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The Distribution of Toxic Sources in Louisiana: An Analysis of Community Socioeconomic Characteristics and Industry Behavior.

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THE DISTRIBUTION OF TOXIC SOURCES IN LOUISIANA: AN ANALYSIS OF COMMUNITY SOCIOECONOMIC CHARACTERISTICS AND INDUSTRY BEHAVIOR

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by
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To the memory of my father,
Sarkis Y. Djoundourian

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Abstract

The distribution patterns of toxic sources in Louisiana reveal that some communities may be disproportionately exposed to potential environmental risks. This dissertation examines whether the location and environmental control behavior of toxic polluters are systematically related to the socioeconomic and racial characteristics of communities. The study identifies who lives in the immediate proximity of toxic sources and determines whether the characteristics of these communities are different from those of Louisiana's general population. The results reveal that income levels in communities that host toxic sources are consistently and significantly lower than the state averages. A distance gradient analysis indicates that as distance from the nearest toxic source increases, the mean percentage of blacks in the community decreases and the mean percentage of whites increases. The results provide support to the hypothesis that low income and minority groups are disproportionately exposed to environmental risks. The study also tests whether changes in potential exposure to risks differ significantly across socioeconomic groups. The estimation results indicate that the higher the income levels, the more educated, and the more politically active the community, the greater the reductions in toxic discharges over time. Furthermore, the greater the percentage of blacks in a community, the greater the reductions in discharges. In terms of relative importance, income is a more important factor than race in explaining aggregate reductions in discharges.

Chapter 1

Introduction

Concern over environmental quality distribution across regions and socioeconomic groups is growing in the United States. Research indicates that environmental amenities are not evenly distributed across the population. Freeman (1972) correlated socioeconomic data with air quality readings in three cities; his findings indicated that low-income and non-white groups were exposed to poorer air quality conditions. Asch and Seneca (1978) reported that exposure to air pollutants was higher in cities with low-income characteristics. In an examination of hazardous waste sites, a study conducted by the United Church of Christ (1987) reported "a striking relationship between the location of commercial hazardous waste facilities and race" (p. xiii). Environmental quality differences between otherwise homogeneous communities is attributed to the intensity of industrial activity. Evidently, the more densely populated an area is with industry the lower its environmental quality. An issue of particular concern, and some debate, is the relative environmental risk borne by low income and racial minority communities. There is growing evidence suggesting that people who live in polluted areas are poor, and most likely, ethnic minorities who cannot afford to live in better neighborhoods. Chapter 2 examines the empirical literature on environmental quality distribution in order to review and evaluate the evidence that racial minorities and low income groups bear a disproportionate risk burden.

This dissertation attempts to determine whether exposure to environmental hazards is systematically related to socioeconomic characteristics of the population. It seeks to establish whether there is a statistical relation between toxic releases or changes in those releases over time and income, race, population, population density, age, sex, and education of nearby residents. The study does not propose to establish whether these relations, if they exist, are fair or equitable, or efficient in any sense. It does not seek to determine any causal factors which may lie behind location decisions of facilities or households. Nor does it seek to determine the historic sequence of location decisions. It investigates more elementary issues of whether risks and risk reductions are consistently related to surrounding community characterestics, given the existing locations of sources and households.

This dissertation attempts to explore the validity of the hypothesis that low income and racial minority communities are "disproportionately" exposed to poorer environmental conditions. Towards this end, several questions should be asked. Who lives in polluted areas? Do the characteristics of these people differ from others? If so, how? This discussion makes up the central thesis for Chapter 3. This chapter examines the geographic and social distribution of toxic sources statewide across Louisiana communities. Louisiana is appropriately chosen as the study area because of the high concentration of chemical and petroleum industry, major sources of toxic emissions into the environment.

Chapter 3 is partially a replication of other studies in the literature. Following the "site distribution" models in the literature, this chapter uses parish and zip code level data to study the geographic distribution of toxic chemical releasing facilities. After identifying the socioeconomic and racial status of the communities surrounding these toxic sources, the study proceeds exploring whether, and how, the characteristics of these communities are different from those of Louisiana's general population. This is accomplished by comparing the means of the parish and zip code samples to that of Louisiana's benchmark values.

Following the "community exposure" models in the literature, the number of toxic releasing firms and the total and per-capita toxic discharges are used alternatively as proxies for potential exposure to risk. Correlation analysis is performed between these exposure measures and several socioeconomic variables characterizing the communities surrounding the polluting firms. It should be stressed that this approach, used intensely in the literature, is not intended to explain cause and effect relationships. It merely shows the degree of spatial association between the two sets of variables. Chapter 3 tests how sensitive the relations are to the level of community aggregation.

A major contribution of Chapter 3 is the explicit recognition of the role that distance from a pollution source plays in determining the burden of potential environmental risks. Exposure to toxics is assumed to be inversely related to distance from the source. This chapter empirically tests whether socioeconomic and racial characteristics of communities change as distance from the pollution sources increases. It uses block group level data which are geographically much smaller than both parishes and zip code areas. They provide high resolution information about communities surrounding the toxic sources. Locational proximity is established by calculating distances of block groups from their nearest polluting facilities using one mile intervals.

This study suggests that persistent forces, such as normal optimizing behavior of individuals and businesses, may lead to "disproportionate" exposures. Residential and industrial location choices of households and firms may help explain why some neighborhoods bear relatively higher risk burdens then others. However, the environmental control behavior of firms and the response behavior of communities may also be important factors in determining which communities are, or will be, exposed to higher environmental risks. Chapter 4 develops a theoretical model that captures the relationship between the hazard production behavior of a firm and the socioeconomic characteristics of the communities surrounding the firm. In this chapter the utility maximizing household is assumed to have several options for remedial actions: adaptation, advocacy, and litigation. A price tag is attached to every option. Firms have a profit motive to reduce pollution when community response is expected to increase regulatory and compliance cost.

