CROSS SECTIONAL VARIATION IN TOXIC WASTE RELEASES FROM THE U.S. CHEMICAL INDUSTRY

By

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Abstract

This paper measures and examines the 1987 cross sectional variation in toxic releases from the U.S. chemical industry. The analysis is based on a unique plant level data set of over 2,100 plants, combining EPA toxic release data with Census Bureau data on economic activity. The main results are that intra-industry variation in toxic releases are as great as, or greater, than inter-industry variation, and that plant, firm, and regulatory characteristics are important factors in explaining observed variation in toxic releases. Even after controlling for primary product and plant characteristics, there are some firms which generate significantly lower toxic waste due to managerial ability and/or technology differences.

Keywords: toxic waste, chemical industry, heterogeneity

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I. **INTRODUCTION**

Industrial activity is a major sources of environmental degradation; waste by-products are frequently released into the air, land and water. One of the greatest challenges currently facing the United States, and other countries, is the economic and environmental consequences of industrial waste.

The purpose of this paper is to measure and examine the observed variation in toxic waste across chemical plants. Most studies on the generation and impact of industrial waste are based on case studies of a few firms or on industry or higher aggregate level data. The unique contribution of this paper is that it combines economic data on chemical plants from the U.S. Census Bureau's Longitudinal Research Database (LRD) with toxic release data from the EPA's Toxic Release Inventory (TRI), producing a rich, plant level database. In addition, the production model developed in this paper distinguishes between three levels of effects on toxic releases: regulatory effects, firm effects, and plant effects, as measured by observable plant characteristics, including state location, firm ownership, primary product, and categories of inputs.

A phenomenon observed in many microdata sets is the extreme variation in measured characteristics. For manufacturing industries, inter-industry variation is often less than intra-industry variation.[1] In an earlier paper Beede, Bloom, and

Wheeler (1992) found that two-digit industry explains less than 2 percent of plant level variation in toxic releases, and four-digit industry explains only 11 percent of the variation; indicating that most variation is indeed within an industry. Cross industry variation can not be used to determine what factors influence the generation of toxic releases. This can be done only by examining the variation across individual plants within the same industry. It is precisely this within industry variation, and its distribution, that are the focus of this paper.[2]

While data on plant specific engineering production technologies in use are not available, this paper begins to address these issues by examining the economic production behavior of plants and the resulting toxic releases, based on the five-digit product structure. I first present summary statistics on the cross sectional distribution of toxic releases in the

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[1]The heterogeneity of several aspects of manufacturing plants is well documented in work by Abbott (prices, 1989),Doms (energy use, 1993), Doms and Dunne (energy and technology, 1993), Olley and Pakes (productivity, 1992), Bailey, et al. (productivity, 1992), Streitwieser (diversification, 1992), Dunne and Roberts (output prices, 1992), and Davis and Haltiwanger(job flows, 1990).

[2]Firm level analysis is non optimal for two reasons. First, large manufacturing firms are often quite diverse, with operations spanning several four digit industries, and sometimes across two-digit industries. Second, preliminary work by Feinstein indicates there may be significant variation in waste management across plants and divisions <u>within</u> companies.

chemical industry. Next, a two stage production and toxic release model is estimated.

Data from three sources are integrated to form the plant level cross-sectional database from 1987. Production input and output data are from the LRD and pollution abatement expenditure data are from the Pollution Abatement Cost and Expenditures Survey (PACE); both collected by the U.S. Bureau of the Census.[3] Data on manufacturing plant releases into the environment of over 300 toxic chemicals are from the U.S. Environmental Protection Agency's Toxic Release Inventory (TRI) database. 1987 is the first year of TRI data and provides a baseline for future longitudinal analysis. In addition, economic census year data provide the greatest possible scope for matching Census and EPA data.

The main findings of this paper are fourfold. First,intra-industry variation in toxic waste releases is frequently greater that inter-industry variation, even at the 5-digit product level. Second, primary product is the most important element for explaining inter-plant variation in toxic releases and regulatory effects are the least important. Third, toxic releases increase with both scale and scope of the plant <u>and</u> firm. Finally, certain firms are consistently better (worse) at minimizing toxic

[3]PACE survey is conducted annually since 1972, except for 1987.

releases, either through managerial ability or other unmeasured effects.

This paper is organized as follows. The dispersion and heterogeneity of toxic releases by the chemical industry are documented in Section II. The empirical model is described in Section III. Sections IV and V, respectively, contain estimation results and concluding remarks. Details of the data sources, construction of the database, and definition of analysis variables are given in Appendix A.

II. **DISPERSION AND HETEROGENEITY IN TOXIC RELEASES**

Results presented in this paper are based on two matched datasets. The primary sample consists of the 2,143 chemical plants, from 912 firms. The sample dataset is neither a random, nor a stratified sample, rather, it is the result of matching EPA's TRI data with the Bureau's LRD. Small plants are under represented in the matched sample data, as shown in Figure 1. This bias towards medium and large plants is largely due to EPA's minimum toxic release reporting requirements, and to a lesser extent, the Census Bureau's exemption to small plants from census reporting requirements (see Appendix A for details). The sample of 2,143 plants represents 17.8 percent of the total 12,039 plants in the chemicals and allied products industry, and accounts for 55.1 percent of total employment, 63.3 percent of total value of shipments, and 84.2 percent of the industry's reported TRI toxic releases (Figure 2). A subsample of 852 plants is constructed by matching these 2,143 plants with the Bureau's PACE data. This subsample represents 7.1 percent of the industry's plants, 42.9 percent of total employment, 52.0 percent of total value of shipments, and 78.5 percent of the reported TRI toxic releases.

Table 1 reports the intensity of toxic releases by two-, three-, and four-digit chemical industries, as well as five-digit product classification for the sample plants. To control for plant size, pounds of toxic releases are scaled by total value of production.[4] The mean and standard deviation of toxic release intensity are also reported in Table 1. Two measures of dispersion also are reported: the coefficient of variation (the ratio of the standard deviation to the mean) and the interquartile range (the range between the first and fourth quartile of the distribution).

Although the data are thin for some five-digit product cells, we can say with certainty that the distribution of all chemical plants is <u>at least as broad as</u> the observed distribution of the 2,143 sample plants. To the extent that small plants do not meet the threshold requirements for reporting their toxic releases to EPA, the sample distribution is likely to be narrower and the mean is biased upward from the true distribution. This

[4] Value of production is the total value of shipments, adjusted for inventory changes.

hypothesis can be tested when the 1992 Census of Manufacturers data are available, as the TRI minimum release reporting requirements have been significantly reduced since 1987. On the other hand, there are incentives for establishments to understate their toxic releases in order to avoid future scrutiny by regulatory agents and the surrounding community; this behavior will bias the observed mean and dispersion downward.

