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Drivers of accident preparedness and safety: evidence from the RMP Rule☆

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Abstract

This paper provides an overview of recent results derived from the accident history data collected under 112(r) of the Clean Air Act Amendments (the Risk Management Program (RMP) Rule) covering the period 1994–2000, together with a preliminary assessment of the effectiveness of the RMP Rule as a form of Management System Regulation. These were undertaken at the University of Pennsylvania by a multi-disciplinary team of economists, statisticians and epidemiologists with the support of the US Environmental Protection Agency and its Office of Emergency Prevention, Preparedness and Response (OEPPR, formerly CEPPO).

Section 112(r) of the Clean Air Act Amendments of 1990 requires that chemical facilities in the US that had on premises more than specified quantities of toxic or flammable chemicals file a 5-year history of accidents. The initial data reported under the RMP Rule covered roughly the period from mid-1994 through mid-2000, and provided details on economic, environmental and acute health affects resulting from accidents at some 15,000 US chemical facilities for this period. This paper reviews research based on this data. The research is in the form of a retrospective cohort study that considers the statistical associations between accident frequency and accident severity at covered facilities (the outcome variables of interest) and a number of facility characteristics (the available predictor variables provided by the RMP Rule), the latter including such facility characteristics as size, hazardousness, financial characteristics of parent company-owners of the facility, regulatory programs in force at the facility, and host community characteristics for the surrounding county in which the facility was located, as captured in the 1990 Census.

Among the findings reviewed are: (1) positive associations with (a measure of) facility hazardousness and accident, injury and economic costs of accidents; (2) positive (resp., negative) associations between accident propensity and debt-equity ratios (resp., sales) of parent companies; (3) several interrelated associations between accident propensity and regulatory programs in force; and (4) strong associations between facility hazardousness, facility locations decisions, observed accident frequencies and community demographics.

Keywords: RMP Rule; Accident epidemiology; Clean Air Act Amendments

1. Introduction

Section 112(r) of the 1990 Clean Air Act Amendments set forth a series of requirements aimed at preventing and minimizing the consequences associated with accidental releases of chemicals at US manufacturing facilities. Its implementation in EPA regulation, 40 CFR 68, required all facilities storing on-site any of 77 toxic or 63 flammable substances above a threshold quantity (ranging from 250 to 20,000 lbs) to develop a risk management program (RMP). These RMPs include assessments of hazards, details on accident histories during the past 5 years, worst-case accident release scenarios, and prevention and emergency response programs. The focus of this paper is on the 5-year

☆ This paper summarizes recent work of the authors and others associated with the Wharton Risk Center Project on Accident Epidemiology.

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accident tracking records available from the Chemical Emergency Preparedness and Prevention Office (CEPPO) for 1995–1999 in the RMP*Info^{TM} database (CEPPO 1999). A total of 15,219 facilities reported to this database. All facilities were to report accidental releases of covered chemicals or processes that resulted in deaths, injuries, significant property damage, evacuations, sheltering in place, or environmental damage (see Kleindorfer et al. [1] for details).

The wealth of data assembled in the RMP*Info database presents a challenge and an opportunity. The challenge is that the scores of data elements on each of the roughly 15,000 facilities render any simple presentation of the raw data impossible. The opportunity is to use the tools of epidemiology and statistics to summarize the data in a manner useful to practitioners and policy-makers and, in addition, to test specific hypotheses about facility characteristics that might render facilities safer, or less safe.

Epidemiology is the study of predictors and causes of illness in humans. Its use in studying industrial accidents – termed "accident epidemiology" – has been proposed in a number of quarters (e.g., Elliott et al. [2,3], Rosenthal [4], Saari [5]). The motivating idea is to study the demographic and organizational factors of those facilities whose accident histories are captured in RMP*Info to determine whether any of these factors have significant statistical associations with reported accident outcomes, positive or negative, just as one might use demographic or life-style data for human populations to determine factors that might be associated with the origin and spread of specific illnesses. The basic approach followed in the studies reported here has been the epidemiologic methodology known as retrospective cohort study design. This methodology uses the RMP*Info database to determine what statistical associations may link accident propensity and severity to facility, parent company and host community characteristics.