The theoretical model in Chapter 4 suggests that the usual optimizing behavior of firms and households may explain, to a certain extent, the distribution of environmental hazard across communities. The ability and willingness of households to pursue remediation efforts to alleviate or compensate for the environmental disamenity have direct effects on the environmental control behavior of firms. Chapter 5 proceeds with an empirical study of the firms' discharge control behavior. The purpose of this chapter is to test whether the environmental control behavior of toxic chemical releasing firms are related to socioeconomic and racial characterestics of surrounding communities. For example, would firms' decisions to reduce environmental risks be related to racial or economic makeup of surrounding communities? A single equation model of discharge reduction is posited as a function of several variables describing the people and the general area where firms are located. This equation is estimated for different types of discharges, at alternative community aggregation levels.

Chapter 6 concludes the dissertation with a discussion of the results, the shortcomings of the study, and an agenda for future research.

Chapter 2

Literature Review

I. Introduction

The distribution of pollutants across regions and socioeconomic groups and their effects on economic activity have been the subject of many studies. Research indicates that pollutants impose a wide range of adverse effects on economic activity, directly or indirectly, through variety of channels. Human health represents one of the more obvious effects. Numerous studies confirm the existence of a close association between health, as measured by mortality and morbidity rates, and air pollution.[1] Health problems associated with exposure to hazardous and toxic chemicals often necessitate expenditures on health care or absence from school or work and in extreme cases cause permanent disability or death. Pollutants can also have damaging effects on materials and vegetation through influencing deterioration rates of materials and agricultural productivity of land.[2] Finally, pollutants

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[1] See Lave (1972), Lave and Seskin (1970), Liu and Yu (1976), Ostro (1983), and Krupnick, Harrington and Ostro (1990).

[2] For a comprehensive review of the literature see Liu and Yu (1976).

impose aesthetic damages ranging from reduced atmospheric visibility to reduced property values.[3] Improvements in environmental quality would mean reducing the magnitude of these adverse effects. The quantitative significance of these effects has been investigated and often used to evaluate the economic efficiency of proposed environmental programs aimed at improving the quality of life.

While the concern with efficiency aspect of the proposed programs is an important issue, the distributive impact of these programs is equally important. Most empirical studies suggest that environmental quality is not distributed evenly across the population. A wide range of variation in air quality readings are observed across cities. Baumol and Oates (1979) reported that "the average concentrations of sulfur dioxide vary all the way from 47 milligrams per cubic meter in Washington, D.C., to 236 milligram per cubic meter in New York City, a ratio of more than five to one." (p. 226). Liu and Yu (1976) showed that health damage estimates from air pollutants vary across regions; annual mortality damages due to sulfur dioxide vary from less than $0.1 million in Charleston, West Virginia, to $329 million in New York City. Furthermore, a study conducted by Citizen Action showed that, in 1988, ten states alone accounted for over fifty percent of all toxic releases into the environment.

The distributional aspects of environmental policies have always been a source of concern to policy makers and social scientists. An issue of particular concern, and some debate, is the relative

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[3] For property value studies, see: Anderson and Crocker (1971), Freeman (1974), Nelson (1979), Frankel (1985, 1991), Kohlhase (1991), and Greenburg and Hughes (1992).

environmental risk burden borne by low income and racial minority communities. It is reasonable to expect that communities surrounded by multiple sources of air pollution, toxic and hazardous waste facilities, and commercial landfills face higher than average "potential" environmental risks. However, an important research question is whether, and why, particular race and income groups face greater exposure to such risks than others. In fact, there is growing evidence suggesting that low income and minority groups are disproportionately exposed to poorer environmental quality conditions, mostly due to locational proximity to hazard sources.

Until the early eighties the major source of concern has been the impact of environmental policies on different income groups. However, the 1982 demonstrations against siting of a polychlorinated biphenyl (PCB) landfill in Warren County, North Carolina, with predominantly black and poor population, added a new dimension to the distributive issues, namely the impact of policies on minority groups. In response to these demonstrations, District of Colombia Delegate Walter Fauntroy requested that the General Accounting Office (GAO) investigate the siting process of hazardous waste landfills and their correlation with the racial and economic status of the surrounding communities. The GAO study focused on four offsite hazardous waste landfills in eight southeastern States. No explanations were provided as to why these specific sites were selected. Based on 1980 Census data, the study concluded that at three of the four hazardous waste landfill sites the majority of the population was black. Although limited in scope, this study provided evidence in support of racial minorities bearing a disproportionate risk burden. However, its significance was not only in the results it presented but the fact that it provoked further research interest in the environmental quality issues as they relate to the distribution of risk across race and income.

This chapter examines the empirical literature on the distribution of environmental risk across socioeconomic groups in order to review and evaluate the evidence that racial minorities and low income groups bear a disproportionate risk burden. Section II presents a servey of studies attempting to find a relationship between various measures of pollution and socioeconomic characteristics of communities and studies that attempt to measure the incidence of pollution on various income and race groups. Section III presents the anticipated contribution of the current study to the empirical literature.

II. Survey of the Literature

A large body of literature supports the hypothesis that economic activity is adversely affected by the presence of pollutants. While studying the impact of pollutants on human health, materials, and vegetation is an important task, the ultimate objective is to design policies aimed at reducing the magnitude of damages. Tracing the path to exposure and identifying the regions and the communities most affected by the presence of pollutants are necessary for designing and implementing sound environmental control policies.