Four salient facts are evident from the summary statistics in Table 1. First, there is considerable variation in toxic releases across chemical plants. Looking at the first row, we find that the mean of toxic releases is 19 pounds per thousand dollars of production, and the standard deviation is 89.2, over four and a half times greater.

Second, the quantity of toxic releases varies substantially <u>between</u> industries, as seen in the industry total pounds of toxic releases and the mean of toxic intensity (columns 2 and 3). For example, a single four-digit industry (2869), contributes 81 percent of the organic industry group (286) total. The eight four-digit petrochemical industries emit 62.9 percent of the total chemical industry toxic releases.[5] The mean of toxic releases across four-digit industries ranges from 0.8 pounds per thousand dollars of production (toilet preparations, 2844) to 203.0 pounds per thousand dollars of production (cellulosic

[5]The petro chemical industries are SIC 2821, 2822, 2824, 2843, 2865, 2869, 2873, and 2895.

fibers, 2823), indicating that the average cellulosic fiber plant is over 253 times "dirtier" than the average toilet preparations plant.

Third, the intra-industry variation in toxic releases is often greater than the inter-industry variation. However, the difference between inter- and intra-industries lessens as we disaggregate the data. At the three-digit level, the inter-industry coefficient of variation is 80 percent (0.80), less than the intra-industry coefficient of variation for all eight three-digit industries. Two-thirds of the four-digit industries and one third of the five-digit product classes exhibit coefficients of variation greater than the inter-industry coefficient of variation.

Finally, the distribution of the coefficient of variation shifts downward as the level of aggregation decreases. No three-digit industry group coefficient of variation is of less than 200 percent; however, 38 percent of the four-digit industries and 61 percent of the five-digit product classes have coefficients of variation between 0 and 200 percent (Figure 3).

A disadvantage of the coefficient of variation is that it is influenced by extreme values. To adjust for the possible existence of extreme values, the interquartile range is reported (column 6). One fourth of the three-digit industries, 38 percent of the four-digit industries, and half the five-digit product classes have toxic releases tightly distributed about their respective mean (interquartile range within 5 pounds per thousand dollars of production of their category mean).

While these sample statistics control for primary product and plant size, they do not control for other plant characteristics. The econometric model presented in the next section controls for other plant factors, as well as firm and regulatory effects on toxic waste releases.

III. **EMPIRICAL MODEL**

A plant's toxic waste is a function of what is produced and how it is manufactured; this relationship can be characterize by $T = f(X,Y;t)$, where T represents toxic releases, X represents inputs, Y represents outputs, and t represents the production technology, including pollution prevention and abatement efforts. Ideally, a multiproduct cost or profit function with toxic emission as an undesirable output would be estimated. One limitation of the data set is that it does not contain information on input and output prices; therefore, real inputs and outputs cannot be accurately measured. For this reason, the toxic release model is estimated in two stages: (1) $Y = f(X)$ and (2) $T = g(Y^*,p,f)$, where p and f are vectors of observable plant and firm characteristics. In the first stage, plants are assumed to minimize costs, given competitive input prices. The economic production technology is represented with a four (or five) factor input translog production function and corresponding expenditure share equations. In the second stage, we assume that plants minimize toxic releases, given the optimized output from the first stage and controlling for three levels of effects: regulatory effects, firm effects, and plant effects.   Even assuming cost minimization, one expects some variation within an industry in the generation and treatment of toxic waste due to differences in plant location, size, product structure, and production technology.

Output and factor inputs are measured in thousands of dollars, except labor, which is measured by plant worker hours. Using the assumption that the value of capital input into production is proportional to book value, the book value of buildings and machinery is used to proxy the annual value of capital input. Three-digit industry dummy variables are included in the production equation to control for industry effects. Homogeneity and symmetry are imposed in estimation; constant returns to scale are not imposed. Efficient iterative least square estimates are derived for the system of equations consisting of the production function and the labor, energy, and material expenditure share equations. The limitations of the data are recognized, however, the data appear to fit the model reasonably well.

Plant Effects and Toxic Releases

A number of variables are used to measure plant effects on toxic releases. The major advantage of the LRD data is that they allows identification of major products and material inputs at the plant level. Therefore, dummy variables for key material input classes and the plant's primary five-digit product class are included. Measures of scale and scope in production are also included. The scope, or diversification, of plant production is measured by the primary product's share of total plant shipments.[6] Production scale is measured with predicted output from the first stage production system. This allows for measurement of plant level scalar economies with respect to output in the generation of toxic releases.

Data on plant production technology are not available; therefore, capital intensity and fuel mix are used as proxies for unobserved differences in technology. Pollution abatement is often achieved through the application of capital equipment to capture and/or treat industrial waste. Plants which invest heavily in pollution control should exhibit higher levels of capital intensity, as measured by the log of capital per employee.

[6]One fourth of the sample plants produce only one five-digit product class. Another one third of the plants are highly specialized, with 80-99 percent of their value of shipments in one product class. Only 14 percent of the plants have less than 50 percent of their value of shipments in one product class. Another measure of diversification is the number of five-digit products manufactured. Only 13 percent manufacture more than five-digit products.

Because the production of many chemicals is a thermodynamic process, energy is a critical input. Energy consumption is closely related to many types of environmental pollution, particularly fossil fuel based energy. The share of energy from electricity is included as an indication of energy fuel mix.[7] In general, electricity's share of total energy decreases as energy intensity increases; thus, processors of raw material, which require substantial energy, exhibit lower electricity share (Doms, 1992). Fuels used as feedstock are included in the material input.

Firm Effects and Toxic Releases

To a large degree, plant location, investment, and product lines are firm level decisions. Therefore measures of the parent firm's size, diversification, and management are included in the model. Firm size is measured by total firm employment, across all plants, in all sectors of the economy. Diversification of the firm is measured by the number of two-digit industries which the firm operates in. Firm diversification is included to test two competing hypotheses. One hypothesis is that firms operating solely in the chemicals industry are more aware of and adept in using the latest production and pollution prevention/abatement

[7]The data include information on purchased electricity only. Electricity generated and consumed by the plant is unreported. The energy expenses and electricity share may be understated. It is estimated that 10 percent of electricity consumed in manufacturing in 1986 was generated onsite (Ross, 1991).

technology than diversified firms, indicating an inverse relationship between diversification and toxic releases. On the other hand, if diversification is a proxy for business success, where success encompasses efficient pollution abatement, then we would see an inverse relationship between diversification and toxic releases. Lastly, firm specific dummy variables proxy for differences in management and production processes across firms.

