Environmental Regulation vs. Environmental Information: A View From Canada's National Pollutant Release Inventory

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1 Introduction

In recent years, governments throughout the world have been experimenting with a variety of policy instruments predicated on information dissemination as an alternative or supplement to traditional regulation, including pollutant discharge inventories, ecolabels, and other forms of product or process certification. In contrast to traditional "command and control" regulation, through which the state mandates which facilities should reduce pollutant discharges and by how much, with information-based approaches to environmental protection the state may encourage or require dissemination of information about discharges and environmental practices, but does not require changes in those practices per se. Rather, informational strategies for environmental protection are predicated on the assumption that firms will respond to pressure from consumers, workers, investors, and communities armed with more complete information about those firms' environmental practices.

Arguably the most prominent example of the information-based approach is the community right-to-know inventory or "pollutant release and transfer registry" (PRTR). In 1988, the US EPA established the first such inventory, known as the Toxic Release Inventory (TRI), which requires that firms that meet certain criteria report information on their discharges and off-site transfers of several hundred toxic substances to EPA. In response to the apparent success of TRI in promoting discharge reductions, Agenda 21, the international plan of action that emerged from the UN Conference on Environment and Development in Rio in 1992, recommended that all countries establish pollutant release inventories. Since then, the Canadian government created its National Pollutant Release Inventory (NPRI) in 1993, and similar inventories have also been established in Australia and the UK. The most novel element of the community right-to-know approach is that the information reported to the state by individual facilities is released to the public via the internet and other published sources. Indeed, dissemination of information to the public is the raison d'être of such inventories, allowing citizens to readily determine the magnitude of discharges to air, water, and soil of different chemicals by facilities in their own neighbourhoods.

The early indications have been highly encouraging. Total releases and transfers reported to the US TRI declined by 46% and 36% respectively from 1988 to 1995 (Natan and Miller, 1998). As discussed below, releases reported to the Canadian NPRI also rapidly declined, by 36% in the first

three years alone. Various commentators have concluded that discharge inventories are at least as effective as regulation. For instance, US EPA Administrator Carol Browner has argued that TRI is "quite simply one of the most effective means we have in this country for protecting the health of our people, the health of the environment."[1] Gunningham and Grabosky (1998, p. 64) argue that, "No executive likes to see their company exposed publicly at the bottom of the performance rankings; resulting managerial exhortation is likely to have greater impact than any fixed standard which regulatory authorities might be inclined to impose." Similarly, the Organisation for Economic Co-operation and Development (1996) reports that, "Corporate and environmental group spokespersons alike have said that PRTRs have had a stronger impact than many regulatory programmes even though a PRTR sets no improvement goals mandatorily." Finally, Fung and O'Rourke (2000) has asserted that "it is arguable that TRI has dramatically outperformed all other EPA regulations over the last ten years in terms of overall toxics reductions and that it has done so at a fraction of the cost of those other programs."

This paper considers the impact of the Canadian NPRI, which has received little scholarly attention to date. Our objective is to critically examine the hypothesis that toxic release inventories are effective in promoting voluntary reductions. Our analysis indicates that the evidence that the NPRI has been effective in promoting voluntary emission reductions is rather weak. The majority of reductions that have occurred to date can be attributed to traditional regulation. Moreover, it is by no means clear whether the remaining reductions are attributable to regulatory or market mechanisms. We also raise concerns with respect to cross-media transfers and apparent shifts from less to more toxic substances, which may have been prompted by either regulation or public pressures in response to NPRI, but which are unlikely to be addressed by NPRI alone.

The remainder of this paper is organized as follows. The next section considers theory and evidence concerning the impact of discharge inventories. Thereafter, we review our research methodology and preview aggregate trends in the data. Statistical analyses of NPRI panel data to examine the impacts of community and regulatory pressures are presented in the next section, which is followed by our conclusions.

[1] M. Mansur, and G.S. Reeves, "Lower numbers hide growing toxic dangers," Kansas City Star, October 9 1996, A1, cited in Fung and O'Rourke (2000, p. 116). See also comments by William Reilly, *Aiming Before we Shoot: The Quiet Revolution in Environmental Policy* in an Address to the National Press Club, Washington, DC, September 26 1990, cited in Gunningham and Grabosky (1998, p. 64).

2 Theory and Evidence Concerning the Impact of Discharge Inventories

Several different mechanisms can be offered by which dissemination of information on toxic releases could promote discharge reductions. We distinguish between first order mechanisms, in which those seeking to influence a firm's behaviour have a direct relationship with that firm, and second order mechanisms, in which other actors seek to pressure the firm by influencing those with which it does have direct relationships. We identify five first order mechanisms. First, environmentally conscious consumers may react to discharge information by shifting their purchases to products produced by "greener" firms, thus encouraging firms to reduce their discharges to protect their corporate reputations and markets. Second, workers may respond to pollution release inventories by seeking jobs in cleaner facilities or demanding hazard pay, again prompting profit-oriented firms to reduce discharges. Third, individual citizens or groups may pursue private enforcement or tort actions in the courts, thus imposing penalties or forcing cleanup. Fourth, government officials may respond to discharge reports by adjusting their enforcement strategies or priorities for new regulations. Finally, banks, shareholders, and insurance companies informed about firms' pollutant releases may respond by placing financial pressure on polluting firms, whether in the form of higher premiums or reduced stock prices.

Second order mechanisms represent means by which various actors seek to influence these first order relationships. For instance, environmental groups may use information from discharge inventories to lobby governments to regulate, or public campaigns to educate and influence consumers and investors. Although environmental groups can also approach facilities directly, their influence in so doing is presumably a function of their ability either to enforce reductions through litigation or to influence consumers and governments.

Differences between the motives of those acting on pollutant release information are worth noting. Consumers, workers, regulators, and citizen groups might be expected to respond to discharge inventories either out of environmental self-interest (i.e., because they fear impacts of pollutants on their own health) or perceived collective interest (i.e., because they care about the impacts of pollution on the community as a whole), which we interpret as a form of altruism in light of their willingness to forgo the temptations to free-ride. Although some green investors, lenders, and insurers may

have altruistic motives, others may shun polluting firms out of pecuniary self-interest because they fear financial risks as a result of litigation or increased pressures from environmentally-motivated consumers, workers, and regulators. Although these actors have a first order relationship with the firm, they are driven by second order motivations, in that the extent to which they pressure the firm depends on the degree to which they anticipate environmental concern from others.

It is also worth distinguishing among the mechanisms noted above between those that involve the state as regulator and those that proceed exclusively through private markets. Mechanisms such as green consumerism, worker pressures, and altruistic green investing are of particular interest, since to the extent they are effective informational strategies can serve as a substitute for regulation. In other cases, such as citizen litigation and lobbying, green investing motivated by regulatory threats, and enhanced governmental enforcement, information enhances and thus complements regulation. The remainder of this section reviews what we know about each of these mechanisms.

2.1 "Phantom Reductions"

At the outset it is important to acknowledge uncertainty about the extent to which the reductions reported to date by Canadian and US PRTRs are real and permanent. Individual facilities prepare their own reports to both TRI and NPRI with minimal oversight by regulators. For instance, Environment Canada staff do routine checks for consistency among similar facilities but do not take measurements in the field. Similarly, EPA inspects only about 3% of reports received each year (Fung and O'Rourke (2000)). Indeed, facilities are not required to measure their own discharges; they can estimate them using techniques of varying reliability. Although facilities would have incentives to understate their releases, particularly given the minimal regulatory oversight of their reports, it is not clear why they would exaggerate reductions over time (i.e., rather than just understating emissions from day one.) However, to the extent that facilities move from less reliable estimation techniques, such as out-dated engineering estimates, to more reliable measurements, their reported emissions could erroneously appear to decline over time.

Environmental groups have coined the term "phantom reductions" to describe such reductions (Hearne 1996). A 1991 EPA study found that two of the three most commonly reported factors contributing to reported reductions to the TRI were reductions in production levels and changes in

estimation methods.[2] Although the former are real in the sense that discharges really do decrease, there are no guarantees that reductions associated with economic downturns will be lasting. With respect to the latter, Natan and Miller's (1998) finding that more than half of reported reductions of production-related waste were "paper reductions," such as recategorizing waste streams so that they no longer have to be reported, is particularly troubling. The fact that, until 1998, reporting of waste reduction, reuse, and recycling to NPRI was voluntary may have created opportunities for a unique Canadian version of this shell game.

In the analysis that follows, we consider the impact of production levels on reported NPRI releases. However, examination of estimation methods and sleight of hand in reporting remain for future work.

2.2 Employee Pressures

There has been little attention to the impact of pollutant information dissemination on employees. However, various studies of the chemical industry's voluntary Responsible Care program report that improved workplace morale has been an important fringe benefit of the program, suggesting that workers care about their employers' environmental performance (e.g., Nash and Ehrenfeld, 1997). In addition, Ruis-Quintanilla et al (1996) found that source reduction strategies reported to TRI that directly involved workers were more effective than those that did not. If workers can assist their employers in finding opportunities for source reductions, they could also play a role in advocating such reductions. The role of unions in accessing and interpreting workplace hazards information (Robinson, 1988) and in bargaining for compensation for workplace hazards (Leigh and Gill, 1991), suggests that unionized workers may be better able to access and interpret PRTR information, and to act collectively to demand reductions or compensation. Elsewhere (Antweiler and Harrison, 2000), we have examined the impact of rate of unionization on NPRI releases, changes in releases over time, and pollution intensity of individual facilities, and found little evidence that unionized workers place greater environmental pressure on their employers.

[2]The third was source reduction. G Riley, J Warren, R Baker, "Assessment of Changes in Reported TRI Releases and Transfers Between 1989 and 1990," EPA Contract # CR81760-01-0. RTP, NC: Center for Economics Research, research Triangle Institue, May 1993. Cited in Hearne (1996).

2.3 Green Consumerism

The emergence of a green consumer movement in the late 1980s holds promise for the impact of informational strategies on consumers. Governments and non-governmental groups alike have sought to capitalize on this environmental consumerism through another form of information dissemination strategy, ecolabelling programs. Although such programs have generated a few apparent success stories, an international survey by the Organisation for Economic Co-operation and Development (1997) concluded that "eco-labelled products have not had a significant impact on the market." This is perhaps not surprising since one can anticipate several obstacles to the impact of ecolabels and other informational strategies on consumers. Consumers must care enough to read the information provided and to take it into account, an action that will often require unselfish assumption of personal costs in order to gain widely shared benefits of a cleaner environment. It is noteworthy that the challenge for discharge inventories to influence consumers is even greater than that for ecolabels, since the information provided has not been interpreted and packaged in the form of a simple seal of approval, and it is also provided in a form removed from the point of purchase. Even engaged consumers willing to seek out pollutant release information on the internet might have difficulty connecting a given facility to particular consumer products.

Despite these challenges, there is some evidence that firms anticipate consumer pressures. Both Arora and Cason (1996) and Khanna and Damon (1999) found that firms that were consumer product-oriented were more likely to participate in EPA's 33/50 program, which encouraged voluntary reductions of some 17 chemicals. Since the 33/50 program concerned a subset of chemicals reported to the TRI, 33/50 participants may have been motivated as much by the negative publicity associated with TRI disclosure as by the public recognition EPA offered for 33/50 program participants.