"Community exposure" models attempt to determine whether exposure to air pollutants is related to the socioeconomic characteristics of the population. In these models, the level of ambient pollution measured at an outdoor monitor station serves as a surrogate for individual exposure in the vicinity of a residence, school, or place of work. In assessing the distribution of air pollutants by income or race, the typical approach has been to correlate the average or the median family income and the minority percentage of the community with the measure of exposure. "Site distribution" models focus on the location of hazardous and toxic waste sites and their correlation with the social and economic make-up of the communities surrounding them. The following sections review studies pertaining to the distribution of air pollutants across communities, and those pertaining to the distribution of hazardous sites across communities.

a. Air Pollution Studies

Freeman (1972) undertook the first attempt to determine whether the existing patterns of air pollution impose an absolutely greater burden on low income households. Using air quality readings for sulfates and particulates in Kansas City, St. Louis, and Washington, D.C., together with socioeconomic data at the Census Tract level, he constructed indexes of pollution exposure per family classified by income, race, and housing tenure. His findings suggested a systematic inverse relationship between pollution exposure and average family income in each of the three cities examined. In Kansas City, the average family earning less than $3,000 per year (the lowest income class) was exposed to 76.7μgm/ml of suspended particulates while the average family earning more than $25,000 (the highest income class) was exposed to 58.1μgm/ml of suspended particulates. In St. Louis, these respective exposure levels were 91.3μgm/ml and 64.9μgm/ml; and in Washington, D.C., they were 64.6μgm/ml and 42μgm/ml. While the existing patterns of both air pollutants indicated that air quality was distributed in a manner favorable to the rich within the city, there was a significant variation between the cities in the overall pollution levels. The lowest income class in Washington, D.C. was exposed to lower levels of suspended particulates than the highest income class in St. Louis. Freeman also found dramatic differences in exposure, both within and across cities, between blacks and whites; "[in] each city the average black family has a higher exposure to both air pollutants than does the average family (black or white) with an income under $3,000" (p.264). The study also indicated that home owners were exposed to lower levels of pollutants than renters.

Zupan (1973) examined the quality of air in the New York region in an attempt to determine whether differences in exposure are observed across alternative income groups. To determine the relative exposure of income groups to varying levels of air quality, Zupan employed two sources of air quality data: direct indicators of air quality from monitoring stations and indirect indicators based on the amount and location of major emission sources. By geographically matching air quality data with income data derived from IRS income tax returns, he performed correlation analysis to test the association of four alternative indicators of air quality (sulfur dioxide, smokeshade, settleable particulates, and suspended particulates) with four income measures: mean per capita income, the percentages of tax returns reporting less than $3,000 income (low income households), between $3,000 and $10,000 income (middle income households), and more than $10,000 income (high income households). The results showed a significantly positive association between each of the four air quality indicators and the percentage of low income households in the population. However, the results did not indicate that the converse was necessarily true: "a high proportion of high income people does not necessarily imply high air quality." (p. 3). Although the correlation coefficients between all four indicators and the percentage of high income households had the expected negative sign, only two indicators showed a highly significant relationship. As far as the middle income households were concerned, the results indicated that "the middle class is about as bad off as the poor." (p. 17).

To determine how many persons in each income group were exposed to a particular concentration of residuals, Zupan estimated cumulative exposure profiles by income group. The results, for all four indicators of air quality, revealed a consistent pattern: "the low income population is exposed to higher concentrations then the higher income population." (p. 18). Furthermore, differences in exposure between income groups also revealed a consistent pattern: "the differences between low and middle income groups are always less than the differences between middle and high income groups." (p. 18).

Asch and Seneca (1978) provided further evidence indicating that poorer income groups are exposed to higher pollution levels than their rich counterparts, both within and across cities in the United States. They investigated the intra-state inter-city variations in air quality by correlating the annual geometric mean of particulates with various socioeconomic variables for a sample of 284 cities in 23 states. Their results suggested that "[e]xposure to particulate matter is relatively higher in cities with low-income characteristics, whether measured by income level, income distribution, or the poverty tail of the distribution." (p. 282). Furthermore, their study suggested that "such cities are also characterized by low education levels, low property values, and large and densely concentrated populations which are (to a lesser extent) relatively non-white and aged." (p. 283).

Similar results were obtained in the intra-city study of air quality distribution. Correlation coefficients were calculated between three alternative categories of air pollutants (sulfur dioxide, nitrogen dioxide, and particulates) and Census Tract level socioeconomic variables in three cities: Chicago, Nashville, and Cleveland. Patterns observed in the state-based data also emerged in the intra-city samples for each pollutant. Income variables consistently confirmed that poorer Census Tracts experience higher pollution levels. However, the association between racial composition and pollution exposure was highly variable across both cities and pollutants. In Chicago, for instance, the correlation coefficients between the percentage of the population that is non-white and the annual means of particulates and sulfur dioxide were positive. In Cleveland, the correlation coefficient was "weakly" positive for sulfur dioxide, negative for particulates, and "strongly" negative for nitogen dioxide. Nashville, on the other hand, showed significantly positive coefficients for both particulates and nitrogen dioxide and a negative coefficient for sulfur dioxide.

Harrison and Rubinfeld (1978) analyzed the distribution of benefits, both physical and monetary, from improvements in air quality (in the Boston Metropolitan area), resulting from the implementation of the federal automotive emission controls mandated by the 1970 Clean Air Act amendments. Using Census data on household locations and incomes, together with Boston area air pollution monitoring data, they estimated the average residential exposure to nitrogen oxide (NOX), a major automobile pollutant, by income group and housing tenure. The results revealed that lower income households were exposed to poorer air quality than higher income households. Without regulation, annual NOX concentrations ranged from 5.92 pphm for households earning less than $3,000 to 4.99 pphm for those earning more than $25,000. With automobile emission controls in effect, the estimated residential exposure to NOX was lower at all income levels, ranging from 5.24 pphm for households earning less than $3,000 to 4.53 pphm for households earning more than $25,000 per year. The differences in average residential exposure estimates between pre-control and post-control represented the physical benefit of improved air quality. The results revealed that the physical benefits of emission controls, at place of residence, were distributed in a manner favorable to the poor. However, when workplace physical benefits by income group were combined with residence benefits, the results were much less beneficial to the poor. The distribution of dollar benefits from improvements in air quality was shown to be slightly favorable to the poor when renters retained all benefits. The estimated benefits for households earning less than $3,000 per year was $91 per year, compared to $81 per year for households earning more than $25,000 per year. However, when tenant benefits were capitalized into higher rents and the benefits were passed on to the rental property owners then the distribution of benefits was no longer in favor of the poor. Average benefits ranged from $46 for the lowest income households to $126 for the highest income group. Only when expressed as a percentage of income, monetary benefits were consistently higher for the poor. Nevertheless, when workplace benefits were included in the analysis, the monetray benefits from emission controls were relatively lower for the poor.