Regulatory Effects and Toxic Releases

The impact of environmental regulation on toxic releases is difficult to measure with cross sectional data. Differences in state emissions reflect not only the type of manufacturing activity occurring within each state, the number and size of plants, but also differences in regulatory tightness across states. Manufacturing plants are subject to both state and federal environmental regulation. A number of states implemented toxic waste reduction programs prior to any Federal action. In addition, monitoring and enforcement of some federal regulations are the responsibility of the state.[8] Therefore, state dummy variables are used to proxy regulatory effects.[9]

Studies of air and water emissions generally use pollution abatement expenditures to measure the impact of regulation on facilities. While releases of some chemical toxins on EPA's TRI list are regulated under the Clean Air and Clean Water Acts, most are not federally regulated. Facilities are required only to report their manufacture and use of the listed toxins. Efforts to reduce releases of these toxic chemicals are voluntary. Nevertheless, pollution abatement expenditures are included in the toxin equation to test the strength of the relationship between pollution abatement expenditures and TRI releases. An additive error term is appended to the toxic release equation.

It is unclear how pollution abatement technology enters into a plant's decision and production process. It is reasonable to

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[8]There are a number of works which seek to explain the linkage between plant location and environmental regulation. Levinson's (1992) paper contains a nice review of this literature. Only a few studies have found environmental regulation to have a significant impact on new plant location, such as Levinson (1992) and McConnell and Schwab (1990). Beede, Bloom, and Wheeler (1990) hypothesis that for existing plants, marginal changes in state environmental regulation is meet by changes in production technology to reduce environmental waste or changes in product structure.

[9]State level environmental expenditures, developed by Beede, Bloom, and Wheeler (1992), were insignificant, perhaps because these state expenditures measure the differences across states in the intensity of regulation enforcement, but not of the stringency of the regulations.

include pollution abatement in the production function as such activities impact output by diverting resources away from production. At the same time, pollution abatement also impact emissions. Therefore, I include pollution abatement operating and maintenance expenditures in both the production equation and toxic release equation.

The empirical model is:

Stage I:

$$\begin{aligned} \ln Y &= \alpha_0 + \sum_{k=1}^{7}\beta_k IND_k + \sum_{i=1}^{4}\beta_i \ln X_i + \frac{1}{2}\sum_{i=1}^{4}\sum_{j=1}^{4}\beta_{ij} + \epsilon \\ m_i &= \beta_i + \sum_{j=1}^{3}\beta_{ij}\ln X_j \end{aligned} \tag{1}$$

Stage II:

$$\begin{aligned} \ln T = \alpha_o &+ \Sigma\beta_m MC_m + \Sigma\beta_l PPC_l + \beta_p \ln DIVERSE_p + \beta_y \ln Y* + \\ &\beta_e ELEC + \beta_{kl}\ln CAP/LAB + \beta_l \ln TE + \beta_d \ln DIVERSE_f + \\ &\Sigma\beta_f FIRM_f + \Sigma\beta_s STATE_s + \beta_{pol}\ln PACE + \epsilon \end{aligned} \tag{2}$$

where

lnY	log (value of production), in thousands of dollars
$\ln X_i$	log (factor input)
	capital--book value of assets, in thousands of dollars
	labor--worker hours
	energy--energy expenditures, in thousands of dollars
	materials--materials expenditures, in thousands of dollars
	pace--pollution abatement operating expenditures, in thousands of dollars
IND	three-digit industry dummy variable
lnT	log (pounds of toxins released or transferred offsite)

<u>plant effects</u>:

MC	material dummy variable
PPC	primary product dummy variable
$\ln DIVERSE_P$	log (primary product's share of value of shipments)

lnY*	predicted log(value of production, in thousands of dollars)
ELEC	purchased electricity / fuel expenditures
lnCAP/LAB	log (capital book value, in thousands of dollars/total employment)
firm effects:	
lnTE	log (parent company's total employment)
$lnDIVERSE_F$	log (number of two-digit industries parent firm operates in)
FIRM	parent company dummy variable
regulatory effects:	
STATE	state location dummy variable
lnPACE	log (pollution abatement operating expenditures, in thousands of dollars)

IV. **ESTIMATION RESULTS: INTRA PRODUCT CLASS VARIATION**

Coefficient estimates for two models are reported in Table 2. Model I is estimated with data on 2,143 chemical plants from 1987, with pollution abatement expenditures absorbed into the other input categories. Model II separates out pollution abatement operating and maintenance expenditures from labor, energy, and material expenditures, creates a fifth factor input for pollution abatement operating expenses, and is estimated with the 852 observations for which pollution abatement expenditure data are available.

While our main interest is in the generation of toxic waste, a brief note on the estimated production function is in order. Surprisingly, both models exhibit slight decreasing returns to scale: 0.97 in Model I and 0.96 in Model II. Wald tests on constant returns to scale and the Cobb-Douglas functional form are strongly rejected at the 99 percent level by both models.

Monotinicity conditions, which require that all expenditure shares be non negatives, are met for all but 3.6 percent of the 8,572 predicted expense shares in Model I and 5.4 percent of the 4,030 expense shares in Model II. These violations are related primarily with a negative estimate for the energy share. Estimated own price elasticities are all appropriately negative and fairly elastic, ranging from a low of -1.34 for materials to a high of -5.9 for energy. All cross price elasticities are positive in Model I. Allen and Morishima substitution elasticities indicate substantial scope for substitution among all factor inputs. While all factor inputs are Morishima substitutes in Model II, labor and capital, energy and capital, energy and materials, energy and pollution abatement, and pollution abatement and capital are Allen compliments.

Model I explains 58 percent of the observed cross sectional variation in plant level toxic intensity and Model II explains 62 percent. The following discussion is based on model I, evaluated at the sample mean, unless otherwise stated.

Plant Effects

Toxic releases increase with both the scale and scope of plant activity. Model I exhibits slight increasing returns to scale in the generation of toxic waste. A 1 percent increase in output generates a 1.08 percent increase in toxic waste. However, when pollution abatement operating expenditures are included in the model (Model II), there appears to be decreasing scalar returns in the generation of toxic releases; a 1 percent increase in output generates only a 0.6 percent increase in toxic releases. This difference in scalar returns between the models is not a function of the different samples, but solely due to model specification. When Model I (with pollution abatement omitted) is estimated on the subsample used to estimate Model II, returns to scale are again slightly greater than unity.

Toxic releases increase by 0.3 percent with a 1 percent increase in plant level diversification. This supports the hypothesis that highly specialized producers are more knowledgeable about, and better able to prevent toxic releases than diversified producers. This may be driven by the difference in batch and continuous production. Batch production, where small amounts of a variety of specialized products are produced requires the shutdown and cleaning of equipment between production runs, thereby increasing the likelihood of toxic waste being released.