Canadian consumer product data do not exist to allow a comparable analysis using NPRI data. However, elsewhere (Antweiler and Harrison, 2000) we have reported indirect evidence of a "spillover effect" in which consumers react to discharge information by punishing the entire firm, rather than particular products. While this may have a desirable effect of enhancing consumer pressure, at least on diversified firms, it can also have perverse effects since consumers may penalize "clean" products as well as "dirty" ones.

2.4 Community and Interest Group Pressures

As noted above, various mechanisms of influence by environmental groups and other community activists have been proposed. Maclean (1996) and Lynn and Kartez (1994) document diverse strategies adopted by community activists and environmental groups in response to the release of TRI data, from taking out newspaper ads to shame firms reporting the greatest discharges, to negotiating neighbourhood agreements with individual facilities. It is noteworthy that discharge inventories have been praised not only for promoting reductions in discharges, but also as "a powerful tool for promoting environmental democracy" (EPA, 1992), "revitaliz[ing] civil consciousness" (Vallely, 1993) and promoting deliberative democracy (Karkkainen et al, 2000; Lynn and Kartez, 1994). The US Environmental Defense Fund's sophisticated use of PRTR data in its "scorecard" web page (www.scorecard.org) illustrates the potential for dissemination of information to "empower, enlighten, and engage" citizens (Smith and Ingram, 1993).

Others, however, are skeptical. Rich, Conn, and Owens (1993) question the impact of publication of highly technical TRI information in the absence of more aggressive efforts by governments to interpret and communicate the implied risks to the public. Even if the public does access and digest information available on the internet or in summary reports prepared by environmental groups, others question whether the results will be efficient. Ahearne (1988) has argued that reactions at the community level to discharge inventories could yield a "NIMBY" phenomenon of local opposition to facilities that are in society's collective interest. Moreover, Tietenberg (1998) speculates that the focus of discharge inventories on a subset of pollutants will encourage firms to shift to pollutants not reported to the inventory, which may or may not pose less risk. Similarly, if the public focuses naïvely on total discharges (as reports on TRI by environmental groups have tended to do), rather than distinguishing between more and less toxic substances, firms could respond by reducing discharges of substances with the lowest marginal control or substitution costs, which may not be the most toxic. Such substitutions could yield an increase in risk, even though total reported releases would decline.

Others have expressed concern about the impact of discharge inventories on the distribution of risk. Terry and Yandle (1997, 436) argue that "citizens who have higher incomes are typically more concerned about pollution, are better educated, more informed about the environment, and

more influential in communicating their concerns." Various scholars have found that communities that experience greater exposure to pollution and hazardous wastes tend to be less educated, home to a higher proportion of African Americans, and poorer (though some have found a U-shaped relationship with exposure increasing at higher income levels) (Brooks and Sethi, 1997; Ringquist, 1997; Terry and Yandle, 1997). This effect has been observed in both developing and industrialized countries (Pargal, Hettige, Singh, and Wheeler, 1997).

The aforementioned studies rely on cross-sectional data, rather than following trends over time to investigate community responses to discharge inventories. Dissemination of information could reduce risk disparities to the extent that the information has greater marginal value to less educated poor communities than better educated, wealthier ones. Alternatively, discharge inventories could exacerbate disparities if wealthier communities are better able to access technical information provided on the internet, have more time and background knowledge to digest related reports, and feel more politically empowered to act on that information (Tietenberg, 1998). There is some support for the latter in the US. Analysing data aggregated at the state level, Grant (1997) found smaller relative reductions in TRI discharges in states with higher fractions of non-white residents. Brooks and Sethi (1997) found that communities with a lower proportion of black residents, higher voter turnouts, and higher housing values were less likely to experience increases in exposure to TRI pollutants from 1990 to 1992. Although Shapiro (1999) did not find comparable racial effects, he reports that wealthy communities have apparently been better able to take advantage of US TRI data to achieve risk reductions than their poorer neighbours. In contrast, Hamilton (1999) found no significant effect on TRI reductions from 1988 to 1991 of property values, levels of educational attainment, or fraction of black residents in the surrounding community, though he did find a significant impact of voter turnout, suggesting that the effect of community wealth found in other studies may be a surrogate for political mobilization. Though there are unresolved discrepancies between these studies, they nonetheless collectively suggest that the impact of information dissemination about toxic substances may well be a net transfer of risk from wealthy, well-educated, politically empowered communities to their poorer, less educated, less politically engaged neighbours. This could occur through the NIMBY phenomenon noted above, or because local communities express greater concern for direct releases into their neighbourhoods than transfers destined for disposal elsewhere.

In our analysis, below, we investigate the impact of community characteristics on the rate of change in facilities' toxic releases reported to the Canadian inventory. We also consider trends in off-site transfers and the potential effects of substitution of alternative chemicals on environmental risks.

2.5 Shareholder Pressures

Shareholders (or lenders or insurers) may also react to disclosure of pollution information by pressing firms to reduce their toxic releases, whether as a result of altruistic motives or in anticipation of negative impacts of community, consumer, worker, or governmental pressures. A series of recent articles has found evidence of considerable sophistication by investors using US TRI data. Hamilton (1995) demonstrated that firms that reported large TRI discharges were more likely to be mentioned in media reports, which in turn resulted in losses in the stock market.[3] Konar and Cohen (1997) confirmed that firms that received more negative media attention concerning their TRI discharges made greater emission reductions over the next three years than their peers. Finally, Khanna et al (1998) found that the investor pressure effect did not subside with repeated publication of TRI data. Rather, investors penalized firms whose performance declined over time, and rewarded those that made progress. It is noteworthy, however, that Khanna et al. report that although uncontrolled discharges declined, the sum of releases and transfers for off-site disposal did not, prompting the authors to conclude that "the abnormal losses experienced by firms caused them to substitute off-site tranfers for on-site discharges."

A critical question is what is motivating these shareholders. Investors may be motivated not only by their own and anticipated consumer altruism, but by fear of greater legal liability and regulatory costs. Investors also may simply perceive poor environmental performance as an indication of poor management and a lack of innovation. Consistent with this, Afsah, Blackman, and Ratundanda (2000) concluded that one of the most important benefits of Indonesia's information program was in prompting firms to identify opportunities to reduce their costs and improve their management systems. The literature on investors' responses to discharge inventories cannot distinguish between altruistic and profit-oriented motives. Yet, investors' motivations have significant implications for

[3]The effect was reduced, however, if investors already had reason to be aware of a firm's polluting behaviour, as with firms with multiple Superfund sites.

public policy. To the extent that shareholders are acting altruistically themselves, anticipating altruistic consumer reactions, or simply reacting to perceived mismanagement, discharge inventories can serve as at least a partial substitute for regulation. However, if shareholders are acting in anticipation of enhanced enforcement, new regulations, or increased civil liability, the effectiveness of discharge inventories are predicated on statutory mechanisms for pollution control. Laplante and Lanoie's (1994) finding that firms' announcements concerning investments in pollution control equipment decrease their equity value is consistent with only the latter mechanism.

2.6 Government Responses to Discharge Inventories

The forgoing suggests a critical role for the state in shaping the impact of pollutant release inventories, yet the role of government has arguably received the least attention in studies of discharge inventories conducted to date. Indeed, there has been a tendency to assume that reductions revealed by TRI and NPRI have been voluntary responses to market mechanisms (cf, Tietenberg, 1998: 593, Fung and O'Rourke (2000)). We believe that such an assumption is premature. Facility reports to TRI may alert regulators to risks they had not previously been aware of, and thus prompt new regulations, stricter permit conditions, or more aggressive enforcement activity. Decker (1999) has demonstrated that facilities with larger TRI reports do in fact receive more frequent compliance inspections, though he cannot not rule out the possibility that those facilities were subject to greater regulatory scrutiny before the release of the TRI data. Pollutant release information could also prompt individual citizens to assume the role of private attorneys general in pursuing private enforcement action (Kleindorfer and Orts, 1998). Finally, it is possible that PRTRs may simply track the impact of actual or proposed regulations or liability standards that are quite independent of the inventory. In other words, the reductions reported by PRTRs may not be attributable to information dissemination at all, but merely provide a valuable record of the success of other policy instruments.

With respect to the Canadian experience, we discuss below the impact of several high profile regulatory actions on the NPRI data. With respect to the US data, several studies have considered the impact of State policies on TRI discharges. Grant (1997) found that state funding for right-to-know activities and state right-to-sue policies were among the most significant influences on changes over time in aggregate state discharges. Although Terry and Yandle (1997: 439) found no

significant relationship between TRI discharges and the budgets of state environmental agencies, and thus concluded that "regulation is redundant," researchers using more direct measures for regulatory stringency have found more significant effects. O'Toole et al (1997) found that stringency of state regulations, as measured by environmental groups' rankings, was one of the two most important factors in accounting for state-level reductions of 33/50 chemicals, and that the presence of state programs to promote voluntary reductions and information dissemination was not statistically significant. Maxwell, Lyon, and Hackett (1999) also found state government aggressiveness with respect to environmental policy to be one of the most important determinants of reductions of releases of some 17 TRI chemicals between 1988 and 1992. Using facility level data, Shapiro (1998, 2000) found significant effects of state regulatory stringency, though he found only weak support for the impact of state environmental budgets, the measure used by Terry and Yandle. Finally, only Khanna and Damon (1999) have considered the impact of regulation at the national level. The authors found that potential liability under Superfund and anticipation of new hazardous air pollutant regulations under the US Clean Air Act were among the most significant factors in explaining firms' releases of 33/50 program chemicals. These studies suggest a need for greater attention to the role of regulation and liability in accounting for the rapid progress apparent in discharge inventories.

2.7 Summary

The preceding discussion reviews a relatively recent literature, primarily concerning the US TRI, which has yielded important insights, especially concerning investor influence on toxic discharges. However, much work has been done at a fairly high level of aggregation, at the state or firm level; few studies have been done at the facility or community level. Although there is an important and growing body of literature on the distribution of environmental risks, few authors have considered the impact of community characteristics on changes in discharges over time at the facility level, while those that have, have considered only one or two year intervals. There also has been little attention to the impacts of concurrent regulation, particularly at the national level, on reported releases.

Since the US TRI was launched 5 years before Canada's NPRI, it is not surprising that virtually all the literature published to date concerns TRI. However, the Canadian experience warrants inves-

tigation in light of potentially important differences between the two countries. For instance, Baggs (1998) found that, in contrast to the US, race was not a significant variable in the Canadian context, and that many of the most polluted communities in Canada are rural, reflecting the economic significance of primary resource industries such as mining, smelting, and pulp and paper (though this could also be a function of inclusion of a broader range of industries in the Canadian inventory). The preponderance of rural facilities also suggests that in Canada there may be more single-industry towns, which may react to discharge inventories differently than more heterogeneous urban communities. Finally, Canada and the United States have taken different approaches to toxic substances regulation (Harrison and Hoberg, 1994), with Canadian regulators historically being more receptive to negotiation and less inclined to pursue adversarial litigation. Threats of regulation or regulatory enforcement thus may carry less weight in Canada. This may explain Laplante and Lanoie's (1994) finding that, while US investors react negatively to announcements of lawsuits against a firm, Canadian investors do not respond until there is an announcement of actual fines. It is also potentially significant that, based on a comparison of TRI and NPRI data, Olewiler and Dawson (1998) found that Canadian manufacturing industries had roughly 50% higher discharges than their American counterparts, suggesting that regulation may be less stringent in Canada.