The results of this analysis provide an important record on the accident propensity of facilities in the US chemical industry, and on the consequences of these for the 5-year period of the late 1990s. These results are significant because they allow analysis by specific facilities, sectors, processes and technologies of the magnitude of the risks faced by communities and insurers from chemical facilities.

In order to develop plausible and important hypotheses to test concerning predictors of facility safety, we first developed a conceptual model for predictors of frequency and severity of accidents (Fig. 1).

The following factors, evident in Fig. 1, are proposed as potential predictors:

1. The characteristics of the facility itself, including facility location, size and the type of hazard present; as well as characteristics of the parent company/owner of the facility (capital structure, sales, management systems in place, etc.).
2. The nature of regulations in force that are applicable to this facility and the nature of enforcement activities associated with these regulations.
3. The socio-demographic characteristics of the host community for the facility, which characteristics may represent the level of pressure brought on the facility to operate safely and to inform the community of the hazards it faces (the "community" may be defined in multiple ways here).

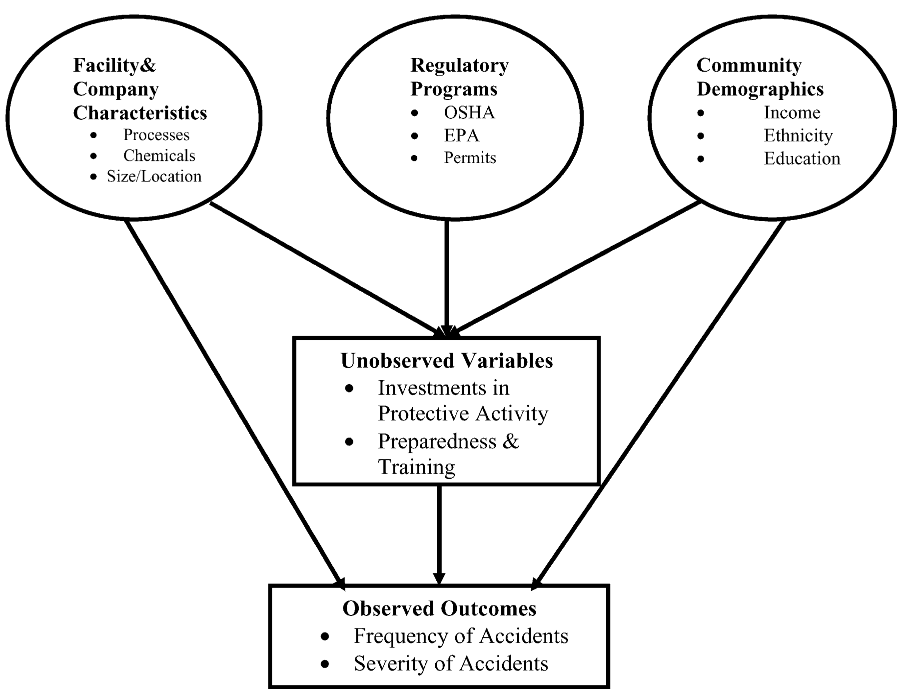

Fig. 1. Framework of analysis.

This paper will provide an overview of the statistical associations between accident frequency and severity and the above noted factors. Most of these have been reported separately in previous papers [1–3].

2. Facility characteristics and regulatory impacts

In Elliott and co-workers [1], we tested the hypotheses that facility characteristics and regulatory programs are associated with a facility's accident history. The facility characteristics that we studied are the following: geographic region; size of facility; and chemicals used at facility.