The two measures of production technology, capital intensity and electricity's share of total energy, are inversely related to toxic releases. This inverse relationship between toxic releases and electricity's share of energy is consistent with the facts that: 1) large energy consuming plants use proportionately less electricity than do small energy consuming plants, 2) large energy consuming plants are generally processors of raw materials, as opposed to finishers, and 3) processors generate greater volumes of industrial waste, including toxins.

Firm Effects

Perhaps the most significant result of this analysis, in terms of industrial behavior, is that certain firms generate significantly different amounts of toxic releases, even after accounting for regulatory effects, product choice, and other plant characteristics. Thirteen firms, with 64 chemical plants, operate with significantly lower toxic emission, and two firms release significantly greater amounts of toxins.[10] There are a number of possible sources of these anomalies. First, differences in toxic waste may reflect differences in production technology across plants of a firm not captured by the model.

The observed heterogeneity may arise from differences in management ability and actions. Certain plants (firms) are just better at using pollution prevention and abatement devices and techniques. Finally, it is plausible that there are certain intra firm "spill-over effects". For example, if management at one plant of a multi-unit firm develops the methods to prevent or reduce toxic releases, say in response to public pressure, location in a tightly regulated state, or court action, these methods are likely to be adopted by all plants within the firm,

[10] Six of the statistically significantly firm dummies from Model I are also significant in Model II. In addition, three other firm dummies are statistically significant in Model II.

but not necessarily spread beyond the firm. Previous analysis of production diversification indicates that plants belonging to the same firm tend to be similar in product structure, while differences across firms is substantial (Streitwieser, 1991). As with the state effects, additional data and modeling effort are necessary to isolate the sources of the firm differentials.

Toxic releases increase with both firm scale and scope, although firm effects are weaker than plant scale and scope effects.[11] A 1 percent increase in the parent firm's total employment is associated with a 0.4 percent increase in toxic releases, and a 1 percent increase in firm diversification results in a .2 percent increase in toxic releases.

Regulatory Effects

Only two state dummy variables in Model I are statistically significant. Chemical plants in Colorado and North Carolina exhibit significantly lower than average toxic releases, after controlling for firm and plant effects. With Model II, only Delaware has toxic releases significantly lower than average, while Tennessee, Texas, and West Virginia have greater than average toxic waste. The difference in the significant state dummies between the two models is driven by the different data

[11]There is a strong linear relationship between firm size and diversification. This results is severe multicolinearity problems when both variables are included in the toxic release equation. To correct for this multicolinearity, the relationship among these two regressors is formalize into a second equation, and the two equations are estimated simultaneously.

samples, not the treatment of pollution abatement expenses. When Model I is estimated on the subset of plants used to estimate Model II Delaware, Tennessee, Texas, and West Virginia dummy variables are significant, Colorado and North Carolina are not. Additional data on state programs and enforcement activities are needed to determine if these state effects truly reflect differences in regulatory tightness or some other unmeasured effect.

From model II, pollution abatement operating expenditures have a significant impact on both production output and toxic releases: 1 percent increase in pollution abatement operating expenses is associated with a 0.4 percent increase in toxins. This should not be interpreted as a causal relationship. Rather, increases in toxic waste generation are met with increased outlays to control the toxins. However, the pollution abatement variable is subject to measurement error. It reflects operating expenditures on all types of pollution abatement activity, not just that associated with toxic releases.

V. **CONCLUSIONS**

This paper uses a unique plant level data set on over 2,100 chemical plants in 1987 to document and explain the heterogeneity of toxic releases. First, I measure the dispersion to show that, even at the four-digit level, intra-industry variation in toxic releases is often as great as, or greater than, <u>inter-industry</u> variation. Next, I estimate a two stage model of toxic releases, in which plants are classified according to their primary product. Empirical results indicate differences in toxic releases vary systematically with measurable plant, firm, and regulatory effects.

The model is able to explain more than half the observed variation in plant level toxic releases. Toxic releases increase with the scale and scope of plant and firm level activities, although plant level effects are stronger. Differences in production technology, as measured by capital intensity and share of energy from electricity, are inversely related to toxic releases.

The firm dummy variables show that a number of firms are more "efficient" in terms of toxic waste, although a few firms are significantly "dirtier", reflecting differences in management ability and/or unmeasured differences in production technology. Finally, few state location dummy variables are significant, suggesting that location is not a close proxy for differences in regulatory stringency.

Data are not currently available to determine the remaining difference in inter plant/firm toxic release intensity. There are two areas to focus our attention on. Either there is consistent measurement error in the data reported by plants of certain firms, or plants of certain firms do not have the standard stream of toxic releases because they do not generate the toxins in the first place, or they are more effective in capturing, neutralizing, and/or recycling the toxins. At this time little can be said about possible measurement error in the economic data. However, an EPA study indicates that the chemical industry has not only the highest compliance rate for required reporting of toxic releases (88 percent), but also a low rate for errors in what is reported.[12] Differences in toxic release streams, *ceteris paribus,* can be due to the selected outputs,use of different production technology, including use of different inputs and/or processes, or differences in management ability. Data on production technology is highly desirable.

The policy implications that can be drawn from this paper are threefold. First, additional data are needed on production processes, management attitudes and actions concerning pollution prevention and abatement, and inputs and outputs of production. An end to the exemption to small plants from reporting detailed data would facilitate more complete examination of scalar economies in pollution prevention and abatement. Second, more research is needed to identify the unobserved firm and plant

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[12]Analysis of Non-Respondents to Section 313 of the Emergency Planning and Community Right-To-Know Act" by Abt Associates, Inc. (March 1990) and "Site Visit Program to Assess 1988 Toxic Release Inventory Data Quality" by Radian Corp. (July 1991). I assume the conclusions reached by Radian based on 1988 TRI data are applicable to 1987 data as well, in terms of relative industry responses.

differences in toxic releases. The relative importance of technology versus management are essential to formulating cost effective public policy.

Finally, where there are cost effective methods for production with lower toxic releases, as evident by broad distributions of toxic intensity for producers of the same products, policy makers could promote the dispersion and adoption of the less toxic production technologies.[13] Where there does not appear to be any existing pollution prevention and abatement technology, the policy should be to promote the research and development of such technology. Considering the substantial intra-product class heterogeneity among plants, is would be surprising if the traditional "command and control" approach to capture pollution with end-of-line equipment is the optimal approach.[14]

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[13]The Office of Industrial Technologies, U.S. Department of Energy currently conducts a joint industry-government program to identify areas where research and development of energy and waste efficient manufacturing technology are most needed.

