DISCUSSION PAPER

June 2015; revised October 2015 ■ RFF DP 15-23-REV

A Retrospective Study of EPA's Air Toxics Program under the Revised Section 112 Requirements of the Clean Air Act

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This paper is one in a series of retrospective analyses from RFF's Regulatory Performance Initiative. www.rff.org/regulatoryperformance.

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RESOURCES FOR THE FUTURE

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Abstract

Under the 1990 Clean Air Act Amendments, the US Environmental Protection Agency (EPA) was required to establish standards limiting air toxics emissions from industrial plants. This paper examines the effect of five of the largest cost rules issued by EPA in the initial round of air toxics rulemaking over the 1995 to 2000 period. Our estimates suggest that plants in the printing and publishing and pulp and paper industries realized important reductions in their air toxics emissions in the period between publication of the final rule and the effective date for compliance with the rule—although the reduction in air toxics emissions by pulp and paper mills falls short of EPA's ex ante projections. However, our estimates suggest that plants in the other three industries—petroleum refining, pharmaceutical, and wood furniture—achieved little or no additional reduction in air toxics emissions over the compliance period in response to EPA's air toxics rules. Finally, the paper explores steps that EPA should take in setting up future retrospective analyses.

Key Words: air toxics emissions, regulation, emissions reductions

Contents

A Retrospective Study of EPA's Air Toxics Program under the Revised Section 112 Requirements of the Clean Air Act

Art Fraas and Alex Egorenkov*

The 1990 Clean Air Act (CAA) Amendments revised the provisions addressing air toxics emissions by requiring the US Environmental Protection Agency (EPA) to set technology-based standards for major sources of air toxics. Congress turned to a technology-based approach because EPA had managed to regulate only a few air toxics and their sources in 20 years of regulation under the 1970 CAA. Technology-based standards were a core piece of the 1977 Clean Water Act (CWA), and their implementation over the 1980s was widely viewed as achieving substantial reductions in the industrial discharge of toxics in water. Through the 1990 CAA Amendments to Section 112, Congress hoped to replicate the CWA experience with a widespread initiative to reduce toxic air emissions.

This retrospective study seeks to evaluate the effectiveness of the 1990s round of air toxics rules issued by EPA pursuant to the 1990 CAA Amendments. We also want to identify ways to improve the ex ante analysis of regulations and what needs to be done to conduct retrospective analyses. Section 1 provides some background, including a summary of the literature. Section 2 outlines our methodology, and Section 3 presents the results. Section 4 discusses lessons learned.

1. Background

1.1. Regulatory Context

Prior to adoption of the 1990 CAA Amendments, EPA had authority to regulate individual air toxics based on their specific health risks. From 1970 to 1990, EPA regulated seven air toxics emitted by a small number of sources. To speed up EPA regulation of air toxics, Congress adopted the 1990 CAA Amendments, which focused regulation on the variety of air

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* Visiting fellow and research assistant, respectively, Resources for the Future. We received financial support for the research from the Sloan and Smith-Richardson foundations. We thank Wayne Gray and Ron Shadbegian for sharing their data for pulp and paper mills and for the League of Conservation Voters index and for their helpful comments on an earlier draft of the paper. We also thank Ann Wolverton and others at the Regulatory Performance Initiative workshop held at Resources for the Future for helpful comments. In addition, we received helpful comments from Randy Lutter and Richard Morgenstern.

toxics emitted by a source category, rather than setting standards one chemical at a time. Section 112, as amended by the 1990 CAA, lists 188 air toxics subject to regulation and charges EPA with identifying major source categories and establishing a schedule for regulation.[1] In 1992, EPA identified 174 categories of sources subject to air toxics emissions standards (57 FR 31576).Section 112 also establishes specific requirements for setting technology-based emissions limits, known as maximum achievable control technology (MACT) standards, which are to be based on the average level of control achieved by the best-performing 12 percent of sources within the relevant industry—the so-called MACT floor.[2] These standards are intended to raise the laggards to the level of the best performers in the industry, rather than force the adoption of exotic and unproven technologies. EPA can adopt more stringent standards beyond the MACT requirements, taking into account a variety of factors, including technological and economic feasibility, cost and effectiveness, and the expected additional risk reduction achieved. In practice, however, EPA has generally adopted emissions standards based on the MACT floor.[3]

Some states also operated programs to reduce air toxics emissions. California and New Jersey, for example, were early movers in setting up programs to reduce air toxics emissions in the 1980s.

1.2. Literature Review

Relatively little research has retrospectively evaluated the industry-specific, technology-based emissions standards for toxic pollutants that EPA has issued to implement the Section 112 MACT standard requirements of the CAA. One such study was recently completed by EPA, which conducted a retrospective cost study of its 1998 pulp and paper Cluster Rule. The study concludes:

> Our findings suggest EPA's ex ante cost estimates overstated the costs of both the Cluster Rule and the MACT II rule. Using publicly available data from NCASI, we found that EPA overestimated the capital cost of the Cluster Rule by 30 to 100 percent, depending on the choice of baseline year from which we derived the incremental cost. Among the reasons for EPA's overestimates of these capital costs are the mills' use of the clean condensate alternative (CCA), flexible

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1 http://www.epa.gov/apti/video/CAAModules/Mod3/CleanAir101Module3AirToxics.pdf.

2 If there are fewer than 30 sources in a source category, the MACT floor must reflect the average level of control achieved by the best-performing 5 sources.

3 For convenience, we will refer to the air toxics standards as MACT standards, even though in some cases the standards were set at levels more stringent than the MACT floor.

> compliance options, extended compliance schedules, site-specific rules, use of equivalent-by-permit, and equipment/mill shutdowns and consolidations. However, the lack of detail in the available data means we can only speculate on which reason(s) is primarily responsible for EPA's overestimate (EPA 2014b, 55).

As part of RFF's Regulatory Performance Initiative, Gray and Shadbegian (2015) examine the effect of EPA's 1998 Cluster Rule on the toxic releases from pulp and paper mills. They report that chloroform releases fell dramatically throughout the sample period, with much of the reduction happening in the 1990s, before the effective date of the Cluster Rule. They find that BAT plants had reductions in chloroform air releases of 99 percent and also report some reduction in other air toxics and VOC emissions—although the reduction is smaller than EPA's ex ante projection for air toxics and in their fixed effects models for VOCs. Finally, they report no significant reduction for fine particulate emissions.

Several retrospective studies have been conducted on other EPA programs aimed at reducing releases of toxic pollutants into the environment, however, including the Toxics Release Inventory (TRI) program and EPA's voluntary programs such as the 33/50 Program and the Common Sense Initiative.

1.2.1. EPA's Toxic Release Inventory (TRI) Program

The TRI program provides annual data on toxic releases from reporting plants beginning in 1988. Reported TRI releases decreased by 37 percent in the first years of the program, from 1988 to 1993, but decreases in reported releases slowed to only a 10 percent reduction between 1993 and 1998 (Hamilton 2005).

A number of studies have examined the effect of the TRI program on toxic releases in the earliest years of the program. Hamilton (1995), Konar and Cohen (1997), and Khanna et al. (1998) state that in the initial years, firms reporting relatively higher TRI releases incurred abnormal losses in stock value. Konar and Cohen (1997) and Khanna et al. (1998) note that these losses in turn resulted in subsequent reductions in on-site toxic releases from 1990 to 1994.

However, Hamilton (2005, 250) points out that given the current state of research, "one cannot say what fraction of reported reductions in TRI arose from the provision of information rather than from other factors, such as command-and-control regulation or market-related fluctuations in production." Other studies appear to support this conclusion. Konar and Cohen (1997) report that they were unable to find any evidence that firms receiving significant negative media attention with respect to their TRI releases reduced their emissions more than other firms of similar size. Kraft et al. (2011, 55) conclude that "the evidence indicates that community pressure does not seem to be a driving force behind chemical management decisions. Rather regulation and concern about potential financial liability more strongly affect corporate decisions about chemical management."[4]

Overall, the largest direct effect of TRI on emissions is likely to have occurred—if at all—only in the first few years of TRI reporting and affected only the largest emitting firms. Thus we believe that the "announcement effect" of TRI had largely dissipated prior to the period of interest for our retrospective study.

1.2.2. EPA's Voluntary 33/50 Program

EPA also sponsored the voluntary 33/50 Program to promote reductions in the releases of 17 target chemicals in the early 1990s.[5] The goal of the program was to reduce the total amount of the target chemicals released into the environment and transferred off-site by 33 percent by the end of 1992 and 50 percent by the end of 1995. EPA adopted the program because it was seeking quick reductions through a voluntary effort without relying on regulatory requirements. Through this program, EPA sought to encourage industry to develop pollution prevention practices and seek continual environmental improvements to go beyond the targeted reductions (EPA 1991).

