Complements or Substitutes: Impact of Environmental Regulations on Workplace Exposures to Toxic Chemicals[1]

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1. Introduction

Right to Know Pollution Inventories, aimed at reducing pollution from manufacturing plants, are prevalent worldwide. The US Toxic Release Inventory program in the United States is the most prominent example, and this program has been emulated in the EU, Japan, Australia, Mexico and Indonesia. Plants are mandated to self-report their pollution released into the environment to environmental protection agencies which then publicize the information to the public. The justification for these disclosure programs is that members of the public, activists, consumers and investors can be citizen-regulators who pressure plants to reduce their pollution into the environment (Hamilton, 2005).

Our study is among the first with a large number of observations that test plants' responses to policies that may affect workers' exposure to pollutants in the manufacturing sector. Specifically, we ask if plants respond to the TRI disclosure program, which publicizes plants' *release of pollutants into the environment,* by reducing or, perversely, by increasing their workers' exposure to toxic pollutants within the plant. We examine Occupational Safety and Health Agency's (OSHA) occupational exposure database, which is the largest occupational exposure database worldwide (Yassin, Yebesi, and Tingle, 2005). Our use of actual worker exposure data, detected personal sampling device worn by workers and analyzed by the regulator, is a major improvement over studies that are forced to rely on plants' self-reported pollution data.[2] We examine the exposure of 6,421 workers to 238 different substances in the chemical manufacturing sector between 1984 and 2009.

Results that plants *reduce* workers' exposure to pollution would provide the first documentation of an important co-benefit from the TRI disclosure policy. This co-benefit would suggest the disclosure program yields greater benefits from the TRI program than previously estimated, and strengthen the argument against roll-backs to the TRI program.[3] Documentation of co-benefits have similarly led to far more favorable benefit-cost ratios in other important environmental policies (Muller *et al.,* 2009).[4] Alternative results that plants *raise* workers exposure to pollutant, a perverse outcome which has been documented in several case studies (see section 2), would call for better coordination between policies reducing pollutants inside and outside plants. The coordination failure in two policies can result in this unintended perverse

[2] Numerous studies including our own on plant-level pollution released into the environment use the self-reported TRI data (Konar and Cohen, 2001; Hamilton, 2005; Greenstone, 2003). Unfortunately, large-N sampling data for these emissions are unavailable.

[3] While the justification for disclosure programs is that it is more cost-effective than traditional regulation at reducing pollution, the TRI programs costs $x per year to regulators and $x per year to reporting industries (citation). Although the 2009 bill, signed President Obama, reversed the 2005 rollback to the TRI program, budgetary constraints may lead to renewed pressure to roll back the TRI program (citation).

[4] Muller *et al.* (2009) estimate that on average, the co-benefits from co-pollutant reductions associated with a nationwide cap on carbon emissions will be on the same order of magnitude as the benefits from carbon emissions reduction itself.

outcome. First, while the implementation of the TRI pressured factories reduce their pollution into the environment, no concurrent policies were implemented to enhance the pressure on plants to reduce the exposure of workers who remained poorly informed about their risks. Second, the Occupational Safety and Health Agency and the Environmental Protection Agency, which regulate pollutants inside and outside the factories, respectively, have failed to coordinate policies(Colten and Skinner, 1996; Armenti, 2003; Armenti, 2004; Robert and Toscano, 2007).

Whether plants have raised or reduced workers' exposure to pollutants within the plant is an important policy question. First, exposure to pollutants in the workplace is the main exposure pathway for many pollutants. The pollutant exposure limits within the plant are often several times the limits permitted for ambient exposures (citation). OSHA has been criticized for its failure to implement stricter exposure limits despite health evidence (citation). Occupational exposures to chemical substances can lead to acute exposures and chronic diseases (Lofgren, 2010). Second, firms are likely to underinvest in reducing workers exposure to pollutants. The long latency between exposure to pollutant and the presentation of symptoms and the difficulty for workers to prove cause and effect in cases of adverse exposure mean that plants can externalize these costs to workers (citation).

We capture plants responses to the Toxic Release Inventory by comparing workers exposure to pollutants before and after the implementation of the TRI program in 1987. Our data on worker exposure is from the OSHA exposure database which was made publicly available only after a court decision in 2007. [5] Therefore, our analysis of the OSHA database captures plants' responses to the TRI program.