[14]Helfand (1991) provides a theoretical framework for the effects of several common types of environmental regulation. Both firm and industry structure can be distorted when a single regulation is imposed on a heterogeneous industry.

Table 1

Chemical Industry Toxic Releases Distribution
Summary Statistics, 1987
(N = 2,143)

Industry (SIC Code)	Sum Toxic Releases[1]	Mean Toxic Intensity[2]	Standard Deviation	Coefficient of Variation	Interquartile Range
Chemicals & Allied Products (28)	2,794.27	19.03	89.17	4.69	8.06
Three-Digit Industry Group					
Industrial Inorganic (281)	360.09	34.07	172.30	5.06	7.21
Plastics & Resins (282)	441.41	11.30	35.07	3.10	7.22
Drugs (283)	85.23	13.73	33.09	2.41	8.26
Soaps & Cosmetics (284)	25.75	3.22	11.86	3.68	0.85
Paints & Allied Products (285)	65.05	9.15	27.14	2.97	7.49
Industrial Organics (286)	1,106.63	34.50	110.04	3.19	22.09
Agricultural Chemicals (287)	649.19	50.45	135.99	2.70	22.58
Misc. Chemicals (289)	60.93	7.48	35.08	4.69	4.07
Across 3-Digit Industry Groups	2,794.27	20.49	16.92	0.83	25.97
Four-Digit Industry					
Alkalies & Chlorine (2812)	8.96	5.92	10.54	1.78	5.15
Industrial Gases (2813)	2.68	18.57	108.74	5.86	0.56
Inorganic Pigments (2816)	199.37	103.84	418.84	4.03	24.85
Industrial Inorganic, NEC (2819)	149.07	30.50	119.41	3.92	7.81

Industry (SIC Code)	Sum Toxic Releases[1]	Mean Toxic Releases	Standard Deviation	Coefficient of Variation	Interquartile Range
Plastics & Resins (2821)	169.49	7.38	12.54	1.70	7.11
Synthetic Rubber (2822)	111.70	20.38	48.87	2.40	9.75
Cellulosic Fibers (2823)	106.17	203.01	163.96	0.81	276.48
Organic Fibers (2824)	54.05	5.71	11.76	2.06	3.94
Medicinals & Botanicals (2833)	56.39	22.81	27.08	0.97	43.09
Pharmaceuticals (2834)	25.53	9.99	36.05	3.61	2.77
Diagnostic Substances (2835)	(D)	(D)	(D)	(D)	(D)
Biological Products (2836)	2.67	3.51	4.27	1.22	6.02
Soap & Detergents (2841)	2.32	1.09	4.35	4.00	0.46
Polishes & Sanitation (2842)	0.83	0.85	1.98	2.33	0.70
Surface Active Agents (2843)	20.52	10.05	21.82	2.17	7.95
Toilet Preparations (2844)	2.08	0.84	1.90	2.27	0.48
Paints & Allied Products (2851)	65.05	9.15	27.14	2.97	7.49
Gum & Wood Chemicals (2861)	(D)	(D)	(D)	(D)	(D)
Cyclic Crudes & Intermed. (2865)	228.12	41.29	89.08	2.16	34.46
Industrial Organics, NEC (2969)	875.78	32.15	117.57	3.66	17.22
Nitrogenous Fertilizers (2873)	273.54	114.16	178.41	1.56	83.09
Phosphatic Fertilizers (2874)	329.04	90.72	211.09	2.33	35.02
Mixed Fertilizers (2875)	0.11	0.91	1.90	2.08	0.59
Agricultural Chem., NEC (2879)	46.49	8.02	22.29	2.78	7.37
Adhesives & Sealants (2891)	11.87	4.85	11.02	2.27	4.39
Explosives (2892)	6.54	7.88	10.32	1.31	8.49

Industry (SIC Code)	Sum Toxic Releases[1]	Mean Toxic Intensity[2]	Standard Deviation	Coefficient of Variation	Interquartile Range
Printing Ink (2893)	2.00	3.30	4.78	1.45	3.69
Chemicals, NEC (2899)	37.53	10.45	52.05	4.98	2.52
Across 4-Digit Industries	2,794.27	27.99	45.19	1.61	22.96
Five-Digit Product Class					
Chlorine (28121)	(D)	(D)	(D)	(D)	(D)
Sodium Hydroxide (28123)	7.01	8.08	13.83	1.71	10.08
Other Alkalies (28125)	1.03	3.99	4.44	1.11	4.94
Carbon Dioxide (28133)	1.40	116.36	287.28	2.47	9.70
Nitrogen (28135)	0.24	3.97	17.47	4.40	0.09
Oxygen(28136)	0.27	0.19	0.46	2.38	0.05
Other Industrial Gases (28137)	(D)	(D)	(D)	(D)	(D)
Titanium Pigments (28161)	134.81	64.89	82.24	1.26	119.48
Other White Opaque Pigments (28162)	1.53	7.07	10.61	1.50	5.27
Chrome Colors (28163)	63.03	150.63	555.85	3.69	6.72
Industrial Inorganics, NSK (28190)	(D)	(D)	(D)	(D)	(D)
Sulfuric Acid (28193)	24.18	138.85	354.05	2.55	77.90
Inorganic Acids (28194)	(D)	(D)	(D)	(D)	(D)
Aluminum Oxide (28195)	(D)	(D)	(D)	(D)	(D)
Other Aluminum Compounds (28196)	0.04	0.98	0.89	0.90	0.41
Potassium & Sodium Comp. (28197)	21.73	23.98	85.67	3.57	5.66

Industry (SIC Code)	Sum Toxic Releases[1]	Mean Toxic Intensity[2]	Standard Deviation	Coefficient of Variation	Interquartile Range
Catalytic Preparations (28198)	19.88	17.66	27.93	1.58	20.43
Plastics Materials, NSK (28210)	0.13	1.85	2.31	1.24	3.55
Thermoplastic Resins (28213)	141.67	6.78	10.84	1.60	6.78
Thermosetting Resins (28214)	27.69	8.59	14.87	1.73	6.50
Synthetic Rubber (29220)	111.70	20.38	48.87	2.40	9.75
Rayon & Acetate Fibers (28230)	106.17	203.01	163.96	0.81	276.48
Nylon (29241)	41.3	18.84	24.17	1.44	30.11
Polyester (29244)	5.14	2.53	2.20	0.87	2.77
Other Manmade Fibers (29247)	6.59	6.18	8.35	1.36	16.15
Textured Manmade Fibers (29248)	1.02	1.48	2.46	1.67	1.27
Medicinal Chemicals (28330)	(D)	(D)	(D)	(D)	(D)
Synthetic Organic Medicinals (28331)	54.34	26.18	25.22	0.96	35.21
Other Medicinals, NEC (28333)	1.46	17.99	34.94	1.94	35.30
Pharmaceuticals NSK (28340)	(D)	(D)	(D)	(D)	(D)
Pharmaceuticals Affecting Neoplasms (28341)	(D)	(D)	(D)	(D)	(D)
Pharmaceuticals Acting on Nervous Systems (28342)	1.59	6.39	22.07	3.45	1.97
Pharmaceuticals Acting on Cardiovascular System (28343)	2.36	1.00	1.05	1.04	2.02
Pharmaceuticals Acting on Respiratory System(28344)	2.13	1.07	1.81	1.69	0.89
Pharmaceuticals Acting on Digestive System(28345)	0.37	0.30	0.48	1.63	0.24