In a retrospective report on the 33/50 Program, EPA (1999b) states the following:

- The program achieved its goal by 1994, one year ahead of schedule, primarily through program participants' efforts. Although the largest reductions in 33/50 Program chemicals reflected US action to phase out ozone-depleting chemicals under the Montreal Protocol, facilities also reduced releases and transfers of the other 33/50 chemicals by 50 percent from 1988 to 1995.[6]

[4] Kraft et al. (2011) report that relatively few people and community groups appear to make direct use of the TRI data. Further, they state that media attention to the annual TRI release dropped off sharply after the early reports of the 1980s and early 1990s. Similarly, Hamilton (2005, 217–18) reports that a 1991 GAO study and a later paper by Atlas, Vasu, and Dimock both found that most of the population "remains rationally ignorant about the TRI data" and does not seek out the data.

[5] These 17 chemicals were selected because they were deemed to be high-volume, toxic chemicals with feasible control costs.

[6] Gamper-Rabindran (2006) reports that the mandatory phase-out of 2 ozone depleting chemicals, out of the 17 targeted chemicals, accounted for a significant fraction of 33/50 Program reductions. She also finds that for most industries, there was little difference between participants and nonparticipants in the reduction in health-indexed emissions of target chemicals.

- Facilities reported more source reduction activity (pollution prevention) for 33/50 chemicals than for other TRI chemicals, and this activity covered a greater percentage of production-related waste for 33/50 chemicals than for other TRI chemicals.
- Reductions continued at a higher rate for 33/50 chemicals than for other TRI chemicals in the year after the 33/50 Program ended.

Khanna and Damon (1999) offer support for EPA's finding, reporting that the program achieved the expected reduction in emissions by participating chemical firms over its first three years (1991–93). Other studies of the 33/50 Program yield a mixed picture. Innes and Sam (2008), Sam et al. (2009), and Bi and Khanna (2012) also find that the 33/50 program was effective in achieving additional reductions in emissions. However, while Sam et al. (2009) report that participating firms continued to achieve further reductions after the program ended, Innes and Sam (2008) and Bi and Khanna (2012) find that the 33/50 program achieved the reductions in the early years of the program, with the strongest effect in 1992, but that participating firms did not achieve significant additional reductions after the program ended. Gamper-Rabindran (2006) finds that only 33/50 participants from some specific sectors achieved additional reductions over the course of the program.

Further, Khanna and Vidovic (2001) and Vidovic and Khanna (2012) reach an even stronger conclusion that the 33/50 Program had little overall effect on emissions. Vidovic and Khanna (2012) suggest that participating facilities would have reduced emissions of the targeted chemicals anyway, for reasons not directly related to the 33/50 Program. They note, for example, that the TRI program and the Chemical Manufacturers Association voluntary Responsible Care program—launched two years before the 33/50 Program, may have already prompted participating plants to reduce their toxic releases.

To the extent that the 33/50 Program affected emissions behavior over the period of interest, we believe it primarily affected emissions behavior in the years before 1995.

1.2.3. Other EPA Voluntary Programs

In the wake of the 33/50 Program, EPA launched a number of other voluntary programs to encourage firms to take environmentally beneficial steps beyond the requirements mandated by regulation. In the period of interest to us (1995–2001), these voluntary programs included the Common Sense Initiative (1994–98), National Environmental Performance Track (2000–9), and

Project XL (1995–2003). The assessment of these programs by Coglianese and Nash (2014) and Coglianese and Allen (2003) is that they did not yield significant environmental improvements.[7]

The Common Sense Initiative (CSI) focused on six industries. CSI only completed 4 regulations that affected emissions behavior. None of the 4 rules involved industries addressed in this study.[8] (Coglianese and Allen 2003).

Coglianese and Nash report that Project XL succeeded in recruiting only a small number of firms—roughly 50—and "lost steam" within a few years of starting operation, falling far short of its goals (2014, 10, 71–73).

Performance Track was just getting started at the end of the period covered by this study.[9] This program offered participating firms certain regulatory benefits—a reduction in certain regulatory requirements and lower priority for routine inspections—and public recognition from EPA.[10] In turn, participating firms needed to achieve specific environmental goals (self-identified by the firm) beyond existing regulatory requirements and maintain a relatively clean record of compliance with existing regulatory standards. Coglianese and Nash conclude that "facilities participating in Performance Track simply could not be shown to be top performers. Rather, what most distinguished these participants was a factor distinct from environmental

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[7] EPA's Inspector General (IG) reported a similar conclusion with respect to EPA's Performance Track program: "Performance Track cannot gauge changes in facilities' overall environmental improvement because they only report on their predefined commitments. … Thus, EPA cannot tell if facilities made overall environmental improvements, or rather improved in one area and faltered in others" (2007, 19–22).

[8] Coglianese and Allen (2003) report that three-quarters of the CSI projects were directed toward research or educational outreach with no direct effect on environmental releases. For petroleum refining and printing and publishing, the CSI projects were small-scale research programs or pilot projects that were unlikely to have any effect on the air toxics emissions of these two industries over the period of interest (Coglianese and Allen 2003). While review of the MACT rule was not identified as one of the proposed projects for the CSI Printing Subcommittee, the final printing and publishing MACT included a pollution prevention option allowing plants to use materials that were low in hazardous air pollutants (known as "low-HAP" materials), an option reflecting the "pollution prevention" principle in the Advisory Committee Charter for the CSI program (61 FR 27133). Coglianese and Allen conclude that "CSI was generally tall on ambition but short on meaningful and measurable accomplishment" (2003, 7–8).

[9] The initial group of participating facilities was selected by the end of 2000. The first progress report on Performance Track gave results for 2003 (Coglianese and Nash 2014).

[10] In its 2007 report, EPA's IG noted that while many members outperformed their sector, "Performance Track does not know if its members are 'top performers,'" and EPA "also found member facilities with more compliance problems or more toxic releases than their sector averages" (26–27). Performance Track was terminated by the Obama administration on May 14, 2009. Just prior to her nomination as EPA administrator by President Obama, Lisa Jackson characterized Performance Track in a *Philadelphia Inquirer* story as "just one of those window-dressing programs that has little value" (Coglianese and Nash 2014, 8).

quality, namely their propensity to engage in outreach with government and community groups" (2014, 1).

Overall, we believe that these programs had little effect on the emissions behavior of plants in the covered industries over the period of interest.

1.2.4. State Programs

States have also pursued both voluntary approaches to the management of toxic chemicals as well as more stringent toxics regulation.[11] However, State programs differ substantially in terms of their stringency and effectiveness. Generally, States in the Northeast and on the west coast adopted more effective toxics programs.[12]

Bui (2005) finds that refineries in states with more stringent toxics regulation in the form of pollution prevention programs had significantly lower levels of emissions than refineries in states with weaker or no regulation. Bui also reports, though, that reductions in toxic emissions intensity were closely related to traditional command-and-control regulation of nontoxic conventional pollutants.[13]

Bui and Kapon (2012, 43) find "strong evidence that both Federal and State P2 programs have led to significant reductions in average facility-level toxic releases." They also report the following:

- Facility-level responses to Pollution Prevention programs differ across program type, while industry-specific technical assistance programs are consistently effective.
- Spillovers from information-based programs operating through industry networks appear to play an important role in the success of these programs.

[11] For example, twenty-seven states had pollution prevention programs in place by 1990, and 48 states had programs in place by mid-1991. (Bui & Kapon, 2012) Thus these programs were in place before the period covered by this study.

[12] Kraft et al. (2011) rank states in terms of the proportion of firms achieving a reduction in toxic chemical releases and the reduction in population exposure risk from 1991 to 1995. On the basis of their ranking, for example, California was sixth in the nation, and "all of the northeastern states fell within the top two tiers of state industrial environmental performance" (2011, 96). Of the 14 states identified by Bennear (2007) as adopting management-based regulations, eight were located in the Northeast or on the west coast.

[13] Bui (2005) did not address the effect of the 1995 MACT rule limiting toxic air emissions from petroleum refineries.

Finally, Gray and Shadbegian (2008) also have found that States with stronger political support for stringent regulation had lower toxic emissions over their sample period (1996-2005).

1.3. Air Toxics Rules for Manufacturing

We started with 21 MACT rules issued between December 1994 and December 1999. We excluded nonmanufacturing source categories adopted within this period—commercial dry cleaning, gasoline distribution, marine vessel loading operations, shipbuilding and ship repair, and off-site waste recovery operations— because they are not manufacturing operations and are generally likely to have dispersed, fugitive emissions that are difficult to monitor.[14] We also excluded three source categories—flexible polyurethane foam production, basic liquid epoxy resins, and elastomer production—that apply to specific chemical manufacturing processes that would likely be part of a much larger-production chemical plant.[15] After excluding these 8 categories, we were left with 13 MACT rules addressing manufacturing industry categories.