3 Data and Methodology

3.1 The National Pollutant Release Inventory: Coverage and Limitations

This study examines the impact of the National Pollutant Release Inventory on toxic discharges in Canada. We analyse the first 6 years of NPRI data for the period 1993-1998, covering roughly 2300 facilities. Although facilities are required to report discharges on 176 substances, to date reports have been received for only 135 substances, with an average between 3 and 4 substance reports per facility each year. Facilities are required to report on-site releases to various media (e.g., air, water, underground injection), as well as off-site transfers of wastes for disposal or storage by various means. It is noteworthy that the category of on-site releases includes both direct releases to air and water as well as waste disposal methods that entail some further degree of risk reduction, such as land application and underground injection. Thus, the distinction between on-site releases and

off-site transfers is not entirely coincident with a distinction between direct releases and waste treatment. Rather, the categories distinguish between releases to the host community and transfers of wastes to other locations. In contrast to the US TRI, reports of waste reduction, reuse, and recycling activities were not mandated by NPRI until 1998. In the absence of complete data on these "3Rs", we have focused exclusively on on-site releases and off-site transfers. It is noteworthy, however, that the NPRI program believes that off-site transfers were overstated in 1993 as a result of confusion that first year about the distinction between off-site waste transfers and the 3Rs (Environment Canada, 1994; Environment Canada, n.d.).

We have made various adjustments to the raw data to account for minor changes to the definition of various NPRI substances over time.[4] However, one important change that could not readily be taken into account concerned the threshold for reporting to NPRI. The effect of this change was to require reporting in 1995 and later years by facilities producing dilute waste streams that previously had not been required to report. The NPRI program estimates that this change resulted in an increase of at least 8,000 tonnes between the 1994 and 1995 annual reports. However, since facilities that cross the threshold have always been required to report all their releases of NPRI substances, however dilute, this change should not have had any effect on reports by facilities already in the database. As noted below, we attempted to account for the impact of this change on aggregate

[4]Iso-butyl alcohol (CAS 78-83-1) was added only in 1994, so we have excluded it in all cases. (In addition, chlormethyl methyl ether (CAS 107-30-2) was deleted from the inventory in 1994. However, since it had not been reported in 1993 anyway, this has no impact on the study.) In 1995, ammonium nitrate and ammonium sulphate were deleted, and "ammonia" was changed to "total ammonia," to include the ammonia portion of the deleted substances and "nitrate ion" was added to account for the nitrate portion of ammonium nitrate. The total weight reported post-1995 should thus be equivalent to the previous total less the weight of sulphate in pre-1995 reports of ammonium sulphate. We have thus corrected the pre-1995 totals by subtracting the weight of sulphate from ammonium sulphate reports, a technique also used by the NPRI program in making year-to-year comparisons (Environment Canada, n.d.b: 37). We made no adjustment for other minor changes that did not appear to have had a significant affect on the data. Thus, no correction was made to account for the addition of the phrase "friable form" to asbestos in 1995 and later years. Also in 1995, the phrase "and its salts" was added to various acids and bases, and guidance on the meaning of this phrase was added in 1996. However, only 3 of the acids and bases in NPRI have salts that are produced or used in Canada (two salts each for CAS numbers 139-13-9; 108-95-2; and 62-53-3). We did not make any adjustment for these, as there did not appear to be any significant changes in reports from facilities reporting these substances. In 1995, NPRI merged the categories "zinc (fume or dust)" and zinc in a new category "zinc and its compounds," which we have assumed to be the sum of the previous two. The reporting threshold for nitrate in solution was decreased from pH>6.5 in 1995 to pH>6.0 in 1996, which we have assumed to have a negligible effect (particularly since any increase in reporting on nitrate could be counterbalanced by decreased reporting of nitric acid.) Finally, we have taken into account estimates provided by facilities reporting discharges of less than 1 tonne of the range of their estimates (e.g., 0.0 to 0.2 tonnes, 0.2 to 0.4 tonnes, etc.) by assuming that discharges are at the midpoint of the relevant range. The NPRI program appears to have assumed these discharges to be zero, which may account for minor differences between our totals and those reported by NPRI.

trends by examining the performance of a subset of "continuous reporters".[5]

Like the US TRI, the NPRI has important limitations in addition to the potential problems associated with self-reporting noted above. First, not all pollutants of interest are included. The 176 substances covered by NPRI exclude pesticides and ozone-depleting substances scheduled to be phased out. (There are also fewer substances than on the TRI list because many TRI substances are not processed in Canada.) As with TRI, because the focus of NPRI is "toxic" substances released in significant quantities, the inventory excludes both high volume, low toxicity pollutants, including "conventional pollutants" such as BOD and particulates, as well as highly toxic substances, such as dioxins, that are released in small quantities.

Second, not all sources of potential interest are covered by the inventory. Although NPRI includes more than just the manufacturing sectors found in TRI, it still excludes some potentially significant sectors, including primary industries such as forestry, fisheries, agriculture, and oil production. Like TRI, facilities below a certain size (i.e., those with fewer than 10 employees that do not produce or use NPRI substances in quantities greater than 10 tonnes) are not required to report. As a result, only about 7% of the roughly 32,000 manufacturing establishments identified by Statistics Canada report to NPRI.

Third, one cannot assume that trends in the weight of discharges reported to either TRI or NPRI reflect proportional trends in environmental or human health risk. The impact of pollutant releases depends not only on the quantity discharged, but also on the toxicity of component substances, their persistence and potential for bioaccumulation, synergies among different substances, dispersion patterns, proximity to other sources, and the presence of greater or lesser numbers of people and other vulnerable species in the vicinity of each source.

3.2 Adjusting for Toxicity

Not all NPRI chemicals are alike. Following the example of Hettige et al. (1992), Horvath et al. (1995), and Shapiro (1999), we have tried to take into account the varying toxicity of NPRI substances. Although doing so brings us one step closer to a measure of environmental risk, we emphasize that we have not been able to incorporate other factors, such as dispersion, exposure

[5]The change in the threshold for reporting has no impact on the statistical analyses reported below, since we compare facilities from year to year once they are already in the inventory.

potential, and efficacy of waste treatment, noted above.[6]

Like Shapiro (1999), we use the EPA Chronic Human Health Indicator (CHHI) for the purpose of toxicity adjustment. The CHHI provides risk-related comparisons of chemical releases to various environmental media. [7] An important advantage of the CHHI data is that EPA has developed separate toxicity scores depending on whether exposure occurs via oral intake or inhalation. We have employed inhalation scores for releases to air, and oral toxicity scores for all other releases.[8] CHHI scores are based only on chronic effects and do not consider acute effects of exposure. However, this is arguably more appropriate in light of the low level exposures resulting from most environmental releases. CHHI indicators do not address effects of concurrent exposures to multiple substances, nor environmental impacts other than human health.[9] Following Hettige et al. (1992) and Horvath et al. (1995), we have also used threshold limit values set by the American Conference of Governmental Industrial Hygienists to confirm the robustness of our results.[10] Due to space limitation, we do not report the detailed results using TLVs, but make them available upon request. To interpret toxicity-adjusted figures, note that the EPA-CHHI adjustment effectively expresses pollution in equivalent "methanol units."

In order to examine the impact of community characteristics on facilities' responses to information disclosure, we have merged the NPRI data with 1991 Canadian national census data. Community characteristics are calculated as the population-weighted average for all census enumeration districts within a 15 km. radius of each facility.

[6]Hamilton (1999) has gone further in incorporating estimates of toxicity and disperson for airborne carcinogens reported to TRI. However, there is no comparable model for Canada to the one he uses. Moreover, Hamilton's approach entails limiting analysis to a subset of pollutants, facilities, and releases (i.e., those to air).

[7]For details about the CHHI see the EPA's web site at http://www.epa.gov/opptintr/env_ind/chgtox.htm.

[8]This assumes that the ultimate source of human exposure from land-based disposal techniques, including landfills, land-farming, and underground injection will be via surface or ground water contamination.

[9]Coverage of toxins by the TLV (see previous footnote) and CHHI measures is incomplete, but we can account for over 90% of the raw weight of pollutants by either method. One potential bias is with respect to nitrate; the CHHI does not provide both oral and inhalation scores.

[10]The TLV approach has several limitations that are at least partly overcome by reliance on CHHI measures. TLVs are designed to reflect the toxicity of airborne substances only, and the same toxicity rankings may not apply to other forms of exposure. Another drawback is that TLVs are developed for occupational settings, where exposures to toxic substances tend to be high relative to ambient environmental exposures. The same toxicity rankings may not hold at lower exposure levels.

4 Findings

4.1 Trends in the NPRI Data

Before turning to the regression analyses, it is illuminating to consider trends in the aggregate data reported to NPRI. Table 1 summarizes trends in on-site releases and off-site transfers, while Table 2 presents the same trends adjusted for toxicity using EPA's CHHI scores. The unadjusted totals in Table 1(A) are based on reports from all facilities that reported to NPRI in one or more of the years between 1993 and 1998. These aggregate data suggest five conclusions. First and most obvious, there was a quite dramatic and very encouraging decrease in on-site releases by 30% from 1993 to 1998. Indeed, there was a 37% decrease in the first 3 years from 1993 to 1996, but that has since been counteracted somewhat by growth in releases.

As noted above, these reductions of both on-site releases and off-site transfers may in fact be understated as a result of the change in reporting requirements in 1995, which mandated participation by some facilities that had not previously reported to NPRI. The totals (Group A in Tables 1 and 2) also include reports from a growing number of facilities reporting to the inventory over time. While some of these are new facilities contributing real increases in waste production others are presumably older facilities that only belatedly learned of the requirement to report to NPRI. The fact that discharges of these latter facilities are not included in earlier years is another reason that the NPRI totals may understate reductions over time.

One way to exclude these factors is to focus on the subset of facilities that reported in both 1993 and 1998, which we refer to as the continuous reporters. As anticipated, these facilities (subset B in Tables 1 and 2) are doing somewhat better that the totals for all facilities. The fact that decreases in on-site and total releases are larger for subset B than in the unadjusted totals reflects the growing contribution of new reporters over time.

Our second observation concerns potential for cross-media transfers. While the overall picture with respect to on-site releases is undoubtedly promising, very different trends are evident in releases to different media. In fact, the decrease in total on-site releases is almost entirely attributable to an 85% reduction of releases to surface water, which compensated for concurrent increases in discharges to air (13%), land (34%) and underground injection (77%). This comparison between trends in releases to different media is illustrated graphically in Figures 1 and 2. Concurrent in-

creases in on-site releases to air and underground injection are also apparent among the continuous reporters.