Gianessi, Peskin and Wolff (1977) assessed the distribution of air pollution damages on a nationwide basis. Their findings did not support the hypothesis that air quality is distributed in a manner favorable to the rich. Mean per capita damage estimates ranged from $72 for families making $1,000 or less to $142.76 for families making above $15,000. In terms of per capita damages, high income groups suffered the greatest damages. The study revealed that non-whites clearly suffer more damage than whites. The mean per capita pollution damage incurred by non-whites was $115.67, while the damage incurred by whites was $97.55.

Wernette and Nieves (1991), in a study of areas designated by EPA as out of compliance with the Clean Air Act, provided further evidence on disproportionate risk borne by racial minorities. A higher percentage of blacks and hispanics, compared to whites, live in air non-attainment areas for particulates, carbon monoxide, ozone, sulfur dioxide, and lead. In 1988, the Agency for Toxic Substances and Disease Registry reported that the percentage of black children with high blood lead levels was significantly higher than white children at all income levels. For both races, increasing income was associated with lower blood lead concentration.

A more recent study, Brajer and Hall (1992), associated levels of exposure to ozone and fine particulate matter in the South Coast Air Basin of California with resident income, race, age, and education. A Regional Human Exposure (REHEX) model provided the basis for estimating exposure not only on location of residence, but also on mobility within the Basin and time spent in various activities indoors and outdoors.

The results confirmed that the highest income groups faced less exposure to ozone and fine particulate matter. It also provided evidence that ethnic minorities and children received the greatest exposure level in the Basin. In addition, the study suggested that if microenvironmental factors such as amount of time spent indoors, outdoors, or in transit are incorporated into the correlation analysis, then the estimated differences in individual exposures will be lower than the estimates based on "community exposure" models.

Using alternative air pollution exposure indices, Gelobter (1992) presented further evidence on the uneven distribution of outdoor air pollution across socioeconomic groups. His study not only examined the absolute levels of exposure to total suspended particulates from 1970 to 1984, but also the changes in exposure due to relative improvements in air pollution since the enactment of the Clean Air Act of 1970. Gelobter's findings indicated that average exposure to total suspended particulates, in urban areas, was regressively distributed, although differences in exposure by income group were relatively small. He found striking differences in average exposure by race. Over the fifteen year period, minorities were consistently exposed to higher levels of pollution than their white counterparts. However, an important finding of his study was that while the poor experienced a much lower relative decrease in exposure than the rich, non-whites experienced slightly greater relative reductions in exposure than whites.

Napton and Day (1992) studied the distribution of the major air polluting industries in the state of Texas in an effort to determine whether the characteristics of people and places most affected by pollutants, those living in Census tracts within approximately one mile of polluting industries, differ significantly from those of randomly selected Census tracts in Texas, the control group. The socioeconomic variables capturing characteristics of people included: age, family size, race, education, employment and income. The variables capturing characteristics of places included: home ownership, age of housing units, value of housing, and stability of the neighborhood (measured by mean number of years housing units are occupied by owners, renters, or by either). Using discriminant analysis, where the dependent variable was whether a Census tract was in the polluted (the study area) or the control area, they determined which of the above variables best distinguished between the two groups. The statistical analysis indicated that the socioeconomic characteristics of the communities in the study group was significantly different from that of the control group. However, a major finding of the study was the rejection of the hypothesis that the population of the most polluted areas are poor, black or hispanic. In fact, contrary to most other studies, the people who lived in the polluted areas were white, somewhat educated (the average adults have completed about 12 years of school), middle-class people. Furthermore, compared to the population of the control area, the residents of the polluted areas were younger, families were larger, fewer families were headed by women, and a greater percentage of the population were home owners. The results indicated that mean rent was the most important discriminating independent variable; the mean rent in the polluted areas was <u>higher</u> than that of the control area. These results suggested that polluting industries were attracting employees who were willing to pay more for housing and tolerate pollutants in order to live near their jobs. Basically, "people may be living in polluted neighborhoods simply because they are in close proximity to their jobs." (p. 523).

b. Site Distribution Studies

All studies reviewed thus far have focused on the distribution of air quality across regions and socioeconomic groups, mostly because air quality readings from outdoor monitor stations have been in the public domain for over three decades. The 1983 GAO study noted in the introduction to this chapter was the first study that did not use air quality data. It focused on the distribution of hazardous waste landfills and their correlation with the social and economic makeup of the surrounding communities. The findings of this study provided support that racial minorities bear a disproportionate risk burden. Several studies since the publication of the GAO study have examined the distribution of alternative sources of environmental hazards across the population.

Toxic Wastes and Race in the United States (1987), published by the United Church of Christ, represents the first comprehensive national study of the demographic patterns associated with the location of hazardous waste sites. This study, more carefully designed than the GAO study, examined the statistical relationship between commercial hazardous waste facility locations and the racial and socioeconomic composition of host communities nationwide. It also studied the demographic patterns associated with the uncontrolled toxic waste sites. The study revealed strong correlations between race and location of commercial hazardous waste facilities. The minority percentage was highest in communities with the greatest number of hazardous waste facilities. In communities with either one of the five largest commercial hazardous waste landfills, or more than one treatment, storage and disposal facility, the average minority percentage was three times greater than in communities without such facilities. The report also concluded that the mean minority percentage of the population was a more significant discriminator than the other variables (mean household income, mean value owner occupied home, pounds of hazardous waste generated per person) for differentiating communities with commercial hazardous waste facilities or large landfills. This is in direct contrast to the findings reported in Napton and Day (1992) study cited above. Three out of the five largest landfills, accounting for 40 percent of the total estimated commercial landfill capacity in the United States, were located in predominantly black and hispanic communities. Furthermore, the study revealed that "[t]hree out of every five Black and Hispanic Americans lived in communities with uncontrolled toxic waste sites." (p. xiv)

Bullard (1983, 1990) tested the historic relationship between the location of waste disposal facilities (incinerators and landfills) and the racial composition of neighborhoods in the Houston area. He reported that the city of Houston, up until the early seventies, owned and operated eight garbage incinerators and five municipal landfills. His findings indicated that while black neighborhoods constituted just one-fourth of Houston's population, more than three-fourths of the city's solid waste disposal facilities were located in these neighborhoods. Six out of eight incinerators were located in predominantly black neighborhoods, one was located in a hispanic community, and one in mostly white area. All five of the city-owned landfills were located in black neighborhoods.