However, we found that small sample size effectively ruled out analysis for 8 of the 13 manufacturing rules. EPA projected that MACT rules would cover only a small number of plants in the magnetic tape (13 plants), primary aluminum (17), and secondary lead smelters (22) categories. In each of these cases, the number of plants consistently reporting to TRI was substantially smaller. In addition, we found that only a small number of plants consistently reported to TRI in the aerospace, chromium electroplating, commercial sterilizer, halogenated solvent cleaning machine, and polyethylene terephthalate polymer and styrene (Group IV) industry categories. Because of the very limited emissions data available for these industry categories, we did not carry out a further evaluation of the effect of the MACT rules on emissions behavior for these categories. EPA projected relatively small compliance costs for most of the rules we dropped from the analysis. (See Appendix A for EPA's cost estimates for these 8 manufacturing MACT rules.)

Thus our analysis covers five industry categories: petroleum refining, pharmaceuticals, printing and publishing, pulp and paper, and wood furniture. The MACT rules for these five

[14] Gasoline distribution and off-site waste recovery operations were added to TRI reporting in 1998; dry-cleaning establishments are not subject to TRI reporting.

[15] In addition, only a relatively small number of facilities were subject to these MACT rules. EPA projected that 11 facilities would be subject to the basic liquid epoxy resins MACT, 26 facilities would be subject to the elastomer production MACT, and 45 facilities would be subject to the flexible polyurethane foam production MACT.

categories include many of the more significant MACT rules issued over this period. See Table 1 for EPA estimates of the HAP emissions reductions and costs for these five industry categories.

Table 1. EPA Estimates of the HAP Emissions Reductions and Costs for Five Industry Categories

	HAP reduction (tons/year)	% reduction	Cost: EPA final rule (million $/year)	Cost: Report to Congress (million $/year)
Petroleum refining	53,000	59%	$80	$160
Pharmaceuticals	24,000	65%	$64	NA
Printing and publishing	7,400	31%	$40	$200
Pulp and paper	153,000	60%	$125	NA
Wood furniture	32,800	59%	$15	$49

Source: EPA (2000, 1999a, 1998b, 1998c, 1996, 1995a, 1995b)

1.4. Available Emissions Data

Beginning in 1987, the TRI program has required industrial facilities to report releases of toxic pollutants into the air and water and the disposal of toxics as waste in land-based facilities.[16] We focused on TRI release data for the years from 1995 to 2003. The dataset contains annual reporting of air toxics emissions at the plant level. We identify individual facilities under a MACT standard using the Air Facility System (AFS) data retrieved from EPA through the Envirofacts Data Service API (EPA 2014a). The AFS lists basic summary information about each facility, including regulations that the plant is expected to meet. We then selected regulated facilities from the TRI with some help from the Facility Registry System (FRS), both of which are available for download on the EPA website.[17]

[16] We also looked at the National Emissions Inventory (NEI) dataset, which provides annual criteria air pollutant emissions at the plant level for 1990 and each year over the 1996–2001 period. The NEI data from before 2002 are more comprehensive than the reports from 2002, 2005, and 2008, containing data for more than twice as many plants as in 2002 and later years. However, the NEI data show a troubling pattern for many of the covered industries: there was a substantial variance in the change in emissions from the previous year for 1996 and 1999 but very tight distributions for the intervening years. This pattern suggests that emissions data were reported for plants in some years (1996 and 1999), and EPA adjusted or interpolated emissions data for the other years over the 1990s.

[17] TRI Basic Plus Data Files, http://www2.epa.gov/toxics-release-inventory-tri-program/tri-basic-plus-data-files-calendar-years-1987-2012; FRS, http://www.epa.gov/enviro/html/fii/ez.html.

The original toxic chemical list contained roughly 300 individually listed chemicals, many of which are volatile organic compounds. We focused on the air emissions data for those chemicals subject to the MACT rules included on the original TRI chemical list.[18]

TRI required plants to report their releases only when emissions exceeded a specified threshold. For example, the reporting threshold was 25,000 pounds per year for chemicals used in manufacturing and processing.[19] In addition, TRI also limits reporting to facilities with 10 or more full-time employees (EPA 1998a).

In 1995, EPA adopted a short reporting form known as the Alternate Threshold Certification Statement, or Form A, for chemicals where the total release is less than 500 pounds and total manufacture, process, or “otherwise use” of the chemical is less than 1 million pounds (EPA 1998a). In using Form A, a plant certifies that its total annual release of the chemical does not exceed 500 pounds. the form does not provide information such as a specific amount of the release or apportion the release across media.[20]

TRI data has been used in a number of studies (Bui 2005; de Marchi and Hamilton 2006; Kraft et al. 2011) to evaluate the effects of the TRI initiative and other programs on toxic emissions behavior. However, even while relying on TRI data, these studies have recognized several issues with the data:

- TRI release data are self-reported, and generally the data are based on engineering calculations and are not from monitoring.
- Changes to reporting in 1991 triggered by the Pollution Prevention Act resulted in a substantial increase in reported releases in subsequent years.
- Both additions and deletions to the listed chemicals and substances occurred over the period; more than 200 chemicals were added in 1995 alone.

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[18] The list has subsequently been expanded over the past 25 years and now covers 683 individual chemicals.

[19] For facilities in the “otherwise use” category, the annual threshold was 10,000 pounds. Certain chemicals known as persistent bioaccumulative and toxic (PBT) also had lower thresholds, but reporting requirements at these lower thresholds for the PBT chemicals did not begin until 2000 (EPA 1998a).

[20] Total releases are measured by the amount released into the air or water, or placed on land,including amounts disposed, treated, recycled, and burned for energy recovery at the facility and amounts transferred from the facility to off-site locations for the purposes of recycling, energy recovery, treatment, or disposal (EPA 1998a).

- TRI reporting thresholds limit coverage to facilities with 10 or more full-time employees and to facilities with releases above specified thresholds for manufacture, process, or "otherwise use."
- The use of Form A beginning in 1995 reduced the availability of quantitative release reports for toxics below the Form A thresholds.[21]
- Chemical releases are reported in terms of pounds, without accompanying information on the toxicity of the chemicals.

In addition to these concerns, as we noted above, we have found that only a limited number of plants in each of the covered industries consistently reported their releases to TRI, sharply limiting the scope of our study.

Finally, there are reasons to be concerned with the underreporting of releases in the TRI database. Tietenberg and Wheeler (1998) point out that "firms have incentives to mislead the public, either by overstating their environmental accomplishments or by selective omission (noting the positive outcomes and ignoring or burying the negative ones." Surveys of reporting plants in the early years of TRI indicate that a significant fraction of reported reductions were a mixture of real and paper changes (Poje and Horwitz 1990; EPA 1993). Dudley (1999) suggests that individual facility reports may contain such large errors that the data may be unreliable for site-specific analysis. On the other hand, EPA (1998d) reports that by the mid-1990s, more than 80 percent of surveyed facilities used an appropriate method to estimate releases.

Our study focuses on TRI release data for the period from 1995 to 2003. We selected this period in part in the hope of skirting the problems identified above with the firm-specific release data from the early years of the TRI program.

1.5. EPA Estimates of Benefits and Costs for these Five Air Toxics Rules

1.5.1. Benefits

EPA provides monetized benefit estimates for only three of the rules covered by this review. For petroleum refineries, EPA estimates benefits of $109 million per year arising from

[21] Beginning in 1995, EPA allowed facilities to file a short form (Form A) if (1) the chemical being reported is NOT a PBT chemical; (2) the chemical has not been manufactured, processed, or otherwise used in excess of 1,000,000 lbs.; and (3) the total annual waste management (i.e., releases including disposal, recycling, energy recovery, and treatment) of the chemical does not exceed 500 lbs.
http://www2.epa.gov/sites/production/files/documents/1998qa.pdf

the projected reduction in emissions of volatile organic compounds (VOCs). EPA uses benefit transfer values developed by the Office of Technology Assessment. These values were developed only for estimated acute health benefits in ozone nonattainment areas, so EPA's benefit calculation monetized only those VOC reductions occurring in ozone nonattainment areas. In addition to its monetized benefits estimate, EPA also discusses the potential reduction in cancer risks. EPA reports, however, that the baseline annual cancer incidence was less than one cancer per year for the HAP emissions from refineries. As a result, it did not consider further the potential reduction in cancer incidence associated with the MACT standards (60 FR 43245).

For pharmaceuticals, EPA estimates that the annual benefits for the air standards would range from $3.9 to $ 67 million per year.[22] The quantified and monetized benefits estimates were based primarily on estimates of the ozone-related air quality benefits from reducing VOC emissions using benefit transfer values of $602 to $2,733 per megagram (Mg) (63 FR 50410).[23]

For pulp and paper, EPA estimated annual benefits ranging from a negative $1,040 million to a positive $1,054 million per year. The benefits were developed using benefits transfer to develop estimates for the projected reduction in VOC emissions and for the projected increase in PM and SO_2 emissions. The benefit transfer estimates were based on benefit studies from earlier rules that covered these pollutants (63 FR 18586).[24]

1.5.2. Projected Emissions Reductions and Costs

The five industry categories we examine in this study were subject to the more significant MACT rules issued between 1994 and 2000, as measured by the projected costs of compliance. (Appendix A provides the expected HAP emissions reductions and cost estimates for the other manufacturing MACT rules issued over this period.)