A third observation concerns the trends in off-site transfers. As noted above, the NPRI program considers the 1993 off-site transfer reports to be overstated due to confusion regarding the distinction between off-site transfers and recycling activities in the first year of the program. Disregarding the 1993 off-site transfers data, there has been a significant increase in off-site transfers reported by all facilities between 1994 and 1997. The trend with respect to continuous reporters is less clear, however, suggesting that growth in off-site transfers is primarily due to the contributions of new facilities.[11]

This increase in off-site transfers suggests that facilities are increasingly utilizing storage and treatment of their toxic wastes. That is encouraging inasmuch as the alternative is release of untreated wastes via the stack or sewer. However, it also reveals persistent reliance on end-of-pipe solutions to toxic wastes, rather than pollution prevention through reduction at the source. The increase in off-site transfers also implies that reductions in on-site releases are, to a large degree, being achieved by shifting wastes to other communities. It is noteworthy that the streams that have witnessed the largest increases, off-site transfers and on-site land application and underground injection, are those that are least visible to the neighbouring community. This suggests that facilities may be motivated, whether by regulation or public pressure we cannot say, to shift their wastes to less controversial venues for disposal. The growth in reliance on underground injection is consistent with trends in the United States, reflecting increasing costs associated with regulation of other means of disposal (Ruhl, 1999). The growing popularity of on-site underground injection and the fact that landfills are the dominant destination for off-site transfers suggest that the dramatic progress in on-site releases to date may have been achieved largely by shifting the risks to other communities and future generations.

Our fourth observation concerns the apparent contribution of traditional regulation to these aggregate trends. It is noteworthy that just 10 facilities account for 73% of the total reduction in on-site releases by continuous reporters. Indeed, a single Quebec facility, Kronos Canada, which produces paint pigments, accounts for just about half the total reductions. Those dramatic reductions were

[11] It is unlikely that the observed increase is attributable either to the threshold change in 1995, since reported off-site transfers actually decreased that year, or to delayed compliance, since the largest increases in off-site transfers have been reported in more recent years when one would anticipate higher levels of reporting compliance.

the result of process changes adopted by the facility in response to regulatory enforcement actions by both the federal and provincial governments in the early 1990s.[12] Besides Kronos, many of the facilities that contributed the greatest reductions were pulp and paper mills (Canadian SIC 27). It is noteworthy that the pulp and paper industry is the only industry that faced new discharge regulations at the national level during this period, and it was also subject to extensive reform of regulations and permits at the provincial level in the early 1990s (Harrison, 1996).

Since there is considerable evidence that these reductions were driven by regulation, rather than stakeholder pressures, the final series of totals in Tables 1 and 2 (Group C) report trends among the continuous reporters with Kronos and CSIC 27 (pulp and paper) excluded. The striking contrasts between trends in on-site releases for all facilities, continuous reporters, and continuous reporters excluding these regulated sources is presented in Figure 3. Once the most obvious impacts of national regulation are excluded, the impressive 30% reduction of on-site releases by continuous reporters evaporates, leaving a net increase of 7%. This suggests that the dramatic reductions of toxic discharges reported to NPRI, especially between 1993 and 1996, is largely the result of traditional regulations adopted prior to and quite independent of the creation of NPRI, rather than a response to public or other pressures associated with information disclosure.

Comparison of Tables 1 and 2 and Figures 1 and 2 yields a fifth insight. The potential contribution of different waste streams to total risk looks very different when one takes into account the toxicity of different NPRI substances. In particular, comparing Figures 1 (unadjusted data) and 2 (CHHI-adjusted), it is clear that on-site land application and off-site transfers assume much greater prominence once toxicity is considered. In addition, there have apparently been important shifts over time in the composition of various waste streams. For instance, although Table 1 indicates that there was a 30% decrease in the weight of on-site releases from 1993 to 1998 (Group A), this decrease translates to a 9% increase after adjusting for toxicity. In other words, while the total weight of releases has declined, the toxicity of those releases has increased, and has done so to a degree that apparently has outweighed the benefits of the reductions. Similarly, the 1% reduction in the weight of off-site transfers in Table 1 corresponds to a 234% increase after adjusting for chronic toxicity. The disparity in trends to different media noted above is even more pronounced after tox-

[12] André Picard, "Plant to shut down for ignoring clean-up orders," Globe and Mail, 30 May 1992, A2; Graeme Hamilton, "Kronos, two executives charged with polluting St. Lawrence," The Gazette, 9 March 1993, A4.

icity adjustment. In fact, the streams that are growing the most by weight – off-site transfers and on-site land disposal and underground injection – are simultaneously becoming more toxic. The significant increase in toxicity-adjusted off-site transfers is particularly noteworthy since, if anything, over-reporting of off-site transfers in 1993 would have tended to understate this increase.

In interpreting these trends, it is important to reiterate that CHHI scores offer only a preliminary assessment of the relative toxicity of different NPRI substances and waste streams. Moreover, toxicity adjustment does not account for dispersion and exposure nor distinguish between direct releases to the environment and releases destined for furhter treatment. However, the disparity between trends based on weight and those taking into account toxicity nonetheless suggest troubling shifts in the composition of NPRI waste streams toward higher toxicity substances. At the limit, this substitution effect could outweigh the benefits of the reductions in the total weight of NPRI releases achieved to date.

4.2 Statistical Analyses

Regression analysis of NPRI panel data allows us to look more closely at the impacts of community demographics and regulatory threats on individual facilities' toxic releases. We focus in the first instance on on-site releases (i.e., excluding off-site transfers). Table 3 presents our benchmark regressions for 4 different dependent variables. Columns 1 and 3 present regressions of the log of annual on-site releases, with column 1 representing toxicity-adjusted releases and column 3 representing unadjusted releases.[13] These annual releases provide a snapshot of facilities' performance in a given year. Columns 2 and 4 present regressions for unadjusted and toxicity-adjusted measures respectively of the change in the log of on-site releases over time.[14] These regressions thus focus on whether facilities are increasing or decreasing their releases over time. To control for technological or other sectoral differences, we have employed random effects regressions based on 3-digit Canadian SIC groups.[15]

[13] As noted in Antweiler and Harrison (2000), the distribution of on-site releases reported to NPRI is approximately log-normal.

[14] Let facilities (plants) be denoted by index $f = 1, .., F_c$ for company $c = 1, .., C$. Index t denotes time. Pollutants are indexed by $p = 1, .., P$ with toxicity W_{pr} for release method $r = 1, .., R$. Raw emissions are denoted by E_{fcprt}. In our regressions, toxicity-adjusted emissions are calculated as $X_{fct} \equiv \sum_{p=1}^{P} \sum_{r=1}^{R} E_{fcprt} W_{pr}$.

[15] We have also examined fixed effects regressions, but found no significant differences between the two approaches (Antweiler and Harrison, 2000) and thus report only random effects here.

The most significant impact on annual releases, both unadjusted and adjusted for toxicity (columns 1 and 3), is the size of the facility, as measured by the number of employees.[16] This is not surprising since larger facilities simply produce more waste. However, the fact that the coefficient is less than one in both columns 1 and 3 is consistent with both economies of scale in pollution control and greater scrutiny of larger facilities by regulators or the public. The coefficient of the variable representing the share of waste sent off-site is also highly significant in both the adjusted and unadjusted regressions.[17] This is indicative of a substitution effect, with an increase in the share of offsite transfers of 1%-point coinciding with a 2% decrease in toxicity-adjusted on-site releases. We also find that on-site releases are affected by population density: facilities in less densely populated communities tend to have significantly lower on-site releases. This may reflect greater regulatory or stakeholder pressure on facilities in urban areas, or simply the fact that in Canada many of the facilities with the largest toxic releases, including mines, smelters, and pulp mills, are located in remote areas in proximity to the primary resources they exploit.

We find that income of the surrounding community has a significant impact on releases, though this is only significant in the toxicity-adjusted case. Consistent with previous work with the US TRI, we test a quadratic specification that gives rise to an environmental Kuznet curve, exhibiting an inverted-U shape with a maximum point at around Cdn$50,000 (1991 prices) of household income, roughly the middle of the Canadian income distribution. This suggests that as economic activity increases, pollution and community wealth both increase to a point. However, beyond that point, wealthier residents either oppose siting of polluting facilities in the first place or "vote with their feet" after the fact.

Columns 2 and 4 provide some indication of whether facilities are changing their behavior over time in response to NPRI disclosure. However, it is important to acknowledge that, because we do not know what trends in toxic releases were prior to the introduction of NPRI, we can only assess whether trends post-NPRI are in the anticipated direction. In these regressions, we introduce two new variables: pollution intensity, defined as on-site releases per employee at a facility (lagged by one period), and the change in the log of employees, which we use as a surrogate for changes

[16] The NPRI provides employment data for each facility since 1994, but no output data. For the 1993 pollution data we employ 1994 employment data where available.

[17] We use the transfer share here because the log of the level is not defined when off-site transfers are zero.

in production levels.[18] The former is the single most important predictor of changes in on-site releases. Facility size is also a significant determinant of changes in on-site releases. In other words, larger and more pollution-intensive firms are the ones that are doing the most to reduce their on-site releases. This is consistent with Hamilton's (1999) finding in the US TRI data. Population density is significant only in the toxicity-adjusted case, but this again suggests that greater efforts are being made where the risks are greatest. These findings are consistent with the hypothesized "field levelling" effects of stakeholder pressure (Fung and O'Rourke, 2000) since one would expect consumers, workers, communities, and investors to put the most pressure on the most pollution-intensive and recognizable facilities. However, they could also reflect similar responses by regulators.[19] Consistent with the off-site substitution effect noted above, we find that reductions in on-site releases are accompanied by an increase in off-site transfers. The significance of the change in employees in both columns 2 and 4 also indicates that the growth rate of emissions is less than the employment growth rate. A closer look at our raw data reveals that big changes in emissions are rarely accompanied by big changes in employment. Since the number of employees at the facilities in our sample has been quite steady, changes in the scale of operation cannot have contributed much to changes in emissions. As in the previous regressions, we employ a quadratic specification to test for income effects, but the coefficients are significant in neither the toxicity-adjusted nor unadjusted cases. While our earlier findings suggest disparities in the distribution of toxic pollution among wealthy, middle-income, and poor communities, the dissemination of additional information about toxic releases via NPRI has neither exacerbated nor reduced those disparities.

Table 4 presents regressions comparable to those in Table 3. Our dependent variable in columns (1) and (3) is the log of off-site transfers rather than on-site releases, while the dependent variable in columns (2) and (4) is the change in the percentage share of off-site transfers with respect to on-site emissions and off-site transfers combined. In general, the coefficients are less statistically significant than those in Table 3. However, we find that larger facilities have higher off-site transfers as well as on-site releases. Consistent with the off-site substitution effect noted above, we find that more pollution intensive facilities have higher and increasing off-site transfers, even though they

[18] Unfortunately, we do not have access to production or sales data at the facility level.

[19] Kronos has been excluded from the analysis as an extreme outlier. However, greater reduction of discharges by more pollution intensive facilities could reflect an impact (among other regulatory actions) of the federal pulp and paper regulations, even after controlling for SIC via random effects, since those regulations for the first time mandated compliance by older, more polluting facilities, a difference that would not be captured by controlling for SIC.

are decreasing their on-site releases over time. We find significant income effects only with respect to unadjusted off-site transfers, but the signs of the coefficients consistently indicate that increasing community wealth initially decreases off-site transfers, but beyond about $60k (1991 prices) increases off-site transfers. This pattern is consistent with our earlier finding of substitution of off-site transfers for on-site releases.