The information contained in RMP*Info database includes details about on-site chemicals and processes; regulatory program coverage; geographic location; and number of full-time employees (FTE). For each regulated chemical, the EPA determined a "threshold quantity," such that facilities were required to file a report if they stored quantities above the threshold. The threshold quantity for each regulated chemical was determined by a consideration of its potential toxicity, its potential for dispersion in the event of an unintentional release, and its flammability. Regulated substances were grouped into hazard levels, with thresholds set to values of 500, 1000, 2500, 5000, 10 000, 15 000, and 20 000 pounds. (threshold levels are inversely proportional to the per-weight hazardousness of the chemical). The quantity and nature of chemicals used at each facility are summarized for our statistical analyses by a single "total hazard measure", defined roughly as a measure of the hazard of the chemicals on site and the size of covered processes at the facility.[1] The regulatory programs studied are OSHA-PSM; CAA Title V; and EPCRA-302. The direction of the statistical association between more stringent regulatory structures and accident rates is not clear ex ante. On the one hand, more stringent regulations might serve to reduce accident rates; however, more hazardous facilities might be the focus of more stringent regulations. The statistical associations identified here therefore reflect the combined effects of investments and regulatory oversight in preparedness/prevention activity and underlying factors driving accident propensity. Such hypotheses, if proven, could provide important insights on the impact of different regulatory programs for particular sectors and types of facilities.

[1] More precisely, the "total hazard" measure used is defined as the sum over all chemicals of $\log_2$ (maximum quantity of inventory on site/threshold), or, alternatively, as the number of chemicals times $\log_2$ of the geometric mean of the maximum-to-threshold quantity ratio. Hence, a total hazard measure of 0 indicates that only threshold levels of chemicals are kept in inventory, a measure of 1 means 1 chemical is kept at up to twice threshold level, 2 means 2 chemicals kept at up to twice threshold level or 1 chemical at up to four times threshold level, and so forth; unit changes in this measure can thus be interpreted as either an doubling of volume inventoried of a single chemical or an addition of another twice-threshold chemical on-site.

Our results on facility characteristics and regulatory factors may be summarized as follows (see [2] for more detailed discussion).

The risk of an accidental chemical release and of attendant worker injuries or property damage increases 10-fold as firms grow in size from less than 10–1000 FTEs, then levels off. Similarly, risk of accident, injury, and property damage increases ten-fold as "total hazard" measure increases from 0 to 50, then levels off, then climbs again as total hazard reaches the 300–400 range that characterizes the very largest facilities.

Facilities in the Mid-Atlantic, Southeast, and South Central had the highest risk of accident, injury, and property damage, and facilities in the Great Plains the lowest. Most of these regional differences are explained by the larger number of employees and greater total hazard measures at facilities in the Mid-Atlantic, Southeast, and South Central regions. However, the much higher rate of property damage in excess of $100 000 among facilities in Region VI (South Central) cannot be entirely explained by the number of employees or the total hazard measure.

Toxic chemicals were more strongly associated with worker injury, whereas flammables were more strongly associated with property damage, which makes sense because fire is obviously capable of causing a much greater degree of damage to property than release of acids or poisonous gases, which are either more contained or less damaging to property.

Facilities regulated under the Right-to-Know Act had a modestly higher risk of accident, injury and property damage than other RMP*Info facilities, while facilities regulated under OSHA Process Safety Management and CAA Title V had a much higher risk. Nearly all of this excess risk for Right-to-Know and CAA Title V facilities could be explained by their larger size and greater total hazard measures, whereas only about one-half of the excess risk for OSHA-PSM facilities could be explained in this manner. This makes sense in that EPCRA-302 and CAA Title V targets facilities with hazards having significant off-site consequences, while the OSHA-PSM standard is focused on on-site hazards, which may not be directly related to inventory levels or numbers of processes, as captured in our hazardousness measure.

3. Capital structure and financial impacts

Let us now consider the influence of capital structure and financial variables, such as total sales, on the incentives that companies might perceive to take protective action against major accidents and, thereby, to influence the accident and injury rates observed in RMP.