2. Plants' emissions into the environment and worker exposure

We use the term emissions to designate *emissions into the environment*.[6] Several studies document a downward trend on TRI emissions since the implementation of the TRI program (Hendrikson, x). The Toxic Release Inventory, with the first reporting year of 1987, has been credited for plant-level reductions in emissions into the environment (Hamilton, 2005).

Studies that argue that plants do respond to the TRI program by reducing their emissions have taken three approaches. The first and most direct study, Bui (2005) examine TRI emissions in petroleum refineries. She finds that despite increases in the use of inputs that contribute to TRI emissions, after the implementation of the TRI program, these refineries *reduced* their TRI emissions.[7] The second set of studies argue that that community pressure on plants to reduce

[5] Even today, the identities of plants and their workers' exposures are not provided in an accessible format to the public. Public knowledge and access to the exposure database is minimal, in contrast to public knowledge of and access to TRI information.
[6] After year t, the TRI also records pollutants that are sent to recyclers and off-site transfers for treatment. Part of these emissions would not enter the environment.
[7] Bui (2005) notes that while the TRI program contributed to TRI reductions, regulatory policies on criteria air pollutants contributed to TRI reductions.

their pollution in the mechanism by which the TRI reduces pollution; and these studies then show that whiter, richer, and politically active communities, in which the community exerts stronger pressure on plants to reduce pollution, show greater declines in TRI pollution (Hamilton, x; Shapiro, x). In the third approach, Scorse and Shenkler (in progress) argue that plants are sensitive to their ranking as top polluters in the TRI in that they are more reluctant to raise their TRI emissions while they are ranked as top polluters. However, on losing this designation for exogenous reasons, plants raise their TRI emissions.[8]

Plants can reduce their pollution into the environment using five strategies that are not mutually exclusive, which can either *raise, reduce or leave unchanged* workers' exposure. First, plants can install end-of-pipe control technologies on waste streams, such as scrubbers. This approach is not likely to affect workers exposure. Second, plants may simply vent a greater amount of their waste streams within the plant and thus increase workers' exposure (Robson and Toscano, 2007). Third, plants can alter their production processes to reduce their overall use of chemicals. Reducing the overall use of chemical can result in reduced workers exposure. Fourth, plants can change their composition of chemicals from those targeted by the regulation to other chemicals to other chemicals. The switch to alternative chemicals may have the unintended consequence of worsening workers' exposure (Wilson et al, 2007). Fifth, plants reduce their output and thus the pollution associated with production. If production entails complementary emissions of pollution outside the plant and workers exposure inside the plant, this output reduction can translate into reduced workers' exposure. Given that theory is ambiguous on the net impact of pollution reduction strategies on workers' pollution, an empirical study is crucial.

2.1 Reducing pollution to the environment and raising workers exposure to pollution

Case studies provide examples in which plants reduction of pollution into the environment has increased workers' exposure to pollutants within the plant. First, plants switch away from chemicals that are targeted by regulations on pollutants released into the environment, and switch to chemicals which worsen workers' exposures. In one example, to improve air quality standards, the California Air Resources Board decided in 1997 to phase out chlorinated solvents used in the auto repair industry; unfortunately, that policy inadvertently contributed to the overexposure of workers to the substitute chemical hexane causing peripheral neuropathy (Wilson et al, 2007). Sivin (2002) provides an additional case study that the alteration to the production method in order to eliminate the release of pollutants into the environment

[8] The authors exploit the administrative change in the program which expanded the industries that had to report to the TRI and therefore brought large polluters into the program. With the entry of top-10 polluters from the new reporting industries in some states, several plants in the old reporting industries that had previously been designated as the top 10 polluter lost their designation and subsequently raised their TRI emissions.

inadvertently led to an increase in workers' exposure. Specifically, the elimination of trichloroethylene (TCE) degreaser in a factory that manufactured air conditioners resulted in an increase of exposure severity for a subset of workers to naphtha (Sivin, 2002).

Second, plants have responded to stack and effluent limits by increasing the fraction of a toxic pollutant that remains in the workplace (Robson and Toscano, 2007). These cases are documented in an OSHA-EPA conference. (This conference volume has been requested).