In light of the apparent impact of national regulations on aggregate trends in NPRI releases, we have employed several different measures to explore the impact of regulation on on-site releases and off-site transfers. Unfortunately, there is no database of federal and provincial regulatory requirements at the facility level.[20] However, the regulatory process established by the Canadian Environmental Protection Act (CEPA) does provide opportunities to investigate the impact of both existing and threatened regulations. (It is noteworthy, however, that improvements made by Kronos and the pulp and paper industry were prompted by enforcement of the federal Fisheries Act.[21] Moreover, Kronos has been omitted from these regressions in any case because it is such an extreme outlier.[22]

CEPA establishes a step-by-step process by which toxic substances are identified, evaluated, and controlled. The first step is generation of a "Priority Substances List" (PSL). Substances on that list are then evaluated to determine whether they are toxic as defined by CEPA. Those deemed to be "CEPA-toxic" are moved to the "List of Toxic Substances," by which action various regulatory measures are authorized (though not required). As substances from the List of Toxic Substances are actually regulated, they join substances on Schedule 1, which were grandfathered from regulations under earlier statutes when CEPA became law in 1988.

In order to assess the impact of regulatory threats of increasing severity, we have identified three variables: CEPA schedule 1, CEPA-toxic (i.e., substances on the first PSL that were deemed toxic), and PSL 2. In each case, the variable represents the fraction of a facility's total waste production (i.e., on-site plus off-site) that falls within that regulatory category. One would expect an increasing regulatory threat as one moves from PSL2 to CEPA-toxic to Schedule 1. However, one complication from the perspective of the NPRI data is that although evaluation of the first Priority Substances

[20] Determination of regulatory requirements in Canada is complicated by the fact that provincial governments have taken the lead in regulating most sources, and that most provinces do so by allocating permits on a facility-by-facility basis.

[21] The pulp and paper industry was also subject to CEPA regulations concerning dioxins and furans, but these substances were not covered by NPRI during this period.

[22] The regressions also exclude one other outlier, the Giant gold mine in the Northwest Territories, which was just coming into production and thus dramatically increased its releases over the relevant period.

List was completed in 1993, a second Priority Substances List was not introduced until December of 1995. As such, the full impact of the second priority substance list may not yet be evident.

These three regulatory variables were included in the off-site transfer regressions reported in Table 4. All but one of the coefficients in columns 1 and 3 are significant. In particular, column 1 indicates a pattern where stricter regulation correlates with higher levels of off-site transfers. To a certain degree this may just reflect that plants subject to regulation tend to have higher toxic emissions. To control for this problem, columns 2 and 4 use the off-site transfer share as a regressor which is immune to this problem. In column 2 the CEPA Schedule 1 regressor remains significant, indicating that regulation has a non-negligible effect shifting the composition of off-site transfers and on-site emissions towards the former. By comparison, the regulatory threat variables have no significant effect.

Table 5 explores the impact of regulation on on-site releases. Here we have repeated the benchmark regressions in Table 3 for two subsets of facilities: those for which regulated schedule 1 substances comprise greater than 10% of total releases (columns 1 to 4), and those for which schedule 1 substances comprise less than 10% of total releases (columns 5 to 8). As in Table 3, the most statistically significant findings are those concerning size of facility, population density, pollution intensity, and off-site transfers. With respect to on-site releases as the dependent variable, comparison of columns 3 and 7 indicates that the unadjusted releases of "regulated facilities" tend to increase with size by more than those of "unregulated facilities."[23] However, comparison of columns 1 and 5 indicates that such facilities tend to increase their toxic-adjusted releases by only half as much as their unregulated counterparts in response to increases in scale of production. Similarly, we find that regulated facilities respond (or are forced to respond) more aggressively to population density than comparable unregulated facilities, as indicated by lower (i.e., more negative) coefficients in columns 1 and 3 relative to columns 5 and 7. Together, these two findings suggest that large and pollution intensive facilities that face federal government regulation tend to have lower toxic releases than comparable unregulated facilities. However, consistent with trends in the aggregate data, that risk reduction is to some extent being achieved via end-of-pipe techniques, as indicated by a stronger off-site transfer substitution effect among regulated facilities.

[23] "Unregulated facilities" here refers to an absence of regulation under CEPA. Such facilities may, however, be regulated under the federal Fisheries Act or provincial environmental statutes.

Analysis of the change in releases over time provides a similar picture. Comparison of columns 2 and 6 and 4 and 8 in Table 5 indicates that larger and more pollution-intensive facilities that release regulated substances have made greater reductions in their on-site releases over time than comparable unregulated facilities. These effects are especially pronounced after adjustment for toxicity, indicating not only that regulation is working but that facilities are not responding to chemical-specific regulation by substituting equally or more toxic alternatives. The effects of changes in off-site transfers are not significant in the unadjusted cases (columns 4 and 8). However, the difference in sign between these coefficients in columns 2 and 6 is noteworthy, suggesting that although on-site and off-site releases move in tandem for unregulated facilities, they are substitutes for regulated facilities. This suggests that although scale effects predominate for unregulated facilities, they are overwhelmed by a technique effect as regulated facilities adopt (end-of-pipe) control measures to reduce their releases.

The foregoing suggests that regulation works; risk increases associated with increasing scale of production and production in more densely populated regions have been curtailed by regulation, albeit to some degree through transfer of substances off-site for treatment and/or storage. In light of the growing attention to voluntary programs as an alternative to formal regulation, one might ask whether the mere threat of regulation might have the same effect. It would appear not. We have replicated the foregoing analysis in Table 6, excluding all observations where the share of CEPA Schedule 1 emissions is greater than 10% (i.e., facilities facing regulation), and then dividing facilities based on whether more or less than 10% of their releases were found to be "CEPA-toxic" when evaluation of the first priority substances list was completed in 1993. Though multi-stakeholder groups have considered alternative strategies and in some cases proposed voluntary programs to control these substances, none have been regulated to date under CEPA.

As in Table 5, we find a substitution effect in Table 6, with greater substitution of off-site transfers for on-site releases evident when facilities are threatened with regulation. However, the differences between the coefficients for facility size and population density in the matching "threatened" and "unthreatened" columns in Table 6 (i.e., columns 1 vs. 5 and 2 vs. 6) are much less pronounced than in Table 5. This suggests that facilities that are merely threatened with regulation under CEPA are doing considerably less to reduce their toxicity-adjusted on-site releases than comparable regulated facilities.

5 Conclusions

In this paper, we have built on a growing literature on information dissemination as a policy tool by extending past analyses of the US Toxic Release Inventory to the Canadian context using data from the National Pollutant Release Inventory. We have also tried to fill gaps in that literature, particularly by devoting attention to the impacts of regulation relative to information dissemination.

Our analysis suggests that the quite dramatic reduction in on-site releases observed during the first few years of the Canadian National Pollutant Release Inventory is less a product of better-informed communities, consumers, workers, and shareholders taking matters into their own hands than of governments pursuing quite traditional command-and-control regulation. In the Canadian case, whatever impacts disclosure of information concerning toxic discharges may be having "through honor and shame," (Afsah and Ratunanda, 1999)[24] they have apparently been overwhelmed by the influence of old-fashioned threats and punishment. Indeed, one of the most valuable, though little-acknowledged, functions of NPRI thus far has been in tracking the success of, rather than substituting for, regulation. Although the effects of regulation under the federal Fisheries Act are particularly pronounced, with coerced compliance by a single facility overwhelming all other effects during the period in question, absent that facility we still find strong effects of regulation under the Canadian Environmental Protection Act. Of particular interest in light of the growing attention to voluntary programs as an alternative to regulation, we find that Canadian facilities have responded much less aggressively to the mere threat of regulation.

The fact that bigger and more pollution-intensive facilities reporting to NPRI are the ones making the greatest effort to reduce their on-site releases provides considerable room for optimism. This was among the most significant findings of our statistical analysis of NPRI panel data. Although this effect was strongest among facilities facing federal regulation, it was highly significant for other facilities as well. However, we emphasize that this finding is consistent with several different mechanisms: pressures from non-governmental stakeholders, pressure from provincial regulators, and recognition by firms of opportunities to save money by reducing their discharges. It is also encouraging that, although significant inequities in the distribution of risk exist in Canada as they do in the US and other countries, there is no evidence that those inequities are being exacerbated (or reduced)

[24] Cited in Afsah et al. (2000).

by information dissemination.

Our analysis provides cause for concern in several respects, however. First, the reductions in on-site releases to date have been almost entirely a result of legally compelled reductions in releases to surface water. Indeed, the overwhelming impact of these reductions on the overall trend in on-site releases masks significant increases in some streams, including discharges to air, underground injection, and land application of wastes. Off-site transfers have also increased as on-site releases have declined. This suggests that reductions in on-site releases are being achieved largely through traditional end-of-pipe solutions, rather than source reduction, though we cannot say to what degree this is a response to NIMBY-type community pressures vs. regulation. Moreover, in light of the disproportionate reliance on storage options of underground injection and landfilling in managing wastes off-site, one might ask to what degree we are engaged in a shell game, with the apparent progress in reducing releases to date merely reflecting transfer of risks to other communities and future generations.

The disparate trends in releases to different media and transfers of wastes to other communities are even more worrisome when one considers the toxicity of different NPRI substances. Although the total weight of on-site releases has declined substantially, the toxicity-adjusted weight of releases has increased. In other words, the benefits of the reductions achieved to date in total releases may well have been outweighed by increases in the toxicity of those waste streams. It is noteworthy that regulated facilities appear to be reducing both the volume and toxicity of their releases. This suggests that facilities may be changing the composition of their releases in response to market-driven shifts in production or, alternatively, substituting low volume, high toxicity substances for high volume, low toxicity substances in response to naïve pressures from non-governmental stakeholders. In either case, the trend has yet to be acknowledged and addressed by Canadian regulators.

The foregoing analysis is based exclusively on Canadian data. One might expect more pronounced community effects in the US, where pollution intensive facilities are more prevalent in urban areas, and where there are also greater socio-economic disparities than in Canada. The greater pollution intensity of Canadian manufacturing industries relative to their US counterparts (Olewiler and Dawson, 1998) may also suggest the potential for stronger regulatory effects: there simply they may be more ”low hanging fruit” available for Canadian regulators to harvest. The implications of this for interpretation of trends in toxic release inventory data are less than clear-cut, however. On

one hand, the greater ease with which Canadian regulators may be able to deliver significant reductions might lead one to expect a greater impact of regulation on the Canadian pollutant inventory. On the other hand, the seemingly greater historical aggressiveness of US regulators suggests a need to carefully consider the degree to which the decline in US TRI reports may also be a response to regulation rather than stakeholder pressures.

Our analysis suggests that complacency with respect to the impact of pollutant information dissemination as a policy tool is premature. In the end, the Canadian National Pollutant Release Inventory Data most clearly reveals both the promise of regulation and the significant challenges that remain.

References

Afsah, Shakeb, Allen Blackman, and Damahanti Ratundanda (2000) "How Do Public Disclosure Pollution Control Strategies Work? Evidence from Indonesia's PROPER Program." Discussion Paper 00-44, Resources for the Future.

Ahearne, J. (1988) "Addressing public concerns in science," *Physics Today*, pp. 36–42.

Antweiler, Werner and Kathryn Harrison (2000) "Environmental Information, Consumers, and Workers: Economic Theory and Canadian Evidence." Working Paper, University of British Columbia.