The total number of filers in the initial implementation of 112(r) was 15, 219 through 11 December 2000. The analysis below of financial issues is restricted to the 2023 facilities owned by 306 parent companies for which complete financial parent company data from 1994 to 2000 is publicly available. The accident-related information includes date and time of accident; number of associated injuries or deaths among workers, public responders, and the public at large; and other consequences such as property damage (on-site, off-site), evacuations, confinement indoors of nearby residents, and environmental damage. Our main outcomes of interest were frequency of accidents and severity of accidents, with the latter measured as total number of persons injured as a result of accidental releases.

We consider four main predictor variables of parent company financial performance: previous year debt/equity (D/E) ratio, total (net) sales, return on assets (ROA), and return on equity (ROE). Debt-equity ratio was determined as the ratio of the long-term debt to the common equity. Return on assets was defined as the ratio of income before extraordinary items divided by total assets minus depreciation and amortization. Return on equity was defined as income before earnings and interest divided by common equity.

To account for the fact that more "intrinsically" hazardous processes tend to involve capital-intensive infrastructure that might confound relationships between attention to safety and financial performance, we used two control variables as proxies for facility hazardousness: number of full-time-equivalent employees (FTEs), and a "total hazard" measure (as defined in footnote 2).

Our primary method to relate accidents and injuries per facility to the financial predictors of interest is negative binomial regression [6]. The interpretation of the regression parameters is that of a log relative risk (RR), similar to that of Poisson regression. As a preliminary step, we compute the total number of accidents reported by a parent company's facilities in a fiscal year, denoted by $Y_{ijg} = \sum_k Y_{ijk}$, where $i = 1, \ldots, 306$ indexes the parent company, $j = 1, \ldots, 7$ indexes the fiscal year, and $k = 1, \ldots, K_i$ indexes the RMP*Info reporting facilities owned by a parent company (K_i ranged from 1 to 126). (In principle there are 1836 [6 × 306] "parent company-fiscal-year" units, although only 1642 parent company-fiscal-years cover RMP*Info reporting periods for at least one parent company facility). We then model the expected rate of accidents as follows:

$$\log\mu_{ij} = \log T_{ij} + \beta_0 + \beta_1 x_{i,j-1} + \gamma_1(z_{1i} - \bar{z}_1) + \gamma_2(z_{1i} - \bar{z}_1)^2 + \gamma_3(z_{2i} - \bar{z}_2) + \gamma_4(z_{2i} - \bar{z}_2)^2 + \gamma_5(z_{2i} - \bar{z}_2)^3$$

where $\mu_{ij} = E(Y_{ij})$ is the expected number of accidents among the parent's companies facilities in the jth fiscal year, T_{ij} is the total number of "facility-years" across the parent company's jth fiscal year (which may be less than the total number of parent company facilities during 1994, 1995, 1999, and 2000, because fiscal years may extend beyond the reporting range of RMP*Info for a particular facility), $x_{i,j-1}$ is the financial predictor of interest for the previous fiscal year, z_{1i} is the average number of FTEs among the parent company facilities, z_{2i} is the average total hazard measure among the parent company facilities, and $\bar{z}_1$ and $\bar{z}_2$ are the means of the average size and hazard measures across the parent companies themselves. The Greek symbols are unknown parameters to be estimated from the RMP data. The main parameter of interest is β_1, which is interpreted as the log of the change in risk of an accident in a parent company's facility for each unit change in the previous year's financial predictor of interest, adjusted for the average size and hazardousness of the parent company's facilities. A similar model is fit using total reported injuries per fiscal year as the outcome of interest.