The lack of coordination between environmental and worker exposure policies can lead to plants' meeting stack or effluent limits while worsening workers exposure. The TRI program provides the added pressure on plants to focus on reducing emissions into the environment. During our study period, regulations aimed at reducing emissions to the environment do not account for workers' exposure to hazards.[9] As of 2004, "there was no formal consideration of the overlap between environmental and occupational exposures (outside versus inside the plant) and the potential of pollution prevention strategies for addressing both" (Armenti, 2004). This disconnection stems from the distinct regulatory framework separating the EPA and OSHA and the agencies' lack of coordination (Armenti et al., 2003). Adam Finkel, Director of Health Standards Programs at OSHA between 1998 and 2003, notes that efforts to reduce stack or effluent emissions often do not account for worker exposure. Gillen (2000), from the EPA Office of Pollution Prevention and Toxics, reports that as of 2000, "pollution prevention strategies have not typically included the additional step of coordinating on worker health issues."

Our study focuses on plants' degree of substitution between emissions inside the plant and emissions into the environment. Related studies have documented substitution between different media into which plants can release their pollution. In her study of chlorinated solvents, Sigman (x) documents increases the costs of disposal of hazardous waste has led to increases in emissions into the air.

2.2 Co-benefits from reducing the target pollutant into the environment

Studies on co-benefits from policies aimed at pollution reduction have focused primarily on the reduction of co-pollutant into the environment. Several empirical studies have documented that policies that target the reduction of specific pollutants into the environment have resulted in the reduction of non-target pollutants. For example, Bui (2005) document that being in a county that is subject to more stringent *formal* air pollution regulation on criteria air pollutants leads to lower levels of *toxic air* pollution intensity. Bui (2005) also reports that higher pollution abatement expenditures for the control of non-toxic air pollution leads to lower

[9] OSHA's and EPA's interagency committees coordinate their interactions in industrial accidents such as their activities under EPA's Risk Management Plant and OSHA's Process Safety Management.

toxic pollution intensity.[10] Mazurek (x) reports that reductions of greenhouse gas emissions can result in reductions in co-pollutants which yield local health benefits.

Previous studies on the impact of policies on worker exposure.

Our study is among the first studies to analyze how public policies have affected workers' exposure to pollutants in the manufacturing sectors using a large sample from the OSHA exposure database. To date, only a handful of OSHA researchers analyzed the national-level exposure database for general trends in worker exposure and to identify the most hazardous industries for specific pollutants. None of these studies tied the economic characteristics of the plants to workers exposure. Froines, et al. (1986), one of the first studies to use the exposure data, identify hazardous industries with overexposures to airborne crystalline silica dust. Froines et al. (1990) examined worker exposures to airborne lead. Yassin, Yebesi, and Tingle (2005) examine workplace exposures to crystalline silica dust, updating previous studies and estimating trends.

Data

The OSHA exposure dataset is part of the OSHA Integrated Management Information System (IMIS) database which documents information collected during the inspection process. OSHA undertakes two types of inspections: first, programmed inspections, which are randomly assigned within the industry-state cells; and second, non-programmed inspections, which are undertaken in response to an accident, a complaint or referral, or as a follow-up to a previous inspection. We include exposures information collected during both types of inspections. Comprehensive worker exposure data is only available for the 29 states in which OSHA is operated at the federal-level, as opposed to OSHA-approved state plans.

We focus on personal samples which measure exposure of an individual worker who wears a sampling device. This is the most direct measure of exposure of employees to hazardous chemicals. Exposure data includes chemical substances tested, sample types, and sample results. Samples may be recorded as 8-hour time weighted averages (TWA), 15-minute short-term exposures (STEL), or single sample ceiling results. Other information in our analysis from the IMIS inspection data includes plant characteristics such as the four-digit SIC code of the facility, company, union status, and address. The date and reason for inspection are also reported.

We also use TRI data from 1988 until 2001 from the TRI. This data was used in Gamper-Rabindran and Finger (2011), and linked to OSHA inspections in Finger and Gamper-Rabindran

[10] Bui(2005) argues that "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 should not include expenditures that relate to the TRI"

(2011). Our emissions data comprise chemical manufacturing plants (SIC-28) which are required both to report their pollution to the TRI and report their number of employees to D&B. The self-reported TRI data is one of the few comprehensive sources of pollution data and it has been widely used (Konar and Cohen, 2001; Hamilton, 2005; Greenstone, 2003). Emissions data are from the TRI. Pollutants are restricted to those chemicals reportable since 1987 to the TRI. The chemical-specific toxicity-weights are from the Risk Screening Environmental Indicators model (EPA, 2009).