White (1992) examined the relationship between the number of hazardous waste sites in Baton Rouge, Louisiana and the racial composition of the communities surrounding these sites. Using Zip Code level data, he selected the ten largest black communities and the ten largest white communities in the city and studied the distribution of hazardous waste sites in each group. Fifteen of the twenty hazardous waste sites were located in predominantly black communities. He reported that while minority communities have an average of one site for every 7,349 residents, white communities have only one site for every 31,100 residents. Furthermore, more than 99 percent of the total hazardous waste was disposed of in black communities.

Mohai and Bryant (1992) studied the distribution of commercial hazardous waste facilities in the Detroit area. They hoped to determine whether race has a relationship with the location of these facilities that is independent of income and to compare the relative strength of the relationship of race and income with the distribution of the sites. The study reported that a total of 21 commercial hazardous waste facilities were located in the state of Michigan; of which, 16 were located in the Detroit area, which includes the city of Detroit and the three counties surrounding it: Macomb, Oakland, and Wayne. And of these 16, half were located in the city of Detroit. The minority percentages for the state, three-county area, and the city of Detroit were 16 percent, 21 percent, and 76 percent, respectively. The study concluded that these facilities were clearly located disproportionately where minorities were most heavily concentrated. A detailed analysis of the distribution of the hazardous facilities in the study area indicated that while 18 percent of the population living more than 1.5 miles from the facilities were minority residents, 39 percent of those living within 1.5 miles but more than 1 mile from the center of the facility were minority, and of those residents living within 1 mile from the facility, 48 percent were minority. A similar pattern was observed when the percentage of people living below the poverty level was examined. Using multiple regression analysis, they tested whether race had a relationship with the distance of residence to a hazardous waste facility independent of income. The test not only revealed that the relationship between the two existed, but it also showed that race was a better predictor than income.

Hird (1993) examined the geographic distribution of the Superfund sites across all counties in the United States in an effort to determine whether the number of sites in each county was related to the socioeconomic characteristics of the surrounding areas. Specifically, he wanted to determine "whether Superfund-site risks disproportionately affect the poor or racial minorities" (p. 332). His findings, based on a multivariate Tobit analysis, indicated that the wealthier counties were likely to have more Superfund sites than the poorer counties. The county's median housing value (used as a proxy for wealth) was positively correlated with the number of Superfund sites, while the percentage of population below poverty level was negatively correlated with the number of sites. Furthermore, the data indicated that counties with greater concentration of minorities were associated with more Superfund sites. Hence, Hird's conclusion that "counties occupied by the wealthy, well-educated, or nonwhite stand to benefit disproportionately from cleanup of Superfund sites." (p. 333).

This conclusion was based on the analysis of more than 3,000 counties nationwide. In order to find any possible significant relationships within subsets of counties, Hird considered the relationships between the number of Superfund sites and counties characterized by high proportions of: individuals living below the poverty level, unemployed people, racial minorities, and people living in lower-valued housing units. The results of his analysis indicated that while the number of Superfund sites in counties overrepresented by the poor and the unemployed was significantly below the national average, the number of sites in counties overrepresented by nonwhites was insignificantly below the national average. This is in direct contrast to the findings reported in the 1987 United Church of Christ study cited above. In addition, significantly more sites were located in counties where the median house values were above the national average.

Hird also analyzed the pace of Superfund site cleanups in order to establish whether community socioeconomic characteristics had any influence in determining the speed of cleanup. His analysis indicated that there was "virtually no relationship between a site reaching a particular cleanup stage and the county's socioeconomic characteristics." (p. 337).

III. Contribution of the Current Study

The main purpose of the current study is to examine the distribution pattern of toxic sources in Louisiana and to determine whether there is a systematic relationship between the location and environmental control behavior of polluting firms and the socioeconomic and racial composition of the communities. Although the research question is similar to that posed by many, this study is characterized by several unique features that will make it a valuable addition to the existing literature.

The first feature of the current study that sets it apart from the existing literature is its choice of the environmental quality indicator. While most studies in the literature concern themselves with the distribution of air quality and hazardous waste sites, this study focuses on the distribution of toxic sources. Numerous tragic accidents in the United States and around the world have indicated that toxic releases into the environment present a potential risk to human health and overall well being. However, a systematic study of the social distribution of toxic hazards has not been yet undertaken, mainly because of lack of information on these sources. The current study fills this gap in the literature by employing a relatively new data base, the EPA's *Toxics Release Inventory*, that provides the most comprehensive record of toxic emissions into the environment, nationwide.[4]

The current study is concerned with the distribution of toxic sources statewide across Louisiana communities. Unlike other studies, the choice of the study area is not randomly determined. Louisiana communities are particularly vulnerable to hazardous and toxic materials since the state hosts a large number of chemical and petroleum refining plants, major sources of toxic emissions into the

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[4] The information contained in this data base opens a whole new set of possibilities for researchers interested in studying the impact of pollutants on human health and economic activity. This data base expected to become a widely used indicator of environmental quality.

environment. According to a recent national study, Louisiana was ranked the largest per capita generator of toxics in 1988.[5] Hence, compared to the people of other states, Louisiana communities are disproportionately exposed to higher levels of environmental hazards. Within the state, it is reasonable to expect that communities in the immediate vicinity of toxic sources face greater than average potential for toxic exposure. A question of particular interest to the current study is whether the socioeconomic status of these communites is significantly different from that of Louisiana's general population characteristics. This question will basically investigate the claim that the poor and the racial minorities are particularly hard-hit by environmental pollution.