In addition, EPA's 1999 Report to Congress also provides cost estimates for most of these industries. While the cost estimates across most of the industry categories are generally

[22] EPA estimates that water limits for the pharmaceutical Cluster Rule would yield benefits of $0.9 million to $14 million per year (63 FR 50408).

[23] The benefit transfer values were taken from the 1997 Ozone National Ambient Air Quality Standards (NAAQS) Regulatory Impact Analysis (RIA); $602/Mg does not include ozone mortality, while the $2,733/Mg does include the mortality risk reduction effects of reductions in ambient ozone concentrations.

[24] With the final Cluster Rule, EPA issued an additional proposed rule, designated as MACT II, to limit emissions from boilers located at these mills. EPA projected that the proposed MACT II rule would also limit PM and SO_2 emissions as cobenefits and that the net result across the MACT I and MACT II rules would be little or no increase in PM and SO_2 emissions.

comparable, EPA (1999a) has significantly higher annualized cost estimates for the petroleum refinery, wood furniture, and printing and publishing industry categories.

EPA (2000) also provides estimates of the projected HAP emissions reductions for the five industries covered by this review, projecting that the five rules would achieve important reductions in organic HAP and VOC emissions.[25]

We provide a summary of the projected emissions reduction and costs for each of the covered industries below.

Petroleum Refineries (126 plants)

The MACT limited organic HAP and VOC emissions by requiring a percent reduction (generally greater than 90 percent, varying by type of equipment) or an emissions concentration less than 20 parts per million by volume (ppmv) (60 FR 43247). The MACT also required control of benzene emissions for certain wastewater streams. For benzene waste streams, control equipment had to reduce benzene mass emissions by 99 percent using suppression followed by steam stripping, biotreatment, or other treatment processes. Vents from steam strippers and other benzene waste management or treatment units were required to be controlled by a control device that achieves a reduction of 95 percent or a concentration less than 20 ppmv (60 FR 43248).

EPA's preamble to the final rule estimates annual costs of $80 million; EPA (1999a) estimates annual costs of $160 million. EPA projects that the standard will reduce emissions of 11 air toxics by 53,000 tons per year, a 59 percent reduction, and that it will reduce VOC emissions by 252,000 tons per year, a 60 percent reduction (60 FR 43248).

Typically petroleum refineries are among the largest sources of VOC and air toxics emissions within their states. As a result, they are likely to receive the continuing attention of the regulatory agencies in their communities and states. This is consistent with Bui's (2005) finding that reductions in toxic emissions intensity were closely related to traditional command-and-control regulation of nontoxic conventional pollutants.

[25] EPA (2000) estimates reductions in VOC emissions of 277,000 tons per year for the petroleum refining industry and 450,000 tons per year for the pulp and paper industry. The EPA final rules anticipate substantial reductions in VOC emissions for the other three industry categories but did not offer estimates of the VOC reductions, because the size of any reduction would be affected by the extent to which plants take advantage of the pollution prevention options offered by these rules.

Pharmaceuticals

The MACT limits were based on end-of-pipe controls to limit organic HAP emissions—that is, a 98 percent reduction or < 20 ppmv, or an EPA-approved control device. This rule also provided an innovative pollution prevention alternative for the pharmaceutical industry that allowed plants to reduce HAP emissions through reductions in HAP solvent consumption instead of installing end-of-pipe controls (63 FR 50282). EPA estimates that the rule would reduce HAP emissions by 24,000 tons per year, a reduction of 65 percent from baseline.[26] Projected reductions in organic VOCs accounted for most of the expected reduction in HAP emissions. EPA estimates pretax annualized costs for the MACT rule of $64 million (63 FR 50287).[27]

Printing and Publishing (129 plants)

The MACT limited organic HAP emissions by requiring a specified reduction in emissions from the inks and coatings applied each month (e.g., a 92 percent reduction for rotogravure plants in the total volatile matter applied each month). The rule also allowed pollution prevention measures—that is, a shift to the use of low-HAP/VOC coatings.

EPA projects that the rule would reduce HAP emissions from publication rotogravure printing industry (27 plants) by 5,220 tons per year—a reduction of 27 percent from a baseline of 19,200 tons per year. In addition, EPA estimates that the rule would reduce HAP emissions from the product and packaging and wide web flexographic printing industry (1,200 facilities) by 2,140 tons per year—a reduction of 46 percent from a baseline of 4,620 tons per year (60 FR 13673). EPA reports that it could not predict the reduction in VOC emissions because of uncertainty about the extent to which printers would substitute water-based and non-VOC organics for organic HAP coatings (61 FR 27135).

EPA's preamble to the final rule estimates annual costs of $40 million, including annualized costs for capital recovery over 10 years, annual operating, monitoring, recordkeeping, and reporting costs (61 FR 27135); EPA (1999a) presents estimated annual costs of $200 million.

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[26] The rule also reduced emissions of hydrogen chloride, an inorganic HAP (63 FR 50284).

[27] EPA originally proposed best available technology (BAT) limits based on steam stripping plus advanced biological treatment, but because MACT standards would require steam stripping, EPA decided it was not "appropriate" or "necessary" to include it as a basis for BAT (63 FR 50394).

Pulp and Paper

The MACT limited organic HAP emissions by requiring a percent reduction (generally greater than 90 percent, varying by type of equipment), an emissions rate (e.g., emit no more than 0.44 kilograms [kg] of HAP per Mg of product), or an emissions concentration (e.g., concentrations must be less than 20 ppmv). EPA projects that the MACT rule would reduce organic HAP emissions by 60 percent and VOC emissions by 45 percent (63 FR 18575).[28]

EPA's preamble to the final rule estimates annualized pretax costs of $125 million, including annualized costs for capital recovery, annual operating, monitoring, recordkeeping, reporting costs, and administrative costs (63 FR 18580). EPA (1999a) does not provide a corresponding cost estimate.

Wood Furniture (166 plants)

The MACT limited organic HAP/VOC emissions by establishing limits on VOC emitted (in kg) per kilogram of solids used in production. The rule allowed pollution prevention measures based on the substitution of water-based or low-HAP coatings. EPA projects that the standard would yield a reduction of 33,000 tons per year in organic HAP/VOC emissions from morethan 700 facilities (60 FR 62932, 60 FR 62934), a reduction of roughly 60 percent (EPA 2000, 17).[29]

EPA's preamble to the final rule estimates annual costs of $15 million; EPA (1999a) estimates annual costs of $49 million.

2. Methodology

We used an approach similar to an event study approach, in that we are looking for a marked change in the targeted emissions over the period of EPA rulemaking. We examined emissions behavior over four separate two-year periods, beginning with an ex ante period prior to promulgation of the final rule, then an early compliance period covering the initial promulgation of the final rule, the compliance period including the year of the effective date for compliance with the rule, and the two-year ex post period immediately after the compliance date.

[28] Note that EPA also projects a small increase in PM emissions and an increase in SO_2 emissions of 105,000 tons per year. The increase in SO_2 emissions arises from the control of sulfur-containing compounds through combustion of the vent streams at kraft mills.

[29] http://www.epa.gov/oaqps001/takingtoxics/sum2.html#15

For the pharmaceutical and pulp and paper industry categories, we aggregated emissions across all organic HAPs on the original TRI list. For the other three industry categories, we aggregated a shorter list of organic HAPs specifically identified in the rule preamble as the focus of the MACT rule.[30]

We used two different OLS estimation methods to explore the effect of the pulp and paper Cluster Rule MACT limits on air toxics emissions—a difference-in-difference model (Model 1) and a first-difference estimate in toxic discharges (Model 2).

2.1. Difference-in-Difference Model (Model 1)

We considered a difference-in-difference model (Model 1) based on the level of emissions. For this model, we used the level of emissions as the dependent variable and the level of production (as measured by our TRI production index), the LCV score, and the NA status as control variables. The model also includes year dummies for both the control and the regulated industries:

Z = g(P, NA, LCV, D)

where Z is the level of emissions for each plant in the odd years from 1993 to 2003.

The independent variables are as follows:

P = the TRI production index over each of the periods

NA = the one-hour ozone nonattainment status of the area where the plant was located

LCV = the League of Conservation Voters' score for the state where the plant was located

D = a set of dummy variables for each year in the database First-Difference Estimate (Model 1)

2.1.1. TRI Reported Production Index (P)

Firms reporting to TRI also included information on the change in production activity for the reporting year relative to the previous year. We used this information to construct a

[30] For example, for petroleum refining, we aggregated the reported TRI air releases for 14 organic HAPs: benzene, cresol, m-cresol, ethylbenzene, N-hexane, methyl ethyl ketone, methyl tert-butyl ether, naphthalene, phenol, toluene, m-xylene, o-xylene, p-xylene, and xylene (mixed isomers). (60 FR 43245)

production activity index over the relevant period. The production index controls for changes in production activity over the several periods.[31]

2.1.2. Nonattainment Area (NA)

Plants located in ozone nonattainment areas may face continuing pressure to reduce their emissions of conventional pollutants (especially VOC emissions to meet ozone standards). In a study of toxic releases from petroleum refineries, Bui (2005) finds that "TRI air releases are affected by being in more stringent regulatory regions for the criteria pollutants." If this is the case, then we would expect the sign to be negative. We used the 1992 nonattainment status for the one-hour ozone standard for the ex ante period and the 1998 nonattainment status for the compliance and ex post periods.