We used industry (SIC-4) averages from 1988-2001 as a static measure of the degree of industry emissions. We also calculate the average annual changes in industry emissions for both the first 5 years of the TRI and 10 years of the program to capture differences in industry responses to TRI.

There a number of limitations to our data. First, although the OSHA data is the most comprehensive data source for employee exposures to toxic chemicals, there are only 300 facilities in the sample that have multiple chemical exposure inspections over the 25 year period. Only 77 of these facilities have inspections in both the pre-TRI and post-TRI years. This makes it difficult to control for unobserved facility characteristics. Along the same lines, we only have our emissions data comes from the TRI, meaning we do not have a measure of pre-program emissions. Therefore we must make assumptions as to how facilities in different industries will react to the program with respect to their emissions. Lastly, to date we have only matched facilities' inspection data to emissions data for inspections that occur from 1988-2001. This limits the number of facility-years in which we have both types of data.

Method

We include all inspections that occur at chemical manufacturing plants (SIC-28) between 1984 and 2009. Our data encompasses 1,576 inspections, and 6,421 total samples. Individual samples are tested for multiple substances, and we have 15,801 substance tests, covering 238 different substances[11]. These tests include 35,340 individual sample results, some of which are used to calculate time-weighted averages.

We compare sample results to the associated permissible limits (PELs). PELs provide us with a baseline against which to measure exposures. PEL exceedances also allow us aggregate samples from different chemical substances. While PELs are not necessarily meant to provide the boundary between safe and unsafe levels of exposures, and indeed PEL have been criticized as inadequate (citation), they provide an established benchmark based on national consensus standards (OSHA, 2011).

We estimate probit models of the probability that an inspection leads to at least one PEL exceedance. Over 60% of inspections with PEL violations have only one or two sample-

[11] Currently, we are excluding airborne silica measurements due to complications in calculating PELs.

substance violations. We have also estimated tobit models of the number of exceedances and our results are qualitatively similar.

Estimation strategy

Our observations are plant-level inspections in year j. Our measure for workers' adverse exposure to pollution is the presence of at least one PEL exceedance during an inspection. Our analysis compares the probability of at least one PEL exceedance at during inspections at plants before and after the TRI program, controlling for other observed factors that influence PEL exceedances. The result of decreased probability of at least one PEL exceedance during inspections would indicate that plants responded to the TRI program by reducing workers' exposure to pollutants within the plant. The converse result would indicate that plants worsened workers' exposure to pollutants within the plant.

Identification assumptions

Our first hypothesis relies on a first difference, i.e., a comparison between the period before and after the TRI program implementation to identify the program effect. To test this hypothesis, our study makes the assumption that no other events other than the TRI program implementation in 1987 affected the change in the probability at least one PEL exceedance before and after 1987. We acknowledge that the limitation in this first difference strategy.

Our second and third hypotheses are able to rely on the difference-in-difference approach, which is more robust. These hypotheses test if the TRI lead to larger declines in the probability of exceedance in more polluting industries and in industries that experience greater declines in TRI emissions, respectively. We compare the changes in the probability of exceedances in two sets of plants; and we make the plausible assumption that these two sets of plants would have similar changes, if any, in their probability of exceedance before and after 1987, and that any differences in the changes between these two sets of plants captures the TRI differential effect.

We compare the probability of at least one PEL exceedance at plants inspected before the TRI programs and at plants inspected after the TRI program. [12] We recognize that OSHA targets non-programmed inspections based on unobservables (or in a similar vein, complaint or referral inspections occur at selected plants for unobserved reasons) and a study that focuses only the set of plants inspected can potentially suffer from sample selection. However, our strategy of comparing plants inspected before and after the TRI is less prone to the criticism of sample selection. We make the assumption that the process of targeting non-programmed inspections is similar in these two time periods. In other words, the sets of plants that are inspected before and after the TRI programs are similar enough that we can simply compare the exceedance at plants

[12] We cannot restrict our comparison to plants that are inspected both before and after the TRI program because of the small sample size. Morever, that estimation strategy may find it difficult to distinguish the effect of the TRI from the effect of OSHA's prior inspection on the probability of exceedance.

inspected before the TRI program and the exceedance at plants inspected after the TRI program. We assume that the TRI program (or a third factor related to exceedances) did not cause a change in the composition of plants that are inspected, which would have affected the exceedances.