Arora, S. and T. N. Cason (1996) "Why do firms volunteer to exceed environmental regulations? Understanding participation in EPA's 33/50 Program," *Land Economics, 74* (4), 413–432.

Baggs, Jen (1998) "Pollution Exposure, Economic and Community Characteristics: An Empirical Study of Pollution Distribution in Canada." M.A. thesis, Department of Economics, University of British Columbia.

Brooks, Nancy and Rajiv Sethi (1997) "The Distribution of Pollution: Community Characteristics and Exposure to Air Toxics," *Journal of Environmental Economics and Management, 32*, 233–250.

Decker, Christopher (1999) "Corporate Environmentalism and Regulatory Responsiveness: An Analysis of Count Data." Working Paper, Kelly School of Business, Indiana University.

Environment Canada (1994) *Summary Report, 1993: The National Pollutant Release Inventory*, Ottawa: Minister of Supply Services Canada.

—— (n.d.) *National Pollutant Release Inventory: Summary Report 1996*, Ottawa: Minister of Supply Services Canada.

Environmental Protection Agency (1992) "Environmental democracy in action: Community right-to-know." EPA 700-K-92-003.

Fung, Archon and Dara O'Rourke (2000) "Reinventing Environmental Regulation from the Grassroots Up: Explaining and Expanding the Success of the Toxics Release Inventory," *Environmental Management, 25*, 115–127.

Grant, Don Sherman (1997) "Allowing Citizen Participation in Environmental Regulation: An Empirical Analysis of the Effect of Right-to-Sue and Right-to-Know Provisions on Industry's Toxic Emissions," *Social Science Quarterly, 78*, 859–73.

Gunningham, Neil and Peter Grabosky (1998) *Smart Regulation: Designing Environmental Policy*, New York: Oxford.

Hamilton, James T. (1995) "Pollution as News: Media and Stock Market Reactions to the Toxics Release Inventory Data," *Journal of Environmental Economics and Management, 28*, 98–113.

—— (1999) "Exercising Property Rights to Pollute: Do Cancer Risks and Politics Affect Plant Emission Reductions," *Journal of Risk and Uncertainty, 18*, 105–124.

Harrison, Kathryn (1996) "The Regulator's Dilemma: Regulation of Pulp Mill Effluents in the Canadian Federal State," *Canadian Journal of Political Science, 29*, 469–496.

—— (1999) "Racing to the Top or Bottom? Industry Resistance to Ecolabelling of Paper Products in Three Jurisdictions," *Environmental Politics, 8*, 110–136.

—— **and George Hoberg** (1994) *Risk, Science, and Politics: Regulating Toxic Substances in Canada and the United States*, Montreal: McGill-Queen's University Press.

Hearne, Shelley A. (1996) "Tracking Toxics: Chemical Use and the Public's Right-to-Know," *Environment, 38*, 5–9, 28–34.

Hettige, H. R., E. B. Lucas, and D. Wheeler (1992) "The Toxic Intensity of Industrial Production: Global Patterns, Trends and Trade Policy," *American Economics Review, 82* (2), 478–481.

Horvath, Arpad, Chris T. Hendrickson, Lester B. Lave, Francis C. McMichael, and Tse-Sung Wu (1995) "Toxic Emissions Indices for Green Design and Inventory," *Environmental Science and Technology, 29*, 86A–90A.

Karkkainen, Bradley, Archon Fung, and Charles Sabel (2000) "After Backyard Environmentalism: Towards a New Model of Information-Based Environmental Regulation," *American Behavioral Scientist, 44*, 692–711.

Khanna, Madhu and Lisa A. Damon (1999) "EPA's Volunary 33/50 Program: Impact on Toxic Releases and Economic Performance of Firms," *Journal of Environmental Economics and Management, 37*, 1–25.

—— **, Wilma Rose H. Quimio, and Dora Bojilova** (1998) "Toxics Release Information: A Policy Tool for Environmental Protection," *Journal of Environmental Economics and Management, 36*, 243–266.

Kleindorfer, Paul R. and Eric W. Orts (1998) "Informational Regulation of Environmental Risks," *Risk Analysis, 18*, 155–170.

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*, 109–124.

Laplante, B. and P. Lanoie (1994) "Market Response to Environmental Incidents in Canada," *Southern Economic Journal, 60*, 657–672.

Leigh, J. Paul and Andrew M. Gill (1991) "Do Women Receive Compensating Wages for Risks of Dying on the Job?," *Social Science Quarterly, 72*, 727–737.

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

Maclean, Alair (1996) "The Right Stuff: Information in the Public Interest," *New Solutions, 6*, 48–58.

Maxwell, John W., Thomas P. Lyon, and Steven C. Hackett (1999) "Self-Regulation and Social Welfare: The Political Economy of Corporate Environmentalism." unpublished working paper.

Nash, J. and J. Ehrenfeld (1997) "Codes of environmental management practice: assessing their potential as a tool for change," *Annual Review of Energy and Environment, 22*, 487–535.

Natan Jr, Thomas E and Catherine G Miller (1998) "Are Toxic Release Inventory Reductions Real?," *Environmental Science and Technology, 3* (8), 368A–374A.

Olewiler, Nancy and Kelli Dawson (1998) "Analysis of National Pollutant Release Inventory Data on Toxic Emissions by Industry." Dept. of Finance, Canada, Working Paper 97-16.

Organisation for Economic Co-operation and Development (1996) *Pollutant Release and Transfer Registers (PRTRS): A Tool for Environmental Policy and Sustainable Development. Guidance Manual for Governments, OCDE/GD(96)32*, Paris: OECD.

—— (1997) *Eco-Labelling: Actual Effects of Selected Programmes. ECDE/GD(97)105*, Paris: OECD.

O'Toole Jr, Laurence J., Chilik Yu, Games Cooley, Gail Cowie, Susan Crow, Terry DeMeo, and Stephanie Herbert (1997) "Reducing Toxic Chemical Releases and Transfers: Explaining Outcomes for a Voluntary Program," *Policy Studies Journal, 24*, 11–26.

Pargal, Sheoli, Hamamala Hettige, Manjula Singh, and David Wheeler (1997) "Formal and Informal Regulation of Industrial Pollution: comparative Evidence from Indonesia and the United States," *World Bank Economic Review, 11*, 433–450.

Rich, Richard C., W. David Conn, and William L. Owens (1993) "Indirect Regulation' of Environmental Hazards through the Provision of Information to the Public: The Case of SARA, Title III," *Policy Studies Journal, 21*, 16–34.

Ringquist, Evan J. (1997) "Equity and the Distribution of Environmental Risk: The Case of TRI Facilities," *Social Science Quarterly, 78,* 811–829.

Robinson, James C. (1988) "Labour Union Involvement in Occupational Safety and Health, 1957-1987," *Journal of Health, Politics, Policy and Law, 13*, 453–68.

Ruhl, Suzi (1999) "Statutory Rape," *Environmental Forum, 16*, 19–27.

Ruis-Quintanilla, S. Antonio, John Gunge, Adrienne Freeman-Gallant, and Ed Cohen-Rosenthal (1996) "Employee Participation in Pollution Reduction: A Socio-Technical Perspective," *Business Strategy and the Environment, 5*, 137–144.

Shapiro, Marc D. (1998) "The Power of Information: Community Exposure and the Efficacy of State Information Regulation Policy." Paper presented at the Annual Meeting of the American Political Science Association.

—— (1999) "Equity and Information: Risks from Toxic Chemicals, Environmental Justice, and Information Regulation Policy." Paper presented at the annual meeting of the Association for Policy Analysis and Management, November 1999.

Smith, Steven Rathgeb and Helen Ingram (1993) "Public Policy and Democracy," in Helen Ingram and Steven Rathgeb Smith, eds., *Public Policy for Democracy*, Washington, DC: Brookings.

Terry, Jeffrey C. and Bruce Yandle (1997) "EPA's Toxic Release Inventory: Stimulus and Response," *Managerial and Decision Economics, 18* (6), 433–441.

Tietenberg, Tom (1998) "Disclosure Strategies for Pollution Control," *Environmental and Resource Economics, 11*, 587–602.

Vallely, Richard M (1993) "Public Policy for Reconnected Citizenship," in Helen Ingram and Steven Rathgeb Smith, eds., *Public Policy for Democracy*, Washington, DC: Brookings.

Table 1: Summary of Trends in On-Site Releases and Off-Site Transfers (tons of discharges unadjusted for toxicity)

(A) All Facilities Reporting							
Release Method	1993	1994	1995	1996	1997	1998	%-Chg. 1993-98
Air	94,682	106,091	103,597	97,974	109,466	107,287	13.3
Water	107,617	55,463	34,327	13,014	15,071	16,626	-84.6
Land	13,967	14,088	13,813	13,869	18,793	18,725	34.1
Underground Injection	9,364	14,265	15,809	17,821	18,225	16,599	77.3
Total On-Site Release	226,068	190,160	167,762	142,883	161,763	159,424	-29.5
Offsite Transfers	88,718	64,271	52,111	62,341	96,322	87,730	-1.1
Total Release	314,785	254,431	219,873	205,224	258,086	247,154	-21.5
(B) Subset of continuous reporters 1993 through 1998							
Release Method	1993	1994	1995	1996	1997	1998	%-Chg. 1993-98
Air	88,617	82,212	87,748	80,968	90,971	91,770	3.6
Water	95,435	41,658	21,246	11,591	10,607	12,181	-87.2
Land	13,445	11,820	10,797	10,092	12,790	12,193	-9.3
Underground Injection	9,361	9,340	11,908	14,786	16,021	13,969	49.2
Total On-Site Release	207,229	145,224	131,863	117,589	130,540	130,240	-37.2
Offsite Transfers	87,186	47,109	39,517	48,096	53,873	43,581	-50.0
Total Release	294,414	192,333	171,380	165,685	184,414	173,821	-41.0
(C) Same as (B) but without Kronos and SIC27							
Release Method	1993	1994	1995	1996	1997	1998	%-Chg. 1993-98
Air	69,046	69,238	74,367	68,292	77,967	78,132	13.2
Water	12,619	11,615	7,898	6,923	6,556	8,222	-34.8
Land	13,251	11,688	10,656	9,917	12,501	11,801	-10.9
Underground Injection	9,361	9,340	11,908	14,786	16,021	13,969	49.2
Total On-Site Release	104,637	102,071	104,989	100,065	113,191	112,248	7.3
Offsite Transfers	83,922	43,577	37,099	45,485	51,160	42,494	-49.4
Total Release	188,559	145,648	142,088	145,551	164,351	154,741	-17.9

Table 2: Summary of Trends in On-Site Releases and Off-Site Transfers (tons of discharges adjusted for toxicity with EPA exposure measures)