2.1.3. State Regulation (LCV)

Several studies have reported that supplemental state regulation and voluntary programs achieved additional reductions in toxic releases beyond those required by EPA (see Bennear 2007; Bui and Kapon 2012). Gray and Shadbegian (2008) have also found that more stringent local regulatory requirements can result in lower emissions. Gray and Shadbegian use an index for states based on proenvironment voting behavior reported by the League of Conservation Voters (LCV). We would expect the sign to be negative if states with higher LCV scores required additional reductions in toxic emissions over the relevant period. On the other hand, if these states had already required substantial reductions from plants within their jurisdictions in earlier periods, plants in these states with higher LCV scores may have been well controlled and would not have needed to make substantial additional reductions. We used the LCV score from 1992 for the ex ante period, 1996 for the early compliance period, 1999 for the compliance period, and 2001 for the ex post period.

For the difference-in-difference model, we compared the change in emissions for the printing and publishing and the pulp and paper industries over the compliance years vis-à-vis a specific paired unregulated industry (see Section 2.3). We also carried out a similar comparison for each of the five MACT regulated industries with the emissions behavior of a group of plants from six unregulated industry categories (see Section 2.3). (The unregulated plants in the two

[31] We obtained sales data for pulp and paper mills from Gray and Shadbegian (2008). The correlation between our construction of a production index from the TRI database and the sales data was relatively good; the R-squared for the equation relating sales as a function of the TRI production index and paper capacity was 0.6.

separate paired industries and in the six industry groups were subsequently regulated by EPA for their VOC HAP emissions four to seven years later, with compliance dates ranging from 2005 to 2007.)

2.2. First-Difference Estimate (Model 2)

We also considered an ordinary least squares (OLS) first difference model to identify the effect of the air toxics rules, as follows:

Y = f(DP, NA, LCV, C, XP)

The independent variables are as follows:

DP = the change in the TRI production index over each of the periods

NA = the one-hour ozone nonattainment status of the area where the plant was located

LCV = the League of Conservation Voters' score for the state where the plant was located

C = dummy variable for the early compliance and compliance periods

XP = dummy variable for the ex post period

2.2.1. Compliance Periods

We considered emissions behavior over four periods: a two-year ex ante period before the rule was issued, an early compliance period for the first two years in which the industry moved to comply with the rule (where applicable), the last two years of the compliance period ("Compliance 2" in Table 2), and a two-year ex post period after the required date for compliance. We used the change in emissions over two-year intervals because we found greater consistency in reporting (and a larger number of reporting plants) using TRI release data for odd-numbered years (1993, 1995, 1997, 1999, 2001, and 2003).

Table 2 presents the periods for each industry category. For each industry, we developed a balanced panel by restricting the panel to firms reporting across all of the periods considered in the regression.[32]

[32] A balanced panel provides an observation for each plant for each year in the dataset. This approach avoids issues with plants that drop out of (and reenter) the panel in a nonrandom way, raising issues with sample selection and attrition.

Table 2. Ex Ante, Ex Post, and Compliance Periods for Covered Industries

	Ex ante	Early compliance	Compliance 2	Ex post
Petroleum refining	1993–95	1995–97	1997–99	1999–2001
Pharmaceuticals	1995–97	1997–99	1999–2001	2001–03
Printing and publishing	1993–95	1995–97	1997–99	1999–2001
Pulp and paper	1995–97	1997–99	1999–2001	2001–03
Wood furniture	1993–95	1995–97	1997–99	1999–2001

For the first-difference estimate (model 2), we compared the change in emissions for the printing and publishing and the pulp and paper industries over the four periods vis-à-vis a specific paired unregulated industry (see Section 2.3). We also carried out a similar comparison for the change in emissions for each of the five MACT regulated industries with the emissions behavior of a group of plants from six unregulated industry categories (see Section 2.3). (The unregulated plants in the two separate paired industries and in the six industry groups were subsequently regulated by EPA for their VOC HAP emissions four to seven years later, with compliance dates ranging from 2005 to 2007.)

2.3. Comparisons with Unregulated Industries

We paired regulated in these five industry categories with similar unregulated industry categories to compare emissions behavior. For printing and publishing, we used paper and other web (surface coating) as a paired unregulated industry category (67 FR 72329). For pulp and paper, we used another wood products manufacturing category, plywood and composite products, as a paired industry category (69 FR 45943). EPA issued its final rules for paper and web surface coating on December 4, 2002, and for plywood on July 30, 2004. (EPA 2002a, EPA 2004a) For petroleum refining, pharmaceuticals, and wood furniture, we were not able to identify a closely related unregulated manufacturing industry category.

We also compared emissions behavior for the five MACT industries in our study with the behavior of six additional unregulated industries emitting organic HAPs as a control, which we have termed the “potpourri group.” The six selected industries are metal can, metal coil, metal furniture, miscellaneous coating manufacturing, miscellaneous metal parts and products, and plastic parts. (EPA 2002b, EPA 2003a, EPA 2003b, EPA 2003c, EPA 2004b, EPA 2004c) EPA established MACT standards limiting the organic HAP emissions from the surface coating operations of these six industries in 2002 to 2004, with compliance dates of 2005 to 2007.

Appendix B presents the average plant-level emissions (by year) for each of the five industries and for the plants in the control groups.

3. Model Results for Covered Industries

3.1. Model 1: Difference-in-Difference Results for the Level of Emissions

The model results for printing and publishing and pulp and paper suggest a sustained reduction in emissions from peak 1995 levels, with negative, statistically significant coefficients for the years from promulgation of the rule to the MACT compliance date for the potpourri control cases and for the paired industry case for mills in the pulp & paper industry. (See Appendix C, Tables C-1 and C-2.) For the paired industry control for printing and publishing, the coefficient for the compliance years is negative, but not statistically significant. For the other three industry categories, the results are generally not statistically significant. The positive—but not statistically significant--coefficients for the years after promulgation of a final rule for the petroleum refining industry suggest an increase in emissions over the compliance period.

The explanatory power is limited. The F-statistic is statistically significant and the R-squared ranges from 0.129 to 0.203 for the paired industry runs for printing and publishing and the pulp and paper industry categories. For the potpourri runs for four of the five industries (excepting petroleum refining), the F-statistics are statistically significant and the R-squared ranges from 0.065 to 0.172.[33] For petroleum refining, while the F-statistic is statistically significant, the R-squared is only 0.034.

Looking at the control variables, the coefficient for the production index is positive and generally statistically significant; however, the magnitude of the effect of a change in production on emissions is relatively modest. The sign for the nonattainment variable is positive and statistically significant for the pulp and paper industry; the sign for the NA variable for the printing and publishing category is negative and statistically significant. The LCV variable carried a statistically significant, negative sign for the pulp and paper industry. The

[33] Based on analysis of variance tests for the printing & publishing and pulp & paper industries, we can reject the hypothesis that the coefficients are zero for the compliance periods for the potpourri case for both industries and for the paired industry case for the pulp & paper industry.

nonattainment and LCV variables were generally not statistically significant for the other industry categories.

3.2. Model 2 Results for Changes in Emissions

For the printing and publishing industry category, one or both of the compliance dummy variables are negative and statistically significant plants moved to comply with the MACT standards over the course of the compliance period, using both the paired industry and potpourri group of six industries as a control. For the pulp and paper and wood furniture (potpourri only) industry categories, the compliance variables are generally negative—as expected—but they are not statistically significant (see Appendix C, Tables C-3 and C-4)But the results for the other two industry categories over the two compliance periods yield largely positive coefficients, although these are not statistically significant.[34]

However, the explanatory power is limited across all of these runs. While the F-statistic is generally statistically significant, the R-squared ranges only from .05 to .11 for printing and publishing and pulp and paper. For petroleum refining and wood furniture categories (potpourri case only), the F-statistic is statistically significant, but the R-squared ranges only from 0.037 and 0.074. For the pharmaceutical industry, the R-squared is0.018 to 0.027, and the F-statistic is not significant.

Looking at the control variables, the change in the coefficient for the production index is positive and generally statistically significant; however, the magnitude of the effect of a change in production on emissions is relatively modest. The sign for the nonattainment variable for NA areas outside of California and the Northeast is positive and statistically significant in the potpourri cases for petroleum refining, pharmaceutical, printing and publishing, and wood furniture. Our interpretation of this result is that the regulation of these plants—likely located in NA areas in the Southeast/Gulf Coast states—was relatively less stringent than for other NA areas. The LCV variable generally carried a positive sign for the pulp and paper category and a negative sign for the other industry categories, but the coefficient is not statistically significant.[35]

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[34] Based on analysis of variance tests for the printing & publishing and pulp & paper industries, we can reject the hypothesis that the coefficients are zero for the compliance periods for the potpourri case for both industries and for the paired industry case for the pulp & paper industry.

