412	412

Notes: Our limited resources allow us to link plant-level exposure with plant-level emissions for a subset of plants. Therefore, these regressions analyze a smaller sample of plants than do our main regressions. The coefficient on "Dummy for TRI years x Plant emissions" and "Dummy for TRI years x Change in plant emissions" capture the effect on the TRI program on plants with larger emissions or larger changes in emissions relative to other plants. Statistically significant at the ***1%, **5% and *10% level, respectively.