(A) All Facilities Reporting							
Release Method	1993	1994	1995	1996	1997	1998	%-Chg. 1993-98
Air	96,389	152,256	98,522	106,752	104,999	97,821	1.5
Water	24,682	16,587	8,498	6,318	3,751	2,970	-88.0
Land	67,386	87,091	83,895	90,201	88,534	99,164	47.2
Underground Injection	180	11,744	11,033	8,856	5,705	5,501	2949.6
Total On-Site Release	188,638	267,678	201,948	212,127	202,990	205,457	8.9
Offsite Transfers	101,544	132,089	212,474	250,768	414,245	338,830	233.7
Total Release	290,182	399,767	414,423	462,895	617,235	544,286	87.6
(B) Subset of continuous reporters 1993 through 1998							
Release Method	1993	1994	1995	1996	1997	1998	%-Chg. 1993-98
Air	95,474	97,154	95,470	102,707	100,192	90,275	-5.4
Water	17,961	16,107	8,163	6,209	3,685	1,931	-89.2
Land	66,810	80,919	75,933	81,982	80,707	71,399	6.9
Underground Injection	180	222	210	147	285	276	53.0
Total On-Site Release	180,425	194,401	179,776	191,045	184,869	163,881	-9.2
Offsite Transfers	77,138	121,842	179,870	196,932	294,164	219,811	185.0
Total Release	257,563	316,243	359,646	387,978	479,033	383,692	49.0
(C) Same as (B) but without Kronos and SIC27							
Release Method	1993	1994	1995	1996	1997	1998	%-Chg. 1993-98
Air	75,065	81,352	85,771	92,422	89,702	82,047	9.3
Water	17,901	16,039	8,150	6,203	3,680	1,927	-89.2
Land	66,772	80,893	75,931	81,982	80,705	71,398	6.9
Underground Injection	180	222	210	147	285	276	53.0
Total On-Site Release	159,918	178,506	170,063	180,754	174,373	155,648	-2.7
Offsite Transfers	77,092	121,811	179,850	196,912	294,144	219,807	185.1
Total Release	237,010	300,317	349,913	377,665	468,517	375,456	58.4

Figure 1: Trends in On-Site Releases and Off-Site Transfers (unadjusted, model A)

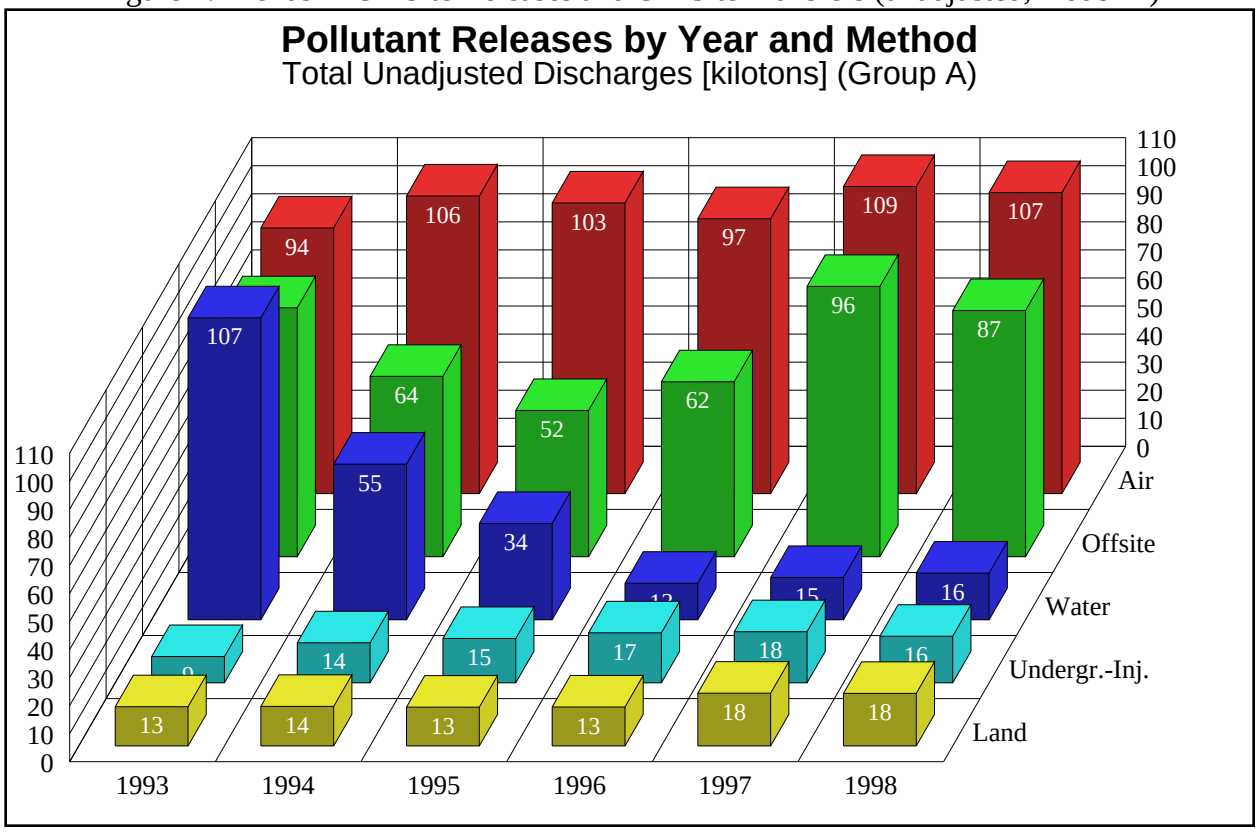

Figure 2: Trends in On-Site Releases and Off-Site Transfers (adjusted using EPA toxicity measures, model A)

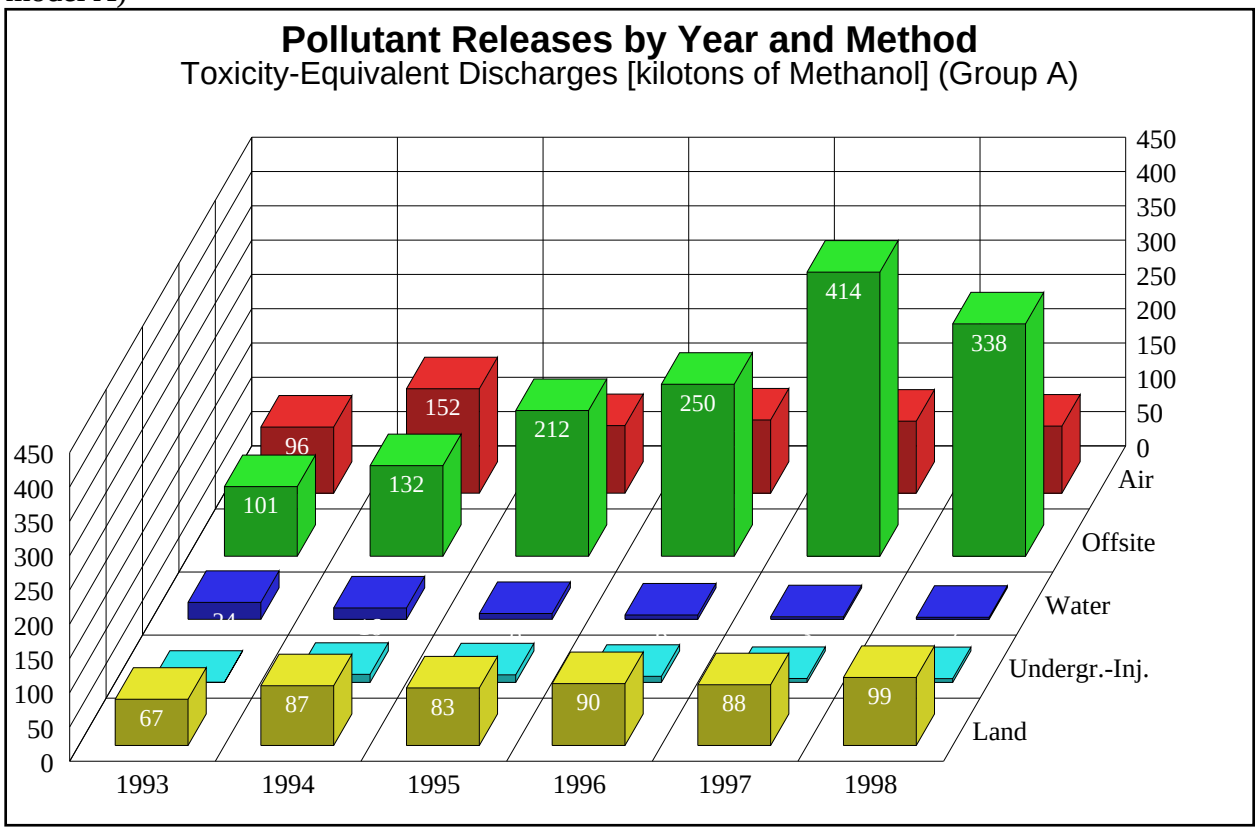

Figure 3: Trends in On-Site Releases (kilotons; unadjusted for toxicity)

Note: **A**: total on-site releases from all facilities reporting to NPRI each year. **B**: total on-site releases from the ”continuous reporter” subset of facilities, which reported to NPRI in each year 1993 through 1998. **C**: total on-site releases from ”continuous reporters” excluding the pulp and paper industry and the Kronos facility in Varenne, Québec.

Table 3: Benchmark Emission Regressions

Dep. Var. Adjustment	CHHI-Adjusted		Unadjusted	
Dependent Variable	x_{cit}	Δx_{cit}	x_{cit}	Δx_{cit}
Variable / Column	(1)	(2)	(3)	(4)
Intercept	-3.926^{c}	-1.243^{b}	-1.236^{c}	-0.337
	(7.39)	(3.01)	(3.44)	(1.02)
Log_{10} of employees at facility	0.970^{c}	-0.113^{c}	0.936^{c}	-0.154^{c}
	(23.07)	(3.23)	(30.70)	(5.46)
Change in employees (diff. of logs)		0.588^{c}		0.520^{c}
		(4.04)		(4.47)
% of Off-site Transfers	-0.009^{c}		-0.004^{c}	
	(13.97)		(10.12)	
Log Change in Off-site Transfers		0.097^{c}		0.047
		(3.66)		(1.56)
Log_{10} Pollution intensity (lagged)		-0.522^{c}		-0.706^{c}
		(64.55)		(111.9)
Income of Region ($10k)	0.640^{b}	0.177	0.131	0.025
	(3.08)	(1.10)	(0.96)	(0.19)
Income squared	-0.063^{b}	-0.018	-0.010	-0.001
	(3.17)	(1.19)	(0.78)	(0.06)
Log_{10} Population Density	-0.137^{c}	-0.056^{a}	-0.055^{b}	-0.032
	(4.61)	(2.27)	(2.60)	(1.62)
Time Trend	-0.009	-0.063^{c}	-0.039^{c}	-0.066^{c}
	(0.80)	(5.38)	(4.67)	(7.04)
Observations	5220	4329	5274	4329
Groups	108	106	108	106
Adj./Pseudo R^2	0.205	0.4217	0.1847	0.7086
Hausman Test / Wald χ^2(df)	7.4	43.72	13.37	67.02

Note: The dependent variable $x_{cit} \equiv \log_{10}(X_{cit})$ is the decadic logarithm of the amount of on-site releases, while $\Delta x_{cit} \equiv x_{cit} - x_{ci,t-1}$ is the log change in on-site releases. Index cit indicates company c in industry i in year t. In columns (1) and (2), on-site releases were adjusted for toxicity using EPA-CHHI measures, while in columns (3) and (4) unadjusted figures were used. Estimation method is random effects (R.E.) in all cases based on 3-digit Canadian-SIC industry groups. Observations where on-site releases are zero were excluded from this set of regressions. T-statistics (without sign) are given in parentheses. Significance at the 95% and 99%, and 99.9% levels are indicated with the superscripts a, b and c.