[35] We also considered an alternative measure based on the 14 states with quantitative toxics management programs identified by Bennear (2007). We believe, though, that the LCV score is conceptually a better measure of state regulatory programs.

3.3. Estimated Emissions Reductions for the MACT Rules

We developed estimates of the emissions reductions achieved (from baseline emissions) by the printing and publishing and pulp and paper plants in coming into compliance with the MACT rules. We focused on these two categories because the OLS regression results were reasonably robust.

The estimated reduction in organic HAP emissions for the average printing and publishing plant ranges from 100 to 150 tons per year as compared with the emissions behavior of the paired paper and web surface coating category and the group of six potpourri industries. This represents a reduction of 60 percent to over 90 percent. EPA estimated ex ante that the rule would reduce HAP emissions by 27 percent from the publication rotogravure printing industry (27 plants) and by 46 percent from the product and packaging and wide web flexographic printing industry (1,200 facilities). Because of the TRI reporting thresholds, these results likely reflect the emissions behavior of the publication rotogravure printing industry—27 plants with the larger average baseline emissions—and suggest HAP emissions reductions that substantially exceed EPA's ex ante projections.

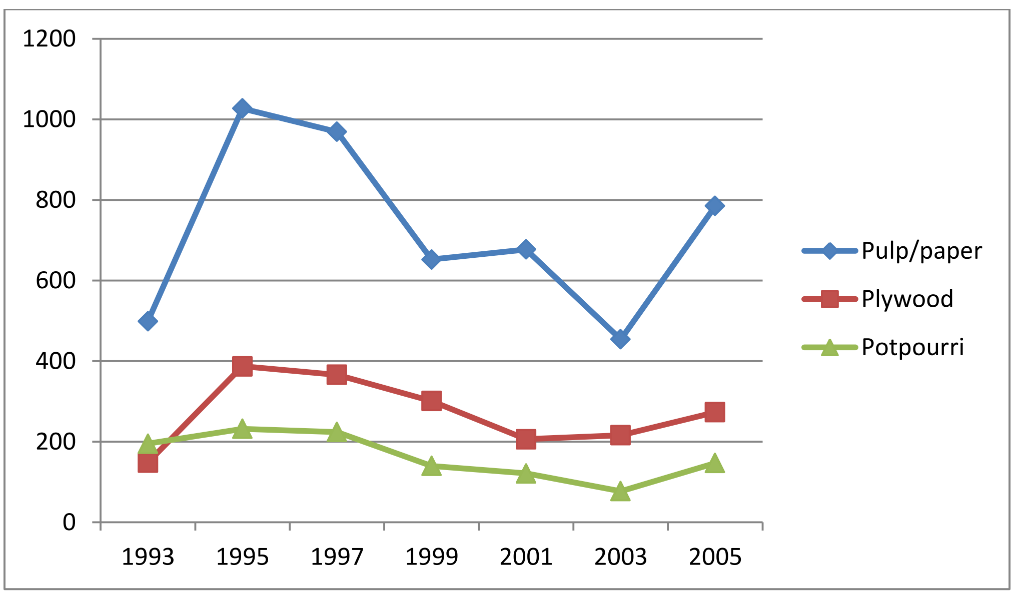
The difference-in-difference results for the pulp and paper industry suggest a reduction in organic HAP emissions ranging from 100 to 180 tons per year for the average plant as compared with the emissions behavior of the paired plywood and composite products category and the group of six potpourri industries. This represents a reduction of 20 percent to 33 percent, well below EPA's ex ante projection of a HAP reduction of 60 percent. For our sample, the mean emissions level in 2001 (the first year that mills were required to meet the MACT limits) was 67 percent of 1995 baseline emissions (a 33 percent reduction).[36] (See Figure 1.)

The results for the pulp and paper industry suggest that EPA may have overestimated the HAP reductions associated with the MACT rule. This result is consistent with EPA's recently completed retrospective cost study finding that the agency significantly overestimated the capital costs of the Cluster Rule (EPA 2014b). EPA offers several possible reasons for an overestimate of the capital costs, including the mills' use of the clean condensate alternative (CCA), the availability of flexible compliance options, extended compliance schedules, site-specific rules, use of equivalent-by-permit, and equipment/mill shutdowns and consolidations. In addition to

[36] For the mills in this sample, the mean emissions level in 2003 was 45% of the 1995 baseline level of emissions (a reduction of 55%), perhaps reflecting the effects of the 2002–03 recession. By 2005, emissions levels were back up to 2001 levels.

these factors, EPA may have overstated baseline emissions. The industry faced substantial regulatory pressure, beginning in the late 1980s, to reduce its releases of toxic pollutants. The available evidence suggests that the industry made substantial reductions in its discharge of toxics to water in the years prior to 1995, and these reductions were also likely accompanied by reductions in air emissions.[37] Second, EPA made changes to its final rule to allow averaging across the various emissions points within a pulp and paper mill, rather than requiring each emissions point to meet a specific limit. This change—providing pulp and paper mills greater flexibility in meeting standards—may have operated to relax the MACT emissions limits. Finally, we note that these emissions reduction estimates are relative to a declining "business-as-usual" baseline, as represented by the emissions behavior of plants in unregulated industries. Even though these unregulated plants were not subject to MACT requirements until the mid-2000s, they also realized a modest reduction in emissions over the 1998 to 2001 compliance period for the pulp and paper industry.

Figure 1. Average Annual HAP Emissions, Pulp & Paper Mills



[37]In 1991, Houck reported that through the Section 304(l) process, dioxin limits were proposed for 88 of 98 pulp and paper mills, and a number of pulp and paper mills had begun to convert to chlorine dioxide and hydrogen peroxide as bleaching agents instead of using chlorine. By 1995, pulp and paper mills had realized substantial reductions of 70% to 80% in dioxin and furan discharges—reductions driven by the Section 304(l) process (61 FR 36481).

For the other industry categories, the results were mixed—the coefficients over the compliance periods were generally not statistically significant and for petroleum refining positive.

3.4. Limitations of the Study

The study is limited by the number of plants reporting consistently to TRI over the period of interest—not only in the early years of the program, but also for some later years. The number of plants reporting is particularly sparse around 2000 (our Y2K problem).[38] Unfortunately, there is no other source of data—at least not a readily accessible source—for toxic air emissions.

For petroleum refining and pulp and paper, our sample covered roughly half of the plants subject to the rule. But coverage for the other three industry categories was more limited, and for printing and publishing and wood furniture, our sample covered less than 20 percent of the projected number of plants subject to the MACT rules (see Table 3). We believe that the TRI reporting thresholds likely limited the number of plants reporting to TRI in these industry categories.

Table 3. Number of Plants Projected by EPA and Sample Size in Our Models

	EPA: projected no. plants	Model 1: Diff-in-Diff-potpourri
Petroleum refining	179[a]	87
Pharmaceuticals	80	24
Printing and publishing	388	23
Pulp and paper	139[b]	71
Wood furniture	571	36

[a] EIA (1999) reports 159 operating refineries.
[b] EPA (2006) identifies 155 mills as subject to the final Cluster Rule when it issued the rule in 1998. In 2004, EPA reported that 12 bleached pulp mills and 5 paper-grade sulfite mills had closed after promulgation of the final rule in 1998.

The explanatory power of these two alternative models is marginal, and the significance attributed to the compliance period may be an artifact of the limitations of our modeling. Other factors not accounted for in the models may in fact be important in explaining the reductions in emissions during the compliance period. For example, complementary information on these

38 EPA first deployed an interactive program for TRI reporting (TRI-ME) to facilitate reporting by covered facilities in 2000 (Kraft et al. 2011).

plants, such as firm profitability, may be important in determining plant emissions characteristics. It would be helpful to have a dataset that combines emissions data with data on plant operations; for example, emissions data could be combined with plant-level data from the Census Bureau.

4. Discussion and Conclusions

We set out with the objective of adding to our understanding of what technology-based standards actually accomplished. In addition, we believed that a retrospective study could offer lessons on ways to improve ex ante analysis of regulations and identify what might be done—and done better—in the future to conduct retrospective analyses.

The ambition of the project was to cover a large number of the air toxics rules issued during the 1990s in the first phase of the program. However, we found that the existing data on releases of toxics are surprisingly limited.

We were only able to carry out an analysis for five of the industry categories because of the limited data available.[39] Even for these five industry categories, the data limitations restrict the findings of the study.