Industry (SIC Code)	Sum Toxic Releases[1]	Mean Toxic Intensity[2]	Standard Deviation	Coefficient of Variation	Interquartile Range
Phar. Acting on Skin (28346)	(D)	(D)	(D)	(D)	(D)
Vitamins (28347)	2.33	6.03	8.96	1.48	7.60
Pharmaceuticals Affecting Infective Diseases (28348)	11.85	6.62	15.77	1.38	3.85
Phar., Veterinary Use (28349)	3.68	36.62	84.53	2.31	15.06
Diagnostic Sub., In Vitro (28351)	(D)	(D)	(D)	(D)	(D)
Blood & Derivatives (28361)	(D)	(D)	(D)	(D)	(D)
Other Biologics (28363)	(D)	(D)	(D)	(D)	(D)
Biologics, Vet. Use (28364)	(D)	(D)	(D)	(D)	(D)
Soap & Detergents, NSK (28410)	0.05	0.55	1.31	2.05	0.41
Soap & Detergents, Not Hshd (28411)	1.07	1.36	5.28	3.87	0.50
Household Detergents (28412)	1.18	0.89	3.51	3.94	0.16
Soaps, Household (28413)	0.02	0.42	0.94	2.23	0.00
Specialty Cleaning, NSK (28420)	0.05	0.98	1.39	1.42	1.72
Household Bleaches (28422)	(D)	(D)	(D)	(D)	(D)
Specialty Cleaning (28423)	0.69	1.60	2.93	1.83	1.06
Polishing Preparations (28424)	0.10	0.54	0.80	1.47	0.75
Surface Active Agents (28430)	20.52	10.05	21.82	2.17	7.95
Perfumes & Cosmetics, NSK (28440)	(D)	(D)	(D)	(D)	(D)
Perfumes (28442)	(D)	(D)	(D)	(D)	(D)
Hair Preparations (28443)	0.78	0.95	2.13	2.24	0.56

Industry (SIC Code)	Sum Toxic Releases[1]	Mean Toxic Intensity[2]	Standard Deviation	Coefficient of Variation	Interquartile Range
Dentifricers (28444)	(D)	(D)	(D)	(D)	(D)
Other Cosmetics (28445)	1.15	0.99	2.19	2.20	0.45
Paints & Varnishes, NSK (28510)	0.36	4.23	5.79	1.37	5.24
Architectural Coatings (28511)	7.91	2.23	5.58	2.49	1.98
Product Finishes (28512)	40.28	15.79	39.91	2.53	13.58
Special Purpose Coatings (28513)	13.46	8.16	14.17	1.36	7.62
Misc. Paint Products (28515)	3.05	7.48	16.58	2.22	8.69
Softwood Distillations (28611)	(D)	(D)	(D)	(D)	(D)
Other Gum & Wood Products (28612)	(D)	(D)	(D)	(D)	(D)
Cyclic Organic Crudes, NSK (28650)	(D)	(D)	(D)	(D)	(D)
Cyclic Intermed. (28651)	167.32	58.00	91.42	1.58	67.41
Synthetic Organic Dyes (28652)	13.90	12.93	16.02	1.24	20.88
Synthetic Organic Pigments (28653)	37.41	50.87	127.81	2.51	24.02
Tars (28655)	4.41	30.14	66.34	2.20	9.38
Aromatics (28656)	(D)	(D)	(D)	(D)	(D)
Industrial Organics, NSK (28690)	10.20	16.70	32.11	1.92	16.49
Liquefied Refinery Gases (28691)	28.05	3.36	1.59	0.47	2.50
Synthetic Organic Chem, NEC (28693)	23.23	46.49	219.71	4.73	10.06
Pesticides (28694)	20.43	16.38	15.38	0.94	29.76
Ethyl Alcohol (28695)	10.19	27.06	51.63	1.91	29.89

Industry (SIC Code)	Sum Toxic Releases[1]	Mean Toxic Intensity[2]	Standard Deviation	Coefficient of Variation	Interquartile Range
Misc. End-Use Chemicals (28696)	22.23	26.43	78.71	2.98	11.62
Misc. Cyclic Chemicals (28697)	761.45	39.45	120.55	3.06	21.39
Nitrogenous Fertilizers, NSK (28730)	(D)	(D)	(D)	(D)	(D)
Synthetic Ammonia Comp. (28731)	211.25	103.70	179.49	1.73	84.32
Urea (28732)	62.30	218.45	161.79	0.74	256.41
Phosphatic Fertilizers, NSK (28740)	(D)	(D)	(D)	(D)	(D)
Phosphoric Acid (28741)	169.02	138.06	171.09	1.24	274.98
Superphosphate Fertilizers (28742)	159.43	120.38	275.52	2.29	92.42
Mixed Fertilizers (28744)	0.59	7.03	12.67	1.80	4.64
Mixed Fertilizers (28750)	0.11	0.91	1.90	2.08	0.59
Pesticides, NSK (28790)	0.04	1.62	2.31	1.43	1.97
Insecticidal Prep. (28795)	2.39	7.42	12.61	1.70	14.79
Herbicidal Preparations (28796)	40.59	13.07	33.94	2.60	16.16
Fungicidal Preparations (28797)	2.76	5.57	10.20	1.83	10.43
Other Pesticidal Prep. (28798)	(D)	(D)	(D)	(D)	(D)
Hshd Pesticidal Prep. (28799)	0.43	1.07	1.01	0.94	1.93
Adhesives, NSK (28910)	0.63	10.72	21.72	2.03	13.10
Natural Base Glues (28913)	(D)	(D)	(D)	(D)	(D)
Synthetic Resins (28914)	10.22	5.48	11.47	2.09	5.79
Structural Sealants (28916)	0.68	3.57	2.80	0.78	1.25