The size and makeup of chemicals used in a facility are important independent predictors of risk, and to the extent that they are associated with the financial predictors of interest, they may confound the association between the financial predictors and the observed injury and accident outcome. To account for a non-linear relationship between risk of accident, injury, and property damage and the number of FTEs and total hazard measure, various polynomial transformations of these confounders were considered. A quadratic (2nd degree polynomial) was used for average number of FTEs, while a cubic (third degree polynomial) was used for the average total hazard measure for accident outcome models; because of numerical complications, injury models utilized a linear model for the average FTEs and a quadratic for average total hazard.

Table 1 shows the descriptive statistics for the outcomes, financial predictors, size and hazard confounders, and percentage of facilities in key sectors of interest. One accident was observed for approximately each four fiscal years of parent company operations, while one injury was observed for approximately each three fiscal years of parent company operations (a single accident could result in multiple injuries).

Table 2 shows the associations between the previous year's financial predictor and the risk of accident and injury

Table 1
Summary statistics for financial analysis

	N	Mean (S.D.)	Min	Max
Number of accidents per parent company	1642	0.28 (0.95)	0	13
Number of injuries per parent company	1642	0.36 (2.01)	0	43
Previous year debt-equity ratio	1642	2.89 (4.01)	.04	20.00
Previous year sales ($ billions)	1642	$6.02 (14.90)	2.6×10^{-4}	168.74
Previous year return on assets (%)	1642	4.55 (9.61)	−126.65	132.78
Previous year return on equity (%)	1594	12.58 (43.30)	−639.52	451.88
Average number of FTEs	304	421(1008)	<0.5	14400
Average total hazard measure	306	12.46 (16.13)	3.87	228.76

Table 2
Percent change in risk of accident per facility associated with previous year's parent company financial performance[a]

	Debt-equity ratio	Sales (billions)	ROA	ROE
Accidents	6.3 (−0.7, 12.8)	**−1.9** (**−3.4**, **−0.4**)	0.3 (−2.6, 3.3)	**−0.8** (**−1.4**, **−0.1**)
Injuries	**12.2** (**3.5**, **21.7**)	**−2.6** (**−4.5**, **−0.7**)	0.6 (−3.4, 4.9)	−1.3 (−4.2, 1.6)

[a] (100% debt-equity ratio, sales in 10^9 dollars, 1% return on assets [ROA], 1% return on equity [ROE]). Results adjusted for average size (in FTEs) and average total hazard measure across all facilities in the parent company; 95% confidence intervals in parentheses. Statistically significant results at $\alpha = 0.05$ in bold. N/S = no significant difference. N/E = Not estimable due to numerical instability.

respectively, adjusted for average facility size and intrinsic hazard measure. We do this analysis only for the combined data set (details on each sector are available in [7]). The associations were generally in the direction that economic theory would lead us to hypothesize. In particular, we see that each doubling in debt-equity ratio was associated with a statistically significant 12.2% increase in risk of injury at a parent company's facility (95% CI = 3.5% − 21.7%). Each billion-dollar increase in sales was associated with a 1.9% decrease in risk of accident at a parent company's facility (95% CI = 0.4% − 3.4%) and a 2.6% decrease in risk of injury (95% CI = 0.7% − 4.5%). Each 1% increase in return on equity was associated with a 0.8% decrease in risk of per-facility accident (95% CI = 0.1% − 1.4%). Return on assets was not associated with a statistically significant change in either risk of accident or risk of injury.

Summarizing our preliminary findings on the effects of financial variables, we note that these are clearly in the direction that both intuition and theory would support. Companies that are more debt-ridden are likely to be less concerned with long-term cash flows, as most of the risk is borne by creditors who are not represented in the company's decision making about risk mitigating investments. Similarly, companies with large sales have a great deal at risk from disruptive accidents and this leads, as expected, to greater care and lower accident and injury rates. The RMP results are therefore consistent with normal economic expectations.