While most studies rely solely on a naive correlation analysis on observed bivariate relationships, this study is methodologically superior. A detailed spatial analysis will provide the basis for the investigation. Exposure to toxics is assumed to be, among other things, a function of locational proximity to pollution sources; the closer a community lives to a source, the higher its potential for toxic exposure. The usual approach to studying associations between pollution exposure and community socioeconomic characteristics is to use city or county level information on pollution and people; more recently, zip code level data have been employed. A major contribution of the current study is the development of a data base that identifies communities based on their distances from polluting firms. This data base is

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[5] Hall, Bob and Mary Lee Kerr, *1991-1992 Green Index: A State-by-State Guide to the Nation's Environmental Health*, (Island Press, Washington, D.C., 1991.

superior to the traditional data sources used in the literature because it allows for capturing variations in community characteristics that might exist within a community but disappear in city or county aggregates. This study performs a distance gradient analysis to determine whether the socioeconomic and racial characteristics of the communities change as the distance from pollution sources increases.

While most researchers agree that rational residential and industrial location choices of households and firms may explain why some communities bear relatively higher exposure burden than others, the current study argues that the environmental control behavior of firms and the response behavior of communities to environmental stressors may be critical in determining the distribution of hazards across communites. Within the context of profit maximization, a public choice theoretic model of firm behavior is introduced to capture relationships between hazard production and community characteristics. The model is then tested to determine whether pollution control behaviors of toxic releasing firms are systematically related to socioeconomic characteristics of surrounding communities.

In summary, this study hopes to identify who lives in Louisiana's most polluted neighborhoods. It seeks to determine whether, and how, these communities differ from Louisiana's general population, and whether or not there is a systematic relationship between the location and the pollution control behavior of the firms and the socioeconomic characteristics of the population.

Chapter 3

Polluting Firms and Host Communities

I. Introduction

Toxic releases into the environment present a potential risk to human health and overall well-being. Numerous tragic incidents involving releases of hazardous and toxic materials into the environment have triggered an increased awareness of the potential effects of toxic exposure. Louisiana communities are particularly vulnerable to hazardous and toxic materials since the state represents home to disproportionately large number of chemical and petroleum refining companies. In 1988, Louisiana was the second largest generator of toxic waste in the nation, more than 2 million pounds of toxic waste were released into its environment per day. Louisiana generated 168 pounds of toxics per person, substantially greater than each of the next three big generator states: Wyoming generated 96 pounds per capita, Utah 81 pounds, and Kansas 70 pounds.[1] This chapter examines the distribution of toxic sources in Louisiana and the socioeconomic

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[1] Hall, Bob and Mary Lee Kerr, *1991-1992 Green Index: A State-by-State Guide to the Nation's Environmental Health*, (Island Press, Washington, D.C., 1991.

characteristics of the communities that may potentially be at risk due to locational proximity to these sources. One objective is to compare the characteristics of the impacted communities with those of the general population. Impacted communities are alternatively defined as toxic source hosting parishes, zip code areas, and block groups. A second objective is to determine whether there is a systematic relationship between levels of potential exposure and the socioeconomic characteristics of impacted communities.

The chapter is organized as follows. Section II presents summary data describing: 1) the total volume of toxic chemical releases reported by Louisiana facilities in 1987 and 1989; 2) the characteristics of these facilities, and 3) their geographic distribution. Section III presents the socioeconomic characteristics of communities surrounding Louisiana's toxic sources. This section provides statistical tests of the following three sets of hypotheses: 1) the socioeconomic distribution of communities in polluted and potentially "at-risk" areas (parish and zip code areas) and the general population distribution in Louisiana are identical; 2) potential exposure levels and socioeconomic status are independent; and 3) proximity of hazard sources and socioeconomic characteristics are independent. Section IV presents the conclusions.

II. Toxic Sources in Louisiana

The United States Environmental Protection Agency's (EPA) *Toxics Release Inventory* (TRI) for the state of Louisiana is the source of data on pollution. TRI is compiled by EPA from reports submitted by manufacturing facilities on the amount and type of chemical releases classified by EPA as being toxic. Approximately 300 specific chemicals and 20 chemical categories are listed as toxic. The levels of toxicity range from acutely lethal to moderately toxic. Appendix A presents the criteria used for listing a chemical as toxic and the criteria for submitting toxic release information as specified in Section 313, Title III of Superfund Amendments and Reauthorization Act of 1986 (SARA Title III).

TRI is a data base with the most comprehensive record to date of toxic emissions into the environment. It provides data on toxic emissions into the air, releases into the water, underground injections, releases on land, and transfers of waste between facilities. A facility is required to submit a separate record for each reportable chemical. Each record in the data base is uniquely identified with a facility. The facility's location is also uniquely identified by latitude and longitude.

The first complete TRI data were published in 1987. It is a relatively new data base and has not been used in many empirical studies. Most pollution studies reviewed in Chapter 2 used air pollution monitoring data which have been in the public domain for over three decades. However, TRI is expected to become a widely used indicator of environmental quality. Two potential problems associated with the data include: 1) it solely relies on self-reporting by facilities; hence, mis-reporting is likely, and 2) the reported quantities are estimated releases not actual releases. For instance, some of the estimates are based on measured concentrations of the chemical in a waste stream and the volumetric flow rate of that stream. Other estimates are based on input and output approach accounting for accumulation and depletion of the chemical in the equipment. Hence, the quality of the data is a function of the estimation technique used.[2]

Table 3.1 presents the breakdown of total volume of toxic releases, by medium, into Louisiana's environment for 1987 and 1989 reporting years. In 1987, a total of 1896 chemical reporting forms were submitted by 239 Louisiana facilities. The total releases and transfers from these facilities amounted to roughly 4 million pounds of toxic chemicals per facility in 1987. Of this total, approximately 46% were injected into underground wells (UNDERGROUND), 21% were released into the water (WATER), 15% to land (LAND), 13% into the air (AIR), and less than 5% were transfered into publicly owned treatment facilities (POTW) and off-site storage, treatment and disposal facilities (TRANSFER). It is apparant that most of the toxics generated by the facilities are disposed of on-site.