To our knowledge, OSHA, in determining their non-programmed inspections did not use the information from the TRI program to re-prioritize their inspections (citation). The TRI data in the early years of the program were not in assessable formats (Hamilton, 2005) and was made available only two years after the reporting year. Moreover, if OSHA had shifted their inspections towards plants that had greater TRI pollution and greater TRI pollution is correlated with greater likelihood of exceedances (as seen in section X), the OSHA shift would bias in our study towards finding that the TRI program contributed to a worsening of workers' exposures. Implying that the bias would work against our actual results that TRI improves workers' exposure. In the absence of this potential bias, our study would have found even stronger effects of TRI in improving workers' exposure.

Covariates

We control for the types of inspections. We control for SIC-4 specific characteristics using SIC-4 dummies. State-level dummies are also serve as control variables.

To test our hypotheses 2 and 3, we define two variables, respectively. The first variable is the industry pollution which is the average plant level pollution in a given SIC-4. Plant level pollution is the log of the total pounds of emissions of 189 toxic TRI chemicals into the air. This variable captures an industry's reliance on pollution intensive technologies. This time-invariant SIC-4 specific measure serves as a baseline measure of the industry's pollution both before and after the TRI program implementation. We calculate this variable from on a larger sample of chemical manufacturing plants for the years 1988 to 2001 (See Gamper- Rabindran and Finger, 2010). The second variable is the change in TRI emissions in the SIC-4. We measure this variable as the change in the first five years of the TRI operation (between 1988 and 1993) or during the first ten years of the TRI operation (between 1988 and 1998).[13] This variable captures the industry's response to the program.

To test hypotheses 3 and 4, we create corresponding variables at the facility-level. Again, because we do not have emissions data for 1984-1987 or for 2002-2009, we create a facility average pollution to serve as a baseline over the entire period measuring a facility's reliance on pollution intensive production processes. We then create two variables calculating the facility's change in pollution in the five and ten years following the creation of TRI to capture the facility's response to the program with regards to emissions.

Results

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[13] We do not use the 1987 TRI data because it is considered unreliable (Levinson, x).

Hypothesis 1: the TRI disclosure policies improved/worsened the probability of detecting at least one PEL exceedance.

Our sample consists of 1496 inspections between 1984 and 2009. We examine the impact of the TRI disclosure policies on the probability that at least one PEL is exceeded during the inspections at plants, by comparing these probabilities in the period before and after the implementation in the TRI program, and holding constant other factors. The TRI dummy captures the change in the probability of exceedance after the implementation of the TRI program relative to the earlier period.

In our first specification in Table 1 column 1, we do not control for underlying time trends. The coefficient on the TRI dummy is negative and statistically significant, indicating that that the probability of at least one exceedance declined. In our second specification (columns 2, 3, 5), we include a time trend. The coefficient on the time trend is negative, but not statistically significant. This suggests that that the probability of at least one exceedance declines over time, though it is estimated imprecisely. Even controlling for the underlying time trends, we continue to find that the probability of at least one exceedance declined after the initiation of the program. This is the case in the specification with a full set of SIC-4 dummies (column 2) or with the average pollution of the plants' SIC-4 sub-industry (column 3).

In our third specification, we separate the post-TRI years into the immediate post-TRI years (1987-1990) and the following years (1991-2009). This allows us to test whether the program had a larger effect in the first few years after implementation and prior to the 1990 Clean Air Act Amendments. Because our first-differences specifications rely on the assumption that no other events other than the TRI program implementation affect exposures, this specification allows us to analyze the effect in a shorter time horizon. In this specification, without and with controlling for the underlying time trend (columns 4 and 5), we continue to find that the probability of exceedance declined after the TRI implementation.

Hypothesis 2: The TRI program led to larger declines in the probability of at least one exceedance in the higher polluting industries relative to the lesser polluting industries.

We compare the changes in probability of exceedance after the TRI implementation in more polluting industries relative to the analagous changes in the less polluting industries. Of interest is the coefficient on the interaction term between SIC-4 pollution and the dummy for the post-TRI years. The specification in column 6 controls for SIC-4 specific effects using the SIC-4 dummies. The specification in column 7 controls for time-invariant SIC-4 effects using the log of the average pollution for plants in a given SIC-4 for a given year. In both specifications, we find that the coefficient of interest is negative but not statistically significant. This result suggests that the effects of the TRI program on the probability of at least one PEL exceedance did not vary between the more and less polluting industries.

Hypothesis 3: The TRI program led to larger declines in the probability of at least one exceedance in the industries that reduce their TRI emissions to a greater degree.