4. Community and demographic effects

"Environmental justice" addresses whether health risks or environmental impacts from industrial activities are distributed in a manner that comports with basic cultural and social notions of fairness. An extensive body of research in political economics, public policy, and public health has noted associations between environmental and health risks arising from industrial facilities and the socio-economic status (SES) of host communities. These associations could be caused by firms' preferring to locate hazardous facilities in lower-SES communities in which they anticipate lower levels of collective action and monitoring. These could also result from migration of groups of lower SES to sites where such facilities have located, since property values may be lower there. Whatever the reason, if certain communities are at significantly greater risk than others, this raises fundamental questions for environmental and health authorities.

Empirical findings on the subject of environmental injustice have been mixed. Brown [8] found that African-Americans and lower-SES Americans are disproportionately likely to live near hazardous waste sites, to be exposed to air pollution or other toxic releases, and not to receive relief from regulatory decision or toxic cleanups. Perlin et al. [9] found that African-Americans lived closer than whites to the nearest industrial emission source, that African-Americans were more likely than whites to live within 2 miles of multiple emission sources, and that African-American children 5 and younger were substantially more likely than white children to live near one or more sources of industrial air pollution. Mitchell et al. [10] found in their examination of South Carolina chemical facilities that, indeed, there are significant negative correlations between the SES of host counties and the risk imposed by chemical facilities, but differences in risk across counties are primarily the result of migration patterns of lower SES individuals to the vicinity of the facilities and not the result of the original location decisions of facility owners.

Concern about the geographical distribution of risk from chemicals and toxic emissions is not isolated to the US Similar activities have been very much in evidence in Europe and Asia, following the disasters in Seveso, Bhopal and Chernobyl. Citizen activism is also on the rise in emerging economies such as India and China [11,12]. In the EU, environmental health monitoring and surveillance systems and regulatory programs have been developed and data are slowly becoming available to assess the geographic distribution of risk. In particular, the Major Accident Reporting System (MARS), set up in 1984 under the SEVESO II directive, has the potential to provide data for the EU that would allow a comparable study to that reported here. Kirchsteiger [13] indicates, however, that the regulation of reporting in the EU is weak and the threshold for reporting so high that the MARS data is very incomplete and thus can only be used at this point for planning.

Using the RMP data together with the 1990 census data,[2] we looked for two potential impacts of community characteristics that reflect two essential sources of risk to surrounding populations: (1) risks associated with the decision about

[2] As one of our reviewers has remarked, a case could be made that the 2000 census data would have been a better reflection of the demographics of host communities than 1990 data. We used the 1990 data both because of its availability at the time of the initial studies on the 1994–2000 data, and because we wanted to assure comparability across these studies.

where to locate hazardous facilities, which we term "location risk"; and (2) risks associated with the methods of operation and standards of care that are used in existing facilities, which we term "operations risk". Our analysis proceeds by first considering the association between community characteristics and "location risk"—the risk of an intrinsically hazardous facility, as reflected by the quantity of chemicals stored there and their potential for harm, being located in a community. The enumeration unit for the demographic studies is the county in which the facility is located. To measure location risk, we analyze whether there is a statistical association between the hazardousness of a facility and the characteristics of the surrounding county. A significant statistical relationship would indicate that more hazardous facilities tend to be located in counties with particular demographic characteristics.

We then consider "operations risk", which is the risk at a facility of an accident and resulting bad outcomes, including injuries and property damage. Two questions can be asked about operations risk: (1) whether the demographics of the communities surrounding facilities are associated with risk of an accident/injury; and (2) whether these community demographics are associated with accident/injury risk *after adjusting for location risk*. Our test for the effects of demographics on operations risk is simple. We analyze whether there is a statistical association between facility accident and injury rates and the demographics of the surrounding county, while controlling for the size of the facility and inherent hazardousness of it (see footnote 2 for our definition of hazardousness). If it were hazardousness or size of the facility alone that determined accident/injury rates, and demographics were not a factor, then there would be no additional explanatory power associated with the inclusion of country demographics. However, if such demographic factors are themselves statistically significant, in addition to facility factors, this would support the hypothesis that operations risk is associated with demographic factors. In particular, we address the issue of whether facilities in low-SES and/or higher proportions of African-American population may exhibit higher accident rates than average, even if they have the same amount of hazardous chemicals on site.