The results were mixed. The TRI data for the printing and publishing industry suggest a substantial reduction in HAP emissions—a reduction exceeding EPA's ex ante projection—over the several years from promulgation of a final rule to the final compliance date. For pulp and paper, the TRI emissions data suggest some reduction in HAP emissions over the relevant period, but the reduction falls short of EPA's ex ante projection. Gray and Shadbegian (2015) report similar results—that is, some reduction in air toxics, but "…smaller than the ex ante prediction and not always significant." This finding represents an important complement to EPA's conclusion in its recent retrospective cost study that it overestimated the capital cost of the Pulp & Paper Cluster Rule by 30 percent to 100 percent (EPA 2014b). Our evaluation suggests that the MACT rules yielded little or no additional reduction for the other three industry categories.

[39] These five categories cover some of the most significant air toxics rules issued during the 1990s. As noted above, most of the other MACT manufacturing rules issued over this period imposed only relatively small costs. As a result, it seems unlikely that the MACT manufacturing rules dropped from this analysis would have been selected ex ante as candidates for a retrospective study.

However, we believe that our results should be viewed as preliminary and deserving of further study because of the limited number of plants covered in these industry categories. We obtained emissions data covering roughly half of the plants subject to MACT in the petroleum refining and pulp and paper industries. For the other three industry categories, data problems limitations restricted our analysis to roughly one-third less than half of the plants subject to MACT in the pharmaceutical industry and less than 20 percent of the plants in the other two industry categories. We believe the TRI reporting thresholds limit the number of plants in these industries reporting to TRI.[40] While there is no obvious bias, we are concerned that the plants in our sample may not be representative of the industry.

To facilitate a retrospective analysis, EPA should include as a part of its final rule a specific plan for conducting a retrospective analysis. The agency should also provide for the collection of data on control measures and costs adopted to comply with the rule, emissions data, and plant production characteristics for at least a representative sample of plants plus a “control” group of unregulated plants. However, even if restricted to a representative sample of covered plants, the collection of information required for these studies would be extensive and costly.[41] To some extent, EPA may be able to reduce the burden of retrospective studies by coordinating its study with existing data collection by the Census Bureau. Nevertheless, the cost of conducting retrospective studies and the competition from other EPA initiatives in a period of tight budgets will limit the number of studies EPA can undertake. As a result, EPA will need to be strategic in its selection of retrospective studies.[42]

In addition, EPA will need to obtain Office of Information and Regulatory Affairs (OIRA) approval under the Paperwork Reduction Act (PRA) for its data collection.[43] To obtain OIRA approval, EPA would have to show that the collection has “practical utility” and is the least burdensome way of obtaining the information. The PRA also requires the agency to go through a public comment process.

[40] The missing TRI data around 2000 also posed a particular challenge. We also had very limited information on plant operating characteristics and control decisions.

[41] Some types of regulations, such as cap and trade or emissions fees, provide information on costs (through prices) and emissions. Collection of emissions data is integral to the enforcement of these programs and prices (or fees) are an indicator of the cost of control.

[42] In the case of the air toxics program, for example, a number of rules impose only modest costs and would seem to be unlikely candidates for an intensive retrospective study.

[43] OIRA is part of the Office of Management and Budget in the Executive Office of the President.

OIRA (2010b) has moved to streamline its PRA review process by establishing a generic clearance process for specific types of information collection focused on scientific research. In a memo titled “Facilitating Scientific Research by Streamlining the Paperwork Reduction Act Process,” OIRA (2010a) has outlined options and strategies for agencies to use to streamline the process of getting OMB approval for research-related information collections. We recommend that OIRA explicitly provide this streamlined PRA process for studies that collect data for retrospective studies.

Finally, in its review of agency rules under EO 13563, OIRA should ensure that agencies establish in the rule a process for ex post evaluation of the effectiveness of its most important rulemakings. To implement this recommendation, OIRA could issue guidance identifying factors that agencies should consider in selecting rules for regulatory review, the kinds of measurable outcomes targeted in the analysis, the associated data requirements, the type of analysis that will be used, and the timeframe to be evaluated. OIRA has already provided some general guidance along these lines. In a memorandum titled “Executive Order 13563: ‘Improving Regulation and Regulatory Review’” (OIRA 2011a), OIRA identified the following topics as areas that agencies should address in conducting retrospective review: public participation, prioritization, analysis of costs and benefits, and coordination with other forms of mandated retrospective analysis and review.[44] OIRA should elaborate further in additional guidance to the agencies on these key elements.[45]

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[44] In an additional memorandum titled “Retrospective Analysis of Existing Significant Regulations” (OIRAb), OIRA also recommended that to promote a consistent culture of retrospective review: “…future regulations should be designed and written in ways that facilitate evaluation of their consequences and thus promote retrospective analyses. To the extent consistent with law, agencies should give careful consideration to how best to promote empirical testing of the effects of rules both in advance and retrospectively.”

[45] Aldy (2014) reviews the Federal governemnt experience with retrospective review and offers a set of recommendations to enhance the role of retrospective analysis in improving Federal regulation.

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Appendices

Appendix A.

Table A-1. EPA Projected Emissions Reductions and Costs for Eight Manufacturing MACT Rules Excluded from the Study Because of Data Limitations

Industry	HAP reduction (tons/yr)	% reduction	EPA final rule annual cost (million $/year)	Report to Congress annual cost (million $/year)
Halogenated solvent cleaning	85,300	63%	$19	$37
Commercial sterilization facilities	1,140[a]	96%	$6.6	$7
Magnetic tape	2,300		$0.8	$0.8
Chromium electroplating	173[b]	99%	$12	$17
Secondary lead smelters	1,353[c]	70%	$3	$2
Aerospace	123,000	60%	$21	$4
Group IV	3,870[d]	20%	$3.3	$5.3
Primary aluminum	5,680[e]	50%	$47	NA

Source: EPA (2000, 1999a).
[a] Ethylene oxide.
[b] Chromium.
[c] Reduction in organic HAP; rule will also reduce metal HAP emissions by 58 tons per year.
[d] Reduction in organic HAP.
[e] Reductions in total fluoride (3,680 tons/yr) and polycyclic organic matter (2,000 tons/yr).

Appendix B. Average Level of HAP Emissions, by Year (pounds per year)

Table B-1. Pulp and Paper: Plywood

treat	N	1993	1995	1997	1999	2001	2003	2005
Control	38	147,610	387,151	366,482	301,134	205,652	216,094	273,431
Treatment	74	498,585	1,026,990	969,447	652,937	677,233	454,134	785,219

Table B-2. Pulp and Paper: Potpourri Control

treat	N	1993	1995	1997	1999	2001	2003	2005
Control	120	194,620	232,404	224,324	139,794	120,564	76,919	146,678
Treatment	71	423,818	1,051,413	976,386	703,614	701,875	478,693	766,436

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Table B-3. Pharmaceutical Manufacturing: Potpourri Control

treat	N	1993	1995	1997	1999	2001	2003
Control	120	148,233	193,792	189,253	124,651	106,198	62,924
Treatment	24	170,252	194,349	138,977	64,858	65,995	26,846

Table B-4. Petroleum Refining: Potpourri Control

treat	N	1993	1995	1997	1999	2001	2003
Control	117	130,453	195,293	185,136	119,422	107,842	71,675
Treatment	87	63,181	100,613	123,568	96,506	57,155	42,321

Table B-5. Printing and Publishing: Paper and Other Web Surface Coating Control

treat	N	1993	1995	1997	1999	2001	2003
Control	40	371,478	443,079	427,147	264,260	286,474	170,112
Treatment	21	654,624	791,734	578,477	391,984	391,248	325,378

Table B-6. Printing and Publishing: Potpourri Control

treat	N	1993	1995	1997	1999	2001	2003
Control	109	196,656	288,915	266,860	181,13	177,481	110,107
Treatment	23	423,700	710,196	450,648	304,511	365,108	157,613

Table B-7. Wood Furniture: Potpourri Control

treat	N	1993	1995	1997	1999	2001	2003
Control	112	173,035	247,283	223,825	150,324	149,754	92,839
Treatment	36	158,873	202,886	150,354	71,144	88,224	84,811

Appendix C. Regression Results

Table C-1. Difference-in-Difference with Paired Industries

	Dependent variable:	
	emissions	
	Printing and Publishing	Pulp and Paper
	(1)	(2)
production	59,264.000	300,939.000*
	(138,414.000)	(156,181.000)
year1993	84,086.000	
	(98,995.000)	
year1997	-23,805.000	7,968.000
	(86,624.000)	(100,736.000)
year1999	-187,530.000**	-94,613.000
	(86,676.000)	(104,120.000)
year2001	-161,050.000*	-161,247.000
	(86,291.000)	(102,121.000)
year2003		-160,588.000
		(102,328.000)
LCV	3,828.000	3,804.000
	(3,719.000)	(2,899.000)
non_attainment	-379,500.000***	206,791.000**
	(119,001.000)	(89,847.000)
year1993:treat	-35,251.000	
	(147,557.000)	
year1997:treat	-188,678.000	15,880.000
	(147,115.000)	(120,409.000)
year1999:treat	-218,984.000	-201,612.000*
	(147,972.000)	(121,817.000)
year2001:treat	-235,433.000	-111,437.000
	(148,069.000)	(120,522.000)
year2003:treat		-336,362.000***
		(120,699.000)
Observations	305	560
R^2	0.129	0.203
Adjusted R^2	0.098	0.159
F Statistic	3.129*** (df = 11; 233)	10.140*** (df = 11; 437)
Note:		*p<0.1;* ***p<0.05;*** p<0.01