We compare the changes in probability of exceedance after the TRI implementation in sub-industries that experience larger declines in TRI emissions relative to the analagous changes in industries that experience smaller declines in TRI emissions. In columns 8 and 9, we measure the change in TRI emissions between 1988 and 1993. Of interest is the coefficient on the interaction term between the change in TRI emissions and the dummy for post-TRI years. We find a positive and statistically significant coefficient. This result indicates the probability of exceedance showed a greater decline in the sub-industries that experience greater declines in TRI emissions. The coefficient on the specification which measure changes in pollution over a longer time period, however, is not statistically significant (columns 10 and 11).

Hypothesis 4: The TRI program led to larger declines in the probability of at least one exceedance in high polluting facilities that reduce their TRI emissions to a greater degree.

In columns 13-19, we include facility emissions variables. This reduces our sample size from 1,496 to 626 as we do not have TRI data for all inspected facilities. However, it gives us more detailed information on the individual facilities.

In column 13, we also include the plant's average emissions. This reduces our sample size, but the coefficient on the TRI dummy remains negative and significant. In columns 14 and 15, we reexamine Hypothesis 2 focusing on facility pollution. Of interest is the coefficient on the interaction term between facility pollution and the dummy for the post-TRI years. The specification in column 14 controls for SIC-4 specific effects using the SIC-4 dummies. The specification in column 15 controls for time-invariant SIC-4 effects using the log of the average pollution for plants in a given SIC-4 for a given year. In both specifications, we find that the coefficient of interest is not statistically significant. This result suggests that the effects of the TRI program on the probability of at least one PEL exceedance did not vary between the more and less polluting facilities.

Hypothesis 5: The TRI program led to larger declines in the probability of at least one exceedance in facilities that reduce their TRI emissions to a greater degree.

In columns 16-19, we compare the changes in probability of exceedance after the TRI implementation in facilities that experience larger declines in TRI emissions relative to the analagous changes in facilities that experience smaller declines in TRI emissions. Of interest is the coefficient on the interaction term between the change in facility-level TRI emissions and the dummy for post-TRI years. Our results are consistent with our tests of Hypothesis 3. We find a positive coefficient on changes in emissions in all four specifications, with the coefficients on the averages changes from 1988-1993 statistically significant. This result indicates the probability of exceedance showed a greater decline for facilities that reduced their TRI emissions to a greater degree.

Preliminary Conclusion

Our study provides robust evidence that the TRI disclosure program on plants emissions into the environment yields an important co-benefits. Specifically, we find that plants responded to the TRI by reducing their workers exposure to pollutants.

Table 1. Probit Regression of PEL Exceedance on Industry Emissions.