Table 4: Offsite Transfers

Dep. Var. Adjustment	CHHI-Adjusted		Unadjusted	
Dependent Variable	o_{cit}	$\Delta\hat{O}_{cit}$	o_{cit}	$\Delta\hat{O}_{cit}$
Variable / Column	(1)	(2)	(3)	(4)
Intercept	-1.383	13.606	1.553^{b}	6.544
	(1.76)	(1.42)	(2.69)	(0.61)
Log_{10} of employees at facility	0.387^{c}	-0.095	0.437^{c}	-1.701^{a}
	(6.23)	(0.14)	(9.60)	(2.32)
Change in employees (diff. of logs)		-5.280		2.863
		(1.64)		(0.73)
Log_{10} pollution intensity	0.219^{c}		0.138^{c}	
	(9.68)		(8.34)	
Log_{10} Pollution intensity (lagged)		1.604^{c}		0.048
		(8.77)		(0.24)
Income of Region ($10k)	-0.264	-3.632	-0.645^{b}	-0.977
	(0.85)	(0.96)	(2.83)	(0.23)
Income squared	0.024	0.344	0.056^{b}	0.083
	(0.80)	(0.94)	(2.58)	(0.21)
Log_{10} Population Density	0.040	0.697	0.068^{a}	0.045
	(0.86)	(1.36)	(1.96)	(0.08)
CEPA Schedule 1	2.356^{c}	2.568^{a}	0.160^{a}	1.672
	(23.90)	(1.98)	(2.19)	(1.16)
CEPA Toxic	0.264^{c}	-0.297	-0.118^{a}	1.651
	(3.90)	(0.34)	(2.35)	(1.69)
PSL 2 [share]	-0.126	0.013	0.253^{c}	2.371^{b}
	(1.90)	(0.02)	(5.21)	(2.58)
Time Trend	0.040^{a}	-0.450	0.024	-0.648^{a}
	(2.33)	(1.73)	(1.86)	(2.05)
Observations	2599	4278	2713	4329
Groups	90	106	92	106
Adj./Pseudo R^2	0.3872	0.0203	0.0929	0.0042
Hausman Test / Wald χ^2(df)	16.56	15.54	11.38	13.28

Note: The dependent variable $o_{cit} = \log_{10}(O_{cit})$ is the logarithm of the amount of offsite transfers O_{cit}, adjusted for toxicity using EPA-CHHI measures in column (1) and unadjusted for toxicity in column (3). Index cit indicates company c in industry i in year t. The measure $\Delta\hat{O}_{cit} \equiv \hat{O}_{cit} - \hat{O}_{ci,t-1}$ is the change in the percentage share $\hat{O}_{cit} = 100O_{cit}/(O_{cit} + X_{cit})$ of offsite transfers with respect to the total of offsite transfers O_{cit} and on-site releases X_{cit}. $\Delta\hat{O}_{cit}$ is adjusted for toxicity in column (2) and unadjusted in column (4). Estimation method is random effects (R.E.) in all cases based on 3-digit Canadian-SIC industry groups. Observations where on-site releases are zero were excluded from this set of regressions. T-statistics (without sign) are given in parentheses. Significance at the 95% and 99%, and 99.9% levels are indicated with the superscripts a, b and c.

Table 5: Regressions with sample split into two groups depending on the proportion of emissions subject to CEPA Schedule 1 regulation: columns (1)-(4) where emission share is above 10%, and columns (5)-(8) where emission share is below 10%

Dep. Var. Adjustment	CHHI-Adjusted		Unadjusted		CHHI-Adjusted		Unadjusted	
Dependent Variable	x_{cit}	Δx_{cit}	x_{cit}	Δx_{cit}	x_{cit}	Δx_{cit}	x_{cit}	Δx_{cit}
Variable / Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	-1.068	0.328	-6.407^{c}	-2.332^{a}	-3.969^{c}	-1.641^{c}	-1.012^{b}	-0.396
	(0.80)	(0.23)	(5.58)	(2.03)	(7.82)	(4.03)	(2.75)	(1.15)
Log_{10} of employees at facility	0.466^{c}	-0.450^{c}	0.944^{c}	-0.160^{a}	0.924^{c}	-0.124^{c}	0.917^{c}	-0.155^{c}
	(5.18)	(4.56)	(12.19)	(2.06)	(22.61)	(3.50)	(28.48)	(5.15)
Change in employees (diff. of logs)		1.384^{c}		0.693^{b}		0.508^{c}		0.504^{c}
		(4.11)		(2.62)		(3.39)		(3.97)
% of Off-site Transfers	-0.017^{c}		-0.009^{c}		-0.014^{c}		-0.003^{c}	
	(14.19)		(8.56)		(19.89)		(8.64)	
Log Change in Off-site Transfers		-0.113^{a}		0.009		0.111^{c}		0.053
		(2.01)		(0.13)		(3.97)		(1.58)
Log_{10} Pollution intensity (lagged)		-0.734^{c}		-0.733^{c}		-0.540^{c}		-0.712^{c}
		(34.28)		(38.19)		(63.98)		(107.3)
Income of Region ($10k)	0.766	0.150	2.365^{c}	0.863	0.592^{b}	0.241	0.067	0.051
	(1.41)	(0.26)	(5.11)	(1.87)	(2.99)	(1.52)	(0.47)	(0.38)
Income squared	-0.052	-0.007	-0.212^{c}	-0.070	-0.056^{b}	-0.022	-0.004	-0.003
	(0.96)	(0.13)	(4.54)	(1.52)	(2.94)	(1.49)	(0.32)	(0.26)
Log_{10} Population Density	-0.339^{c}	-0.227^{b}	-0.389^{c}	-0.341^{c}	-0.125^{c}	-0.052^{a}	-0.031	-0.016
	(4.44)	(2.75)	(5.89)	(5.23)	(4.39)	(2.13)	(1.41)	(0.76)
Time Trend	-0.011	-0.084^{a}	-0.050^{a}	-0.046	-0.006	-0.061^{c}	-0.038^{c}	-0.067^{c}
	(0.45)	(2.56)	(2.32)	(1.81)	(0.56)	(5.29)	(4.42)	(6.85)
Observations	541	460	546	460	4679	3869	4728	3869
Groups	42	43	43	43	105	102	105	102
Adj./Pseudo R^2	0.32	0.5645	0.1897	0.6273	0.2391	0.4496	0.1808	0.719
Hausman Test / Wald χ^2(df)	14.06	16.04	8.36	40.97	7.95	100.12	10.15	30.35

Note: The dependent variable $x_{cit} \equiv \log_{10}(X_{cit})$ is the decadic logarithm of the amount of on-site releases, while $\Delta x_{cit} \equiv x_{cit} - x_{ci,t-1}$ is the log change in on-site releases. Index cit indicates company c in industry i in year t. In columns (1) and (2), on-site releases were adjusted for toxicity using EPA-CHHI measures, while in columns (3) and (4) unadjusted figures were used. Estimation method is random effects (R.E.) in all cases based on 3-digit Canadian-SIC industry groups. Observations where on-site releases are zero were excluded from this set of regressions. T-statistics (without sign) are given in parentheses. Significance at the 95% and 99%, and 99.9% levels are indicated with the superscripts a, b and c.

Table 6: Regressions with sample which is not subject to CEPA Schedule 1 regulation split into two groups depending on the proportion of emissions subject to CEPA Toxic Regulatory Threat: columns (1)-(4) where emission share is above 10%, and columns (5)-(8) where emission share is below 10%

Dep. Var. Adjustment	CHHI-Adjusted		Unadjusted		CHHI-Adjusted		Unadjusted	
Dependent Variable	x_{cit}	Δx_{cit}	x_{cit}	Δx_{cit}	x_{cit}	Δx_{cit}	x_{cit}	Δx_{cit}
Variable / Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	-2.299^{b}	-1.775^{a}	-2.092^{b}	-0.666	-3.946^{c}	-1.673^{c}	-0.721	-0.392
	(3.07)	(2.42)	(3.08)	(1.03)	(6.52)	(3.47)	(1.71)	(0.97)
Log_{10} of employees at facility	0.782^{c}	-0.096	1.007^{c}	-0.122^{a}	0.853^{c}	-0.182^{c}	0.814^{c}	-0.217^{c}
	(12.44)	(1.57)	(17.38)	(2.22)	(17.56)	(4.26)	(21.64)	(6.04)
Change in employees (diff. of logs)		0.119		0.133		0.741^{c}		0.704^{c}
		(0.47)		(0.60)		(4.20)		(4.77)
% of Off-site Transfers	-0.019^{c}		-0.005^{c}		-0.012^{c}		-0.002^{c}	
	(19.61)		(7.61)		(14.33)		(4.89)	
Log Change in Off-site Transfers		0.014		0.016		0.128^{c}		0.079
		(0.33)		(0.31)		(3.69)		(1.93)
Log_{10} Pollution intensity (lagged)		-0.603^{c}		-0.729^{c}		-0.555^{c}		-0.726^{c}
		(39.03)		(57.31)		(55.12)		(94.71)
Income of Region ($10k)	0.511	0.451	0.607^{a}	0.201	0.498^{a}	0.202	0.003	0.078
	(1.76)	(1.58)	(2.30)	(0.80)	(2.09)	(1.08)	(0.02)	(0.50)
Income squared	-0.055	-0.048	-0.060^{a}	-0.023	-0.044	-0.017	0.001	-0.005
	(1.95)	(1.76)	(2.36)	(0.96)	(1.92)	(0.94)	(0.08)	(0.35)
Log_{10} Population Density	-0.153^{c}	-0.092^{a}	-0.102^{b}	-0.030	-0.121^{c}	-0.049	-0.025	-0.020
	(3.51)	(2.18)	(2.58)	(0.79)	(3.64)	(1.70)	(0.98)	(0.81)
Time Trend	0.007	-0.070^{c}	-0.034^{a}	-0.076^{c}	-0.011	-0.052^{c}	-0.041^{c}	-0.067^{c}
	(0.40)	(3.43)	(2.17)	(4.24)	(0.87)	(3.86)	(4.15)	(5.89)
Observations	1211	1012	1211	1012	3468	2857	3517	2857
Groups	62	62	62	62	99	96	99	96
Adj./Pseudo R^2	0.4129	0.5726	0.173	0.7197	0.2271	0.4339	0.1886	0.7197
Hausman Test / Wald χ^2(df)	8.48	20.26	16.31	22.28	10.15	14.42	10.8	14.54

Note: The dependent variable $x_{cit} \equiv \log_{10}(X_{cit})$ is the decadic logarithm of the amount of on-site releases, while $\Delta x_{cit} \equiv x_{cit} - x_{ci,t-1}$ is the log change in on-site releases. Index cit indicates company c in industry i in year t. In columns (1) and (2), on-site releases were adjusted for toxicity using EPA-CHHI measures, while in columns (3) and (4) unadjusted figures were used. Estimation method is random effects (R.E.) in all cases based on 3-digit Canadian-SIC industry groups. Observations where on-site releases are zero were excluded from this set of regressions. T-statistics (without sign) are given in parentheses. Significance at the 95% and 99%, and 99.9% levels are indicated with the superscripts a, b and c.