In 1989, a total of 2206 separate reporting forms were submitted by 308 facilities. The total releases and transfers from these facilities amounted to roughly 1.5 million pounds of chemicals per facility. Injections into underground wells and releases into the air accounted for over 87% of these total releases. The 1989 reported data represent an overall reduction of approximately 55% in total releases compared to 1987. Land and water releases declined by approximately 98

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[2] For a complete assessment of the accuracy of information on toxic chemical releases (TRI data base) see *Tracking Toxic Substances at Industrial Facilities: Engineering Mass Balance Versus Materials Accounting*, Committee to Evaluate Mass Balance Information for Facilities Handling Toxic Substances, Board on Environmental Studies and Toxicology, Commission on Geosciences, Environment, and Resources, National Academy Press, Washington D.C., 1990.

Table 3.1

Volume of Reported Toxic Releases in Louisiana, by Medium (in pounds)

MEDIUM	1987 RELEASES	1989 RELEASES	% CHANGE
AIR	137,890,534	125,754,407	- 8.80
LAND	154,991,410	3,560,799	- 97.70
POTW	444,109	59,753	- 86.55
TRANSFER	46,974,771	11,098,429	- 79.37
UNDERGROUND	484,950,931	285,933,028	- 41.04
WATER	220,898,404	46,117,634	- 79.12
TOTAL	1,046,150,159	472,524,050	- 54.83
NUMBER OF TRI FIRMS	239	308	+ 28.87

Source: EPA, *Toxics Release Inventory*, 1987 and 1989.

and 80 percent, respectively. Air releases, on the other hand, show a modest reduction of only 9 percent.

The progress in reduction of toxic chemical releases is not unique for Louisiana; it is true for the United States as a whole. According to the EPA (May 1991), reported releases and transfers of all chemicals decreased by 18 percent from 1987 to 1989. EPA acknowledges that half of the decrease in land releases may have resulted from facilities' overestimates of 1987 releases of mineral acids and metal compounds.

The breakdown of 1989 Louisiana releases by industry type is shown by 2-digit Standard Industrial Classification (SIC) Codes in Table 3.2. The dominance of the chemical industry in Louisiana is confirmed by the reported data. The broadly defined chemical products industry, SIC code 28, accounted for over 89% of all toxic releases in 1989. The petroleum refining industry, SIC code 29, follows with 7% of all releases. Note that only manufacturing firms with SIC codes between 20 and 39 are required to submit TRI reports. The NA category listed includes facilities with either SIC codes not specified or SIC code not included in 20-39 range.

Table 3.3 presents the distribution of TRI reporting facilities and total volume of releases across Louisiana parishes. Ten parishes alone accounted for approximately 96% of the state's 1989 total reported releases. Jefferson Parish, with 24 reporting facilities, tops the list with over 41% of all releases, followed by Ascension Parish with approximately 30%, and Calcasieu and St. James Parishes with around 6% each. It is evident that toxic releasing facilities are not evenly distributed across Louisiana parishes. Most facilities are located in the southern portion of the state along the lower

Table 3.2

Industry Type and Share of Louisiana's Total Toxic Releases Ranked by Percentage of 1989 Releases

SIC Code	Industry Type	% of Total
28	Chemical Products	89.06
29	Petroleum Refining	6.91
37	Transportation Equipment	1.44
26	Paper Products	1.03
34	Fabricated Metals	0.71
33	Primary Metals	0.36
20	Food and Kindred Products	0.12
36	Electronics	0.10
24	Lumber and Wood Products	0.09
NA	SIC code not available	0.07
32	Stone, Clay, Glass and Concrete	0.05
35	Machinery and Computers	0.04
38	Medical Instruments	0.01
30	Rubber and Plastics	0.004
27	Printing, Publishing Products	0.002
25	Furniture and Fixtures	0.002

Source: EPA, *Toxics Release Inventory*, 1989.

Table 3.3

Distribution of TRI Reporting Facilities and Total Volumes of Releases (in pounds) in Louisiana Parishes, Ranked by Percentage of 1989 Releases

PARISH	NUMBER OF FACILITIES	VOLUME OF RELEASES	PERCENT OF TOTAL
Jefferson	24	196,107,339	41.5021
Ascension	19	141,675,874	29.9828
St.James	8	26,425,106	5.5923
Calcasieu	22	24,382,431	5.1600
St. Charles	12	19,297,351	4.0839
Ouachita	10	12,750,559	2.6984
East Baton Rouge	23	10,747,197	2.2744
Iberville	13	8,041,717	1.7019
St. Mary	7	5,874,315	1.2432
St. Bernard	4	4,965,501	1.0508
Cameron	3	4,869,520	1.0305
Caddo	18	3,305,334	0.6995
West Baton Rouge	9	2,812,520	0.5952
St. John	10	2,694,230	0.5702
Orleans	13	1,188,182	0.2515
Grant	1	1,108,410	0.2346
Beauregard	4	783,893	0.1659
Evangeline	2	773,351	0.1637
Richland	2	494,150	0.1046
Assumption	3	464,851	0.0984
Rapides	9	411,937	0.0872
West Feliciana	1	395,550	0.0837
Natchitoches	2	381,440	0.0807
Union	1	261,600	0.0554
Plaquemines	6	255,849	0.0541
Sabine	3	233,500	0.0494
Winn	5	227,781	0.0482

(table con'd.)