Our findings regarding the relationship between accident propensity and community characteristics may be summarized as follows (see Table 3 below). First and foremost, the relationship between chemical facility risk and the demographics of the surrounding community is complex. The RMP data is strongly consistent with a finding that heavily African-American counties experience greater location risk and greater operations risk. Greater location risk here means more employees and more hazardous chemicals in use at facilities in these counties. Greater operations risk means that facilities in these counties had greater risks of an accidental chemical release, and of having injuries associated with the chemical release. The operations risk for the most heavily African-American counties persists even after accounting for location risk.

Table 3
"Operations risk": adjusted relative risk (RR) for facility accidents in 1995–2000[a] [2,3]

	Model 1[d]	Model 2[d]
1–10% African-American (vs. <1%)	**1.60 (1.33–1.91)**	1.21 (0.99–1.47)
10–20% African-American	**1.79 (1.41–2.29)**	1.19 (0.92–1.54)
>20% African-American	**3.03 (2.40–3.83)**	**1.85 (1.45–2.37)**
Median income $20–30K (vs. $20 K%)	**1.58 (1.16–2.16)**	0.92 (0.67–1.28)
Median income $30–40K	**2.05 (1.44–2.94)**	0.99 (0.68–1.44)
Median income $40K+	**2.34 (1.42–3.89)**	1.00 (0.60–1.67)
5–10% income below poverty (vs. <5%)	0.91 (0.64–1.30)	0.80 (0.57–1.13)
10–20% income below poverty	1.01 (0.68–1.49)	0.79 (0.52–1.13)
>20% income below poverty	0.82 (0.42–1.61)	0.54 (0.28–1.04)
Income inequality[b] 0.4–0.45 (vs. <0.4%)	1.24 (0.88–1.76)	1.21 (0.86–1.71)
Income inequality 0.45–0.55	**1.46 (1.00–2.14)**	1.44 (0.99–2.10)
Income inequality >0.55	**2.08 (1.05–4.24)**	1.84 (0.93–3.65)
10+% Manuf. (vs. <10%)	**1.57 (1.29–1.91)**	**1.30 (1.06–1.59)**
10–50K Total population (vs. <10K)		**1.61 (1.16–2.26)**
50K+ population		**2.30 (1.64–3.28)**
Number of FTEs (1000s)		**1.68 (1.44–1.99)**
Total hazard measure[c]		**1.05 (1.05–1.06)**

[a] 95% Confidence intervals in parentheses; bold-face values significant at $P < 0.05$.
[b] Gini index of income inequality.
[c] "Total hazard" is calculated as defined in Footnote 2.
[d] "Model 1" is a multivariable regression model that simultaneously estimates the independent relationship between accident risk of a facility and the race, income, poverty, and labor force factors of the surrounding county; "Model 2" attempts to additionally adjust for "location risk" by also adjusting for the surrounding county's population, the number of FTEs in the facility, and the "total hazard" measure (see footnote 2).

The impact of income and poverty is more complex. Larger facilities were more likely to be located in counties with higher median incomes and higher levels of income inequality, although part of this association is explained by the fact that larger facilities tend to also be located in counties with large populations and large manufacturing labor forces. Similarly, facilities in higher-income counties with higher levels of poverty, or at least without corresponding low poverty levels—again, high-income-inequality counties—were at greater operational risk as well. However, after adjusting for "total hazardousness", income and income inequality were no longer associated with operations risk.