	Treated	Controlled
Printing and Publishing	105	200
Pulp and Paper	370	190

Table C-2. Difference-in-Difference with Potpourri Industries

	Dependent variable:				
			emissions		
	Petroleum Refineries	Pharmaceutical Manufacturing	Printing and Publishing	Pulp and Paper	Wood Furniture
	(1)	(2)	(3)	(4)	(5)
production	62,658.000*	113,428.000***	148,683.000**	155,255.000**	102,680.000***
	(36,818.000)	(29,695.000)	(57,954.000)	(62,863.000)	(37,924.000)
year1993	-54,038.000*		-27,448.000		-51,729.000
	(32,376.000)		(50,054.000)		(35,356.000)
year1997	-8,473.000	-9,179.000	-57,514.000	37,065.000	-33,640.000
	(28,168.000)	(25,330.000)	(42,111.000)	(59,835.000)	(29,786.000)
year1999	-77,142.000***	-72,874.000***	-154,610.000***	-15,418.000	-114,099.000***
	(28,629.000)	(26,002.000)	(42,966.000)	(60,624.000)	(30,418.000)
year2001	-91,582.000***	-84,192.000***	-131,943.000***	-30,433.000	-107,939.000***
	(26,523.000)	(26,187.000)	(38,429.000)	(60,874.000)	(27,336.000)
year2003				-107,223.000*	
				(59,641.000)	
LCV	-457.200	221.600	2,980.000	-4,590.000**	596.800
	(1,080.000)	(1,007.000)	(1,889.000)	(1,940.000)	(1,297.000)
non_attainment	-1,669.000	5,739.000	-148,244.000**	169,453.000***	-34,560.000
	(35,723.000)	(31,115.000)	(62,311.000)	(63,492.000)	(42,422.000)
year1993:treat	20,873.000		-204,138.000**		31,819.000
	(41,393.000)		(90,961.000)		(55,511.000)
year1997:treat	32,977.000	-23,781.000	-240,393.000***	-48,009.000	-33,037.000
	(39,955.000)	(45,369.000)	(90,466.000)	(75,219.000)	(54,632.000)
year1999:treat	76,325.000*	-8,631.000	-300,304.000***	-220,494.000***	-47,742.000
	(40,096.000)	(45,451.000)	(90,490.000)	(75,793.000)	(54,778.000)
year2001:treat	49,388.000	-46,822.000	-241,956.000***	-197,293.000***	-33,220.000
	(40,701.000)	(45,354.000)	(90,525.000)	(76,062.000)	(54,810.000)
year2003:treat				-367,909.000***	
				(76,865.000)	
Observations	1,020	716	660	955	740
R^2	0.034	0.087	0.099	0.172	0.065
Adjusted R^2	0.027	0.064	0.077	0.136	0.051
F Statistic	2.604*** (df = 11; 805)	5.588*** (df = 9; 528)	5.160*** (df = 11; 517)	14.220*** (df = 11; 753)	3.660*** (df = 11; 581)
Note:					*p<0.1;* ***p<0.05;*** p<0.01

	Treated	Controlled
Petroleum Refineries	435	585
Pharmaceutical.Manufacturing	120	596
Printing and Publishing	115	545
Pulp and Paper	355	600
Wood Furniture	180	560

Table C-3. First Difference with Paired Industries

	Dependent variable:	
	chgEmissions	
	Printing and Publishing	Pulp and Paper
	(1)	(2)
chgProduction	36,092.000	110,080.000
	(140,271.000)	(192,125.000)
region9	43,597.000	38,451.000
	(209,831.000)	(276,800.000)
region123	847.400	42,430.000
	(70,781.000)	(77,419.000)
non_attainment	-30,930.000	75,289.000
	(72,163.000)	(64,820.000)
early_compliance	-94,673.000	-37,189.000
	(94,486.000)	(125,941.000)
treat	57,211.000	-46,167.000
	(109,420.000)	(108,445.000)
compliance	-237,714.000**	-48,473.000
	(95,147.000)	(128,071.000)
expost	-50,925.000	40,403.000
	(95,875.000)	(125,594.000)
LCV	-1,635.000	1,430.000
	(1,627.000)	(1,511.000)
early_compliance:treat	-260,012.000*	-187,995.000
	(153,976.000)	(153,746.000)
treat:compliance	-94,417.000	166,061.000
	(154,990.000)	(154,440.000)
treat:expost	-88,808.000	-175,765.000
	(153,911.000)	(153,159.000)
Constant	169,599.000*	-150,693.000
	(101,735.000)	(116,742.000)
Observations	244	448
R^2	0.084	0.059
Adjusted R^2	0.036	0.033
Residual Std. Error	403,695.000 (df = 231)	540,467.000 (df = 435)
F Statistic	1.756* (df = 12; 231)	2.273*** (df = 12; 435)
Note:		*p<0.1;* ***p<0.05;*** p<0.01

	Treated	Controlled
Printing and Publishing	84	160
Pulp and Paper	296	152

Table C-4. First Difference with Potpourri Industries

	Dependent variable:				
	chgEmissions				
	Petroleum Refineries	Pharmaceutical Manufacturing	Printing and Publishing	Pulp and Paper	Wood Furniture
	(1)	(2)	(3)	(4)	(5)
chgProduction	95,004.000**	60,109.000*	141,558.000**	101,941.000	109,848.000***
	(42,343.000)	(33,006.000)	(64,347.000)	(72,988.000)	(40,989.000)
region9	8,062.000	34,231.000	-33,286.000	48,789.000	-10,160.000
	(38,545.000)	(69,407.000)	(166,548.000)	(149,633.000)	(112,673.000)
region123	2,777.000	12,706.000	-55,094.000	54,992.000	-11,295.000
	(25,117.000)	(23,989.000)	(40,184.000)	(41,266.000)	(24,624.000)
non_attainment	18,448.000	29,345.000	98,227.000***	28,702.000	55,180.000**
	(21,035.000)	(21,481.000)	(37,072.000)	(36,968.000)	(23,217.000)
early_compliance	-61,847.000*	-48,604.000*	-65,370.000	-43,249.000	-66,822.000**
	(33,584.000)	(28,568.000)	(50,049.000)	(59,282.000)	(32,960.000)
treat	-21,783.000	-55,865.000	213,092.000***	-52,374.000	-30,841.000
	(34,343.000)	(42,754.000)	(76,567.000)	(62,897.000)	(43,423.000)
compliance	-117,921.000***	7,783.000	-119,947.000**	17,392.000	-113,667.000***
	(33,106.000)	(28,235.000)	(49,469.000)	(58,651.000)	(32,696.000)
expost	-58,163.000*	-17,061.000	-23,870.000	-8,285.000	-30,929.000
	(33,314.000)	(28,230.000)	(50,015.000)	(58,643.000)	(33,003.000)
LCV	-27.230	-535.400	-1,280.000	1,361.000	-575.200
	(587.900)	(584.500)	(1,013.000)	(993.600)	(646.800)
early_compliance:treat	48,449.000	43,989.000	-441,715.000***	-129,440.000	-1,636.000
	(47,667.000)	(60,997.000)	(106,983.000)	(87,780.000)	(60,757.000)
treat:compliance	59,808.000	64,386.000	-269,931.000**	70,589.000	17,007.000
	(47,579.000)	(60,850.000)	(107,090.000)	(87,857.000)	(60,754.000)
treat:expost	-13,956.000	46,625.000	-138,661.000	-130,255.000	48,630.000
	(47,803.000)	(60,824.000)	(106,949.000)	(87,944.000)	(60,579.000)
Constant	40,701.000	-10,701.000	63,430.000	-126,085.000*	43,962.000
	(41,574.000)	(38,397.000)	(67,429.000)	(71,776.000)	(43,317.000)
Observations	816	576	528	764	592
R^2	0.037	0.027	0.114	0.053	0.074
Adjusted R^2	0.023	0.007	0.094	0.038	0.054
Residual Std. Error	234,764.000 (df = 803)	190,471.000 (df = 563)	329,014.000 (df = 515)	413,297.000 (df = 751)	222,906.000 (df = 579)
F Statistic	2.564*** (df = 12; 803)	1.320 (df = 12; 563)	5.535*** (df = 12; 515)	3.488*** (df = 12; 751)	3.838*** (df = 12; 579)
Note:					*p<0.1; **p<0.05;** p<0.01

	Treated	Controlled
Petroleum Refineries	348	468
Pharmaceutical Manufacturing	96	480
Printing and Publishing	92	436
Pulp and Paper	284	480
Wood Furniture	144	448