Industry (SIC Code)	Sum Toxic Releases[1]	Mean Toxic Intensity[2]	Standard Deviation	Coefficient of Variation	Interquartile Range
Nonstructural Sealants (28917)	0.32	0.85	1.43	1.69	0.86
Explosives (28920)	6.54	7.88	10.32	1.31	8.49
Printing Ink, NSK (28930)	(D)	(D)	(D)	(D)	(D)
Letterpress Inks (28931)	(D)	(D)	(D)	(D)	(D)
Lithographic & Offset Inks (28932)	0.14	2.08	4.81	2.32	0.72
Gravure Inks (28933)	0.87	5.75	5.73	1.00	6.17
Flexographic Inks (28934)	0.86	2.01	3.50	1.74	1.47
Printing Inks, NEC (28935)	0.13	2.70	3.72	1.38	1.92
Carbon Black (28950)	(D)	(D)	(D)	(D)	(D)
Chemicals, NSK (28990)	0.63	7.58	12.31	1.62	11.34
Evaporated Salt (28991)	(D)	(D)	(D)	(D)	(D)
Fatty Acids (28992)	18.97	25.59	35.88	1.40	32.08
Gelatin, Except Ready-to-Eat (28994)	3.65	53.15	57.15	1.08	89.64
Chem. Preparation, NEC (28995)	14.12	8.92	55.78	6.21	1.99
Across 5-Digit Product Class	2,794.27	21.33	40.42	1.90	16.60

[1] Pounds of Toxins Releases and Transfers, in millions.
[2] Pounds of Toxins/Thousand Dollars Value of Production.
(D) Disclosure protected.

Table 2

PARAMETER ESTIMATES

	Model I		Model II	
TOXIC RELEASE EQUATION				
Plant Effects				
Product Dummies	Yes*		Yes*	
Material Dummies	Yes*		Yes*	
Intercept	8.035*	(0.920)	10.195*	(1.136)
Y*	1.080*	(0.048)	0.637*	(0.106)
CAP/LAB	-0.173*	(0.047)	-0.124	(0.070)
ELEC	-0.332*	(0.121)	-1.355*	(0.573)
$DIVERSE_P$	-0.341*	(0.131)	-0.287	(0.187)
Firm Effects				
Firm Dummies	Yes*		Yes*	
TE_F	0.388*	(0.004)	0.429*	(0.008)
$DIVERSE_F$	0.241*	(0.057)	0.080	(0.092)
Regulatory Effects				
State Dummies	Yes*		Yes*	
PACE			0.367*	(0.069)
Number of Observations	2,143		852	
Adjusted R^2	0.5792		0.6235	

*Significant at 95 percent level
Standard errors in parenthesis

	Model I		Model II	
PRODUCTION EQUATION				
Industry Dummies	Yes*		Yes*	
Intercept	9.914*	(0.024)	10.979*	(0.049)
LAMBDA	0.972*	(0.007)	0.957*	(0.014)
CAPITAL	0.352*	(0.001)	0.392*	(0.004)
LABOR	0.149*	(0.002)	0.126*	(0.002)
ENERGY	0.028*	(0.001)	0.032*	(0.001)
MATERIAL	0.443*	(0.004)	0.396*	(0.006)
PACE			0.011*	(0.000)
$CAPITAL^2$	0.063*	(0.000)	0.167*	(0.003)
$LABOR^2$	0.077*	(0.001)	0.073*	(0.001)
$ENERGY^2$	0.023*	(0.001)	0.025*	(0.001)
$MATERIAL^2$	0.138*	(0.002)	0.170*	(0.003)
$PACE^2$			0.009*	(0.000)
CAPITAL*LABOR	-0.043*	(0.000)	-0.032*	(0.001)
CAPITAL*ENERGY	-0.008*	(0.000)	-0.008*	(0.001)
CAPITAL*MATERIAL	-0.098*	(0.000)	-0.126*	(0.001)
CAPITAL*PACE			-0.001*	(0.001)
LABOR*ENERGY	-0.004*	(0.001)	-0.009*	(0.001)
LABOR*MATERIAL	-0.029*	(0.001)	-0.032*	(0.001)
LABOR*PACE			0.000	(0.000)
ENERGY*MATERIAL	-0.011*	(0.001)	-0.007*	(0.001)
ENERGY*PACE			-0.002*	(0.000)
MATERIAL*PACE			-0.006*	(0.000)
Number of Observations	2,143		852	
Adjusted R^2	0.9085		0.8599	

*Significant at 95 percent level.
Standard errors in parenthesis.

figures 1 & 2

figures 3 & 4

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APPENDIX A

I. **Data Sources**

The data analyzed in this paper are extracted from a database created by integrating four datasets. Two data sets from the U.S. Bureau of the Census and two from the EPA are integrated to form a plant level cross sectional database for 1987. Data on production inputs and outputs are from the Longitudinal Research Database (LRD). The LRD is maintained at the Census Bureau's Center for Economic Studies; it is a concatenation of the 1963, 1967, 1972, 1977, and 1982 Census of Manufacturers (CM) and all Annual Survey of Manufacturers (ASM) since 1977. This paper uses 1987 data as census year data give the greatest possible match rate between the various data sets.[15]

Pollution abatement operating and maintenance expenditures are from the 1988 Pollution Abatement Cost and Expenditures Survey, also from the Bureau of the Census.

Census of Manufacturers (CM)

The CM is a complete enumeration of all manufacturing establishments, conducted every five years by the U.S. Bureau of the Census. An establishment is defined as a single physical location, generally corresponding to a manufacturing plant. Each

[15] The Census of Manufacturers is conducted decennially, in years ending with "2" or "7". It is a complete enumeration of all manufacturing establishments. The Bureau surveys a sample of mostly large plants in non-census years for the Annual Survey of Manufacturers.

plant is classified to an industry according to the Standard Industrial Classification System (SIC). An industry code is assigned based on the plant's primary activity, as determined by the greatest portion of value of shipments. In 1987 there were 12,392 plants classified in the chemical industry (SIC 28). Plant data from the LRD used for this study include the following:

Identifying Information: Name, Address, and Plant Number
Location Information: State, County, SMSA, and Place
Assigned Industry: Four-digit SIC Code
Products Produced: Five-digit SIC Codes
Value of Shipments: Total for each Five-digit Product
Labor Inputs: Total Employment, Production Hours, and Salary and Wages
Energy Inputs: Total Energy Expenditures and Electricity Purchased
Material Inputs: Total Cost of Materials
Materials Used in Production: Six-digit SIC Code
Value of Production: Value of Shipments adjusted for Work In Progress and Changes in Inventory.