Thus, higher-risk facilities are more likely to be found in counties with sizeable poor and/or minority populations that disproportionately bear the collateral environmental, property, and health risks. An alternative, though related, perspective is that communities burdened by low SES and past or present discrimination may be willing to accept these risks in order to obtain the economic benefits of facility location, or that residents not willing to accept this risk move away. For facilities of a similar hazard level, those operated in counties with 20% or higher African-American populations appear to pose greater risk of accident than those in counties with less than 1% African-Americans.

5. Some caveats on the RMP data and these studies

Naturally there are a number of caveats that attach to all of the above analyses. Selection bias remains a more serious possibility, in that the sampling frame containing the RMP*Info facilities may not include all required facilities. It was originally estimated by the US Office of Management and Budget (OMB) that over 66,000 facilities would be required to submit RMPs under 112(r); however, only 15,219 ultimately did so. This lower than anticipated response is in part due to Congress exempting in 1999 from the reporting requirements any listed flammable substance when used as fuel or stored for retail sale as a fuel, effectively reducing the estimated population by about one-half. Also, many facilities responded to the RMP*Info requirement by reducing their inventories below the threshold limits required for reporting. Some facilities may have simply ignored the filing requirements. These non-responders may differ in significant ways from the responding facilities used in these analyses.

A further limitation involves facilities' interpreting accident reporting requirements differently and other uniformity and data quality issues associated with any large database of this sort.

A final limitation of these studies is that our analyses implicitly assume that all facilities were subject to RMP*Info reporting requirements throughout the previous 5 years. If facilities were either non-existent or off-line for substantial periods of time, then the resulting estimates of the associations of risk of accident and injury with parent company financial status could be biased toward or away from the null. For example, if parent companies with high D/E ratios tended to have facilities that operated for only a short period of time, that would tend to artificially strengthen the positive association between high D/E ratio and risk of accident in our financial analysis. However, facilities reporting to RMP*Info tend to have high capital costs; thus they tend to come on-line and go off-line rather slowly relative to the 5-year reference period. We will have additional evidence on the stability of facilities reporting when the next tranche of data becomes available in 2004 on RMP facilities.

6. Reflections on the RMP Rule and the RMP data going forward

The main purpose of implementing the RMP Rule was to reduce the level of accidents and injuries from chemical facilities, and especially to surrounding community residents. The logic of how this was to be accomplished via a Rule that merely requires facilities to develop and file accident history and facility information is interesting. The basic thought is in line with "informational regulation" as articulated by Kleindorfer and Orts [14] that requiring facilities to generate and publish information will attract their attention to the more severe problems that may exist in a facility. It may also attract community pressure to reduce the risks of chemical accidents in facilities hosted by the community. Of course, this will not happen merely through wishful thinking, but rather through changes in facility management systems to assure a stable framework for developing the risk management plans and to mitigate hazards that arise in elaborating these plans.

If this logic is to work, it is therefore important that we use the data available through the RMP Rule, together with other financial, health & safety and organizational data, to reinforce our understanding of the impact of the RMP Rule as a complement to promoting management practices that give rise to discernible improvements in EH&S performance. The RMP data can provide important insights on performance. Over time, we should see decreased accident and incident rates, lower cost from damages of such accidents and improved management oversight and audit results indicating improvement in leading indicators of safety, health and environmental management effectiveness. The RMP Rule can be both a source of documentation of these improvements as well as a driver of these. Viewed as a form of management system regulation [15], the RMP Rule has the potential to provide significant benefits to communities, insurers and regulators by causing firms to assess, manage and reveal their environmental and safety risks, and especially to determine and manage factors underlying worst case scenarios. The next tranche of data under the RMP Rule will be filed in June 2004. It remains to be seen whether the findings reported here on the 1995–2000 data remain stable going forward. It also remains to be seen whether RMP-related outcomes are associated with other approaches to process excellence, safety and management systems effectiveness, both for participating firms and for local emergency response agencies that may now be better informed as a result of the RMP Rule. If so, then the development of Risk Management Programs consistent with the RMP Rule could have significant ancillary benefits beyond those originally envisaged.

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