	Hypothesis 1					Hypothesis 2		Hypothesis 3			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
TRI Years Dummy	-0.320***	-0.273**	-0.222*			-0.316***	-0.301***	-0.304***	-0.303***	-0.317***	-0.316***
	(0.093)	*(0.120)*	*(0.115)*			*(0.093)*	*(0.091)*	*(0.094)*	*(0.094)*	*(0.093)*	*(0.094)*
Year 1987-1990				-0.269**	-0.198*						
				(0.118)	*(0.117)*						
Year Post-1990				-0.342***	-0.329**						
				(0.097)	*(0.163)*						
TRI Years * SIC-4 Pollution						-0.027	-0.052		-0.003		-0.007
						(0.066)	*(0.063)*		*(0.067)*		*(0.070)*
TRI Years * (Ave. Yearly Change in Industry Pollution 1988-1993)								1.822**	1.816**		
								(0.884)	*(0.897)*		
TRI Years * (Ave. Yearly Change in Industry Pollution 1988-1998)										2.087	2.021
										(2.101)	*(2.213)*
Time Trend		-0.004	-0.008		-0.002						
		(0.007)	*(0.007)*		*(0.010)*						
log of Mean Facility Pollution in Industry			0.128***		0.128***		0.170***				
			(0.027)		*(0.027)*		*(0.056)*				
Accident Inspection	-0.032	-0.036	0.120	-0.034	0.122	-0.029	0.133	-0.024	-0.023	-0.032	-0.032
	(0.370)	*(0.371)*	*(0.348)*	*(0.371)*	*(0.349)*	*(0.370)*	*(0.347)*	*(0.370)*	*(0.370)*	*(0.370)*	*(0.370)*
Complaint Inspection	-0.221**	-0.226**	-0.208*	-0.227**	-0.210**	-0.221**	-0.202*	-0.219**	-0.219**	-0.222**	-0.222**
	(0.111)	*(0.111)*	*(0.107)*	*(0.111)*	*(0.107)*	*(0.111)*	*(0.107)*	*(0.111)*	*(0.111)*	*(0.111)*	*(0.111)*
Follow-Up Inspection	0.187	0.177	0.302*	0.177	0.298*	0.185	0.313*	0.195	0.195	0.186	0.186
	(0.173)	*(0.174)*	*(0.167)*	*(0.173)*	*(0.167)*	*(0.173)*	*(0.167)*	*(0.174)*	*(0.174)*	*(0.173)*	*(0.173)*
Other Inspection	-0.327	-0.313	-0.074	-0.314	-0.074	-0.338	-0.121	-0.397	-0.398	-0.344	-0.346
	(0.402)	*(0.402)*	*(0.373)*	*(0.402)*	*(0.373)*	*(0.403)*	*(0.376)*	*(0.410)*	*(0.410)*	*(0.403)*	*(0.404)*
Referral Inspection	0.208*	0.201	0.188	0.201	0.186	0.208*	0.201*	0.208*	0.208*	0.206	0.206
	(0.126)	*(0.127)*	*(0.122)*	*(0.126)*	*(0.122)*	*(0.126)*	*(0.121)*	*(0.126)*	*(0.126)*	*(0.126)*	*(0.126)*
Constant	-0.397**	8.310	14.790	-0.398**	1.938	-0.418**	-2.291***	-0.357*	-0.359*	-0.310	-0.317
	(0.189)	*(14.120)*	*(13.460)*	*(0.189)*	*(19.190)*	*(0.195)*	*(0.599)*	*(0.190)*	*(0.197)*	*(0.208)*	*(0.224)*
Observations	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,496

All specifications include state dummies. All specifications except 3, 5 and 7 include Industry dummies.
Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 2. Probit Regression of PEL Exceedance on Facility Emissions.

		Hypothesis 4		Hypothesis 5			
	(13)	(14)	(15)	(16)	(17)	(18)	(19)
TRI Years Dummy	-0.664***	-0.674***	-0.570***	-0.647***	-0.650***	-0.304	-0.353
	(0.149)	*(0.149)*	*(0.140)*	*(0.223)*	*(0.206)*	*(0.258)*	*(0.232)*
TRI Years * Facility Pollution		0.023	-0.015				
		(0.029)	*(0.026)*				
TRI Years * (Ave. Yr. Change in Facility Pollution 1988-1993)				0.963**	1.016**		
				(0.436)	*(0.405)*		
TRI Years * (Ave. Yr. Change in Facility Pollution 1988-1998)						0.469	0.615
						(0.753)	*(0.659)*
log of Mean Facility Pollution	0.018						
	(0.025)						
log of Mean Pollution in Industry			0.176***		0.250***		0.286***
			(0.046)		*(0.068)*		*(0.082)*
Accident Inspection	0.242	0.242	0.406	0.139	0.635		
	(0.554)	*(0.553)*	*(0.492)*	*(0.904)*	*(0.736)*		
Complaint Inspection	-0.030	-0.030	0.092	0.401	0.424*	0.407	0.491*
	(0.175)	*(0.175)*	*(0.161)*	*(0.263)*	*(0.240)*	*(0.309)*	*(0.274)*
Follow-Up Inspection	0.284	0.281	0.504*	0.486	0.650	0.386	0.497
	(0.289)	*(0.289)*	*(0.274)*	*(0.438)*	*(0.406)*	*(0.474)*	*(0.440)*
Other Inspection	-0.487	-0.506	-0.049	-0.368	-0.045		
	(0.865)	*(0.870)*	*(0.797)*	*(1.021)*	*(0.879)*		
Referral Inspection	0.297	0.300	0.334*	0.898***	0.808***	0.985***	0.866***
	(0.193)	*(0.193)*	*(0.181)*	*(0.298)*	*(0.271)*	*(0.344)*	*(0.307)*
Observations	636	636	636	320	320	235	235

All specifications include state dummies. All specifications except 15, 17 and 19 include Industry dummies.
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

carcinogenic are not likely to reduce deaths or hospitalizations because of the long latency periods between chronic exposure and symptoms of illness (Robson and Toscano, 2007).