Pollution Abatement Cost and Expenditures Survey (PACE)

The PACE, conducted annually by the U.S. Bureau of the Census, surveys approximately 17,000 manufacturing plants about their annual pollution abatement operating, maintenance, and new pollution abatement capital investment expenditures. As no survey was conducted in 1987, data from the 1988 survey are used. The survey is a probability sampling of plants from the 1987 Annual Survey of Manufactures (ASM). The ASM is itself a probability sampling of approximately 57,000 manufacturing plants selected from the 1982 CM, supplemented annually by new manufacturing plants. All plants with fewer than 20 employees are excluded from the PACE survey.[16]

The 1988 PACE survey includes 864 plants in the chemical industry. Data extracted from the survey are:

Identifying Information: Name, Address, and Plant Number
Location Information: State, County, SMSA, and Place
Assigned Industry: Four-digit SIC code
Pollution Abatement Operating Expenditures: Labor, Materials, and Capital Depreciation.

<u>Toxic Release Inventory (TRI)</u>

A chemical is toxic if it causes damage to living tissue, impairment of the central nervous system, severe illness, or death when ingested, inhaled, or absorbed through the skin. Toxicity is an objective measure based on test dosages made on experimental animals under controlled conditions. All known carcinogenic chemicals are classified as toxic. Toxins are a subset of hazardous material, but not all hazardous materials are toxic.[17]

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[16]Early surveys indicated establishments with fewer than 20 employees contributed only 2 percent to the pollution abatement spending estimates but were 10 percent of the sample. Since 1976 these small establishments have been dropped from the sampling frame.

[17]A hazardous material is one which, in normal use, can be damaging to the health and well-being of man. Such material include toxic agents, corrosive chemicals, flammable materials, explosives and strong oxidizers, materials subject to heat build-up during storage, and radioactive chemicals that emit ionizing radiation.

Under Title III of the Superfund Amendments and Reauthorization Act of 1986,[18] all manufacturing facilities are required to report annually to EPA the presence, releases, and transfers offsite of some 320 toxic chemicals if they:[19]

1) engage in general manufacturing activities, and
2) employ the equivalent of ten or more full time employees, and
3) a. produce, and/or import, and/or process 75,000 pounds or more of any TRI chemical, or
   b. use 10,000 pounds or more in any manner.

Much of this data is available to the public through the Toxic Release Inventory database (TRI).

The TRI data files contains information identifying the facility involved and its parent company, the chemical toxin released and/or transferred for off-site disposal, the environmental media which the chemical was released into or transferred to (air, land, or water), the quantity involved (pounds), a four-digit sic code for the facility's activity, and a description of the toxins use.[20] The TRI is intended to

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[18]Data is collected annually under the authority of Section 313 of the Emergency Planning and Community Right-To-Know Act (EPCRA), part of the Superfund Amendments and Reauthorization Act of 1986 (SARA).

[19]The TRI requirements have changed somewhat since 1987. The threshold of 75,000 pounds was lowered to 50,000 pounds in 1988 and lowered again to 25,000 pounds in 1989.

[20]The TRI SIC code frequently does not match the industry classification by the Census Bureau. Selection for inclusion in this study was based on the Census Bureau's classification, as it reflects the primary activity of the establishment. The TRI and

provide communities with information about potential toxic hazards and to improve planning for chemical accidents. In 1987, 21.3 billion pounds of toxins were released or transferred from the 20,805 reporting manufacturing facilities. Over 4,100 of the facilities (20 percent) were engaged in chemical production activities involving toxic chemicals, accounting for 56.6 percent of the total toxins, or 12 billion pounds.

The toxic release data are updated to reflect changes in the TRI listing from 1987 to 1992, resulting in a decrease in releases by the chemical plants in the LRD-TRI data set from 5.9 to 2.8 billion pounds annually, a 51.5 percent reduction. As new information becomes available, EPA drops chemicals judged insufficiently toxic from the TRI list. The 1987 release data is modified by omitting the chemicals removed from the TRI list.

The following data from the 1987 TRI are used for this study:

Identifying Information: Name, Address, Location, Facility Number
Chemical Identification: Number and Quantity
Disposition of Toxin: Released to Air, Land, Water or Transferred Offsite

Four cautionary notes are in order when using the TRI data. First, the EPA's TRI list does not cover all toxic chemicals. The list changes periodically with new information on the

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LRD codes differ for 15 percent of the sample at the two-digit level and for one third of the sample at the four-digit level. In addition, for the chemical industry, two thirds of the SIC codes in the TRI are not legitimate.

toxicity of specific chemicals. Second, the 1987 TRI reporting threshold of 75,000 pounds of releases effectively eliminated most small plants from reporting, thus the report is based on data for only 2100 of 12,000 chemical plants. While releases from each excluded plant are below the required level for reporting, collectively, these plants may be releasing substantial amounts of toxins. Third, the TRI measures <u>releases</u> of toxins, not <u>exposure</u> of the public to the toxins or the <u>effects</u> of any exposure. Finally, TRI releases are self reported, often based on estimates and not actual measurement. As 1987 was the first required reporting year, methodologies for estimating toxic releases were not well developed. A number of different methods were allowed. In addition, there are incentives for firms to both over and under estimate releases. Firms might understate their toxic waste to forestall more stringent regulation. Conversely, they might be tempted to over estimate initial releases in order to make future "improvements" appear substantial to avoid future regulation. Thus the quality of the data is not entirely certain.

II. **Database Construction**

The first stage in constructing the primary dataset is to match the data from the CM and the TRI, maintaining the manufacturing plant as the unit of observation. The matching is based on plant name and location. Of the 12,039 chemical plants in the LRD for 1987, 2,395 match facilities in the TRI. All plants with non-positive employment, value of production, or toxic releases are omitted (210 observations). In addition, all remaining census administrative records (32) and those with extreme data values were dropped (10 observations);[21] 2,143 plants with complete data remained after this procedure. A subset of 806 plants were included in the PACE survey. Ideally, toxic releases would be weighted to reflect overall health risk. This is not possible at this time.[22]

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[21]Manufacturing establishments with 10 or fewer employees are usually exempt from reporting data other than employment and total value of shipments to the census. Thus, all other data values are imputed for these establishments. Of the 2,229 plants which were matched with TRI and had positive employment, value added, and toxins, only thirty were administrative records.

[22]The EPA has developed a number of indices of toxicological potency, including acute human toxicity, chronic human toxicity, acute aquatic toxicity, chronic aquatic toxicity, and cancer potency. The first four indices are ordinal, making direct comparison between chemicals difficult. The only cardinal health risk index is the cancer potency index, which estimates the unit risk factor associated with human exposure to specific toxins. The index estimates the probability of contracting cancer from a seventy year continuous exposure to a concentration of one microgram of a chemical per cubic meter of air. About one third of the chemicals on the TRI list are currently considered to be carcinogenic. Restricting the data to carcinogenic toxins reduces the number of observations substantially.