Lincoln	6	227,413	0.0481
St. Landry	4	167,800	0.0355
Lafourche	6	152,597	0.0323
Livingston	2	136,610	0.0289
Jackson	1	128,980	0.0273
Washington	2	126,360	0.0267
Lafayette	9	121,133	0.0256
Iberia	8	81,474	0.0172
De Soto	3	80,596	0.0171
St. Tammany	4	75,733	0.0160
La Salle	1	75,366	0.0159
Bienville	2	67,440	0.0143
Claiborne	2	47,637	0.0101
St. Helena	1	26,047	0.0055
Acadia	2	20,167	0.0043
Terrebonne	2	19,900	0.0042
Tangipahoa	3	14,151	0.0030
Webster	4	12,457	0.0026
Allen	1	3,000	0.0006
Avoyelles	1	3,000	0.0006
Madison	1	3,000	0.0006
Vermilion	2	2,320	0.0005
Bossier	2	831	0.0002
Red River	1	250	0.0001
St. Martin	2	250	0.0001
Morehouse	1	50	0.0000
Pointe Coupee	1	0	0.0000

Source: EPA, *Toxics Release Inventory*, 1989.

Mississippi River. This portion of the state represents a convenient location choice for the toxic chemical releasing manufacturing facilities that need the waterway for transporting the finished products and the nearby oil and gas fields for feedstock and energy. All this industrial activity translates into a potential for greater exposure to toxic risks in these areas of the state.

III. Community Characteristics

The distribution pattern of toxic sources and releases presented above suggests that some parishes and their communities may be disproportionately exposed to potential toxic risks. However, we should note that these facilities are not distributed evenly within parishes. Most of the facilities are located along the Mississippi River. Consequently, those communities living closer to the river within the parish are more exposed to potential toxic risks than others in the same parish. Hence, in studying the socioeconomic characteristics of the communities at risk of toxic exposure, to accommodate for differences in relative exposure, we use three alternative levels of aggregation; parishes, zip code areas, and block groups. The analysis of impacted communities is divided into three parts. First, we study the characteristics of parish and zip code area communities that host TRI reporting firms and determine whether they differ from Louisiana's general population characteristics. Second, we test whether there are any spatial associations between socioeconomic status of the population and alternative measures of toxic activity. Finally, we test for possible distance effects using block group variables.

a. Parish and Zip Code Communities

Louisiana can be alternatively broken down into 64 parishes or 574 non-overlapping zip code areas. *The Sourcebook of County Demographics* and *The Sourcebook of Zip Code Demographics* are the sources of socioeconomic variables for the parish and zip code areas, respectively. TRI reporting facilities are distributed over 55 parishes and 153 zip code areas. Merging parish and zip code data with TRI is relatively straightforward. Each TRI reporting facility is required to provide a physical plant location address, including its zip code and the parish where it is located. Over 200 different zip code areas and 55 parishes were registered for the combined 1987 and 1989 TRI data. However, the study of the raw data revealed that some facilities reported their mailing or post office zipcode rather than their physical location zipcode. A telephone survey of all TRI reporting facilities was initiated to verify their location zip code. After the corrections were made, the total number of different zipcode areas was only 153.

It is reasonable to expect that communities surrounding TRI reporting facilities face greater than average potential for toxic exposure. The question of interest is whether the socioeconomic status of these communities differs from Louisiana's general population characteristics. Table 3.4 describes the socioeconomic variables used for the study.

Table 3.5 presents the means of parish (column 1, $\bar{X}_p$) and zip code area (column 2, $\bar{X}_z$) variables and the statewide means (column 3, μ). The statewide mean is obtained from the 1990 Census of Population. Parish populations are approximately 5 times greater than those of

Table 3.4

Description of Socioeconomic Variables

VARIABLE	DESCRIPTION
POP	Total Population
HSHLD	Total Number of Households
WHITE	Percent Population, White
BLACK	Percent Population, Black
MEDINC	Median Household Income
AVGINC	Average Household Income
CAPINC	Per Capita Income
INC A	% Families, Income Less Than $10,000
INC B	% Families, Income Between $10,000-14,999
INC C	% Families, Income Between $15,000-24,999
INC D	% Families, Income Between $25,000-34,999
INC E	% Families, Income Between $35,000-49,999
INC F	% Families, Income Between $50,000-74,999
INC G	% Families, Income More Than $75,000
EDUC	Median Years of Education
COLLEGE	Percent Population, College Graduates
HOME	Median Home Value
RENT	Median Rent

Sources: *The Sourcebook of County Demographics*, 1990.
The Sourcebook of Zip Code Demographics, 1990.

Table 3.5

**Population Characteristics in
TRI Reporting Parishes and Zip Code Areas**

VARIABLE	PARISH MEAN $\bar{X}_p$ (1)	ZIP CODE MEAN $\bar{X}_z$ (2)	STATE μ (3)	TESTS OF HYPOTHESES t-stat $\bar{X}_p = \bar{X}_z$ (4)	$\bar{X}_p = \mu$ (5)	$\bar{X}_z = \mu$ (6)
POP	73,560 (13,736)	14,426 (1,059)	4,497,128	3.99[a]	-	-
HSHLD	29,981 (5,902)	4,984 (370)	1,572,889	3.98[a]	-	-
WHITE	70.29 (1.77)	68.16 (1.67)	70.50	0.62	-0.12	-1.40[c]
BLACK	28.61 (1.81)	30.34 (1.69)	27.70	-0.49	0.50	1.56[c]
MEDINC	22,243 (726)	23,861 (527)	24,096	-1.29[c]	-2.55[a]	-0.45
AVGINC	26,455 (603)	27,608 (452)	28,445	-1.09	-3.30[a]	-1.85[b]
CAPINC	8,979 (199)	9,399 (164)	9,949	-1.16	-4.88[a]	-3.34[a]
INC A	26.25 (1.07)	23.81 (0.72)	22.70	1.36[c]	3.32[a]	1.54[c]
INC B	10.71 (0.24)	10.30 (0.20)	10.20	0.93	2.12[a]	0.50
INC C	18.71 (0.26)	18.61 (0.25)	18.80	0.20	-0.35	0.76
INC D	15.80 (0.30)	16.66 (0.26)	16.40	-1.53[c]	-2.00[a]	1.00
INC E	15.92 (0.62)	17.05 (0.44)	17.05	-1.07	-1.74[b]	0.11
INC F	8.90 (0.50)	9.54 (0.37)	10.20	-0.73	-2.60[a]	-1.78[b]
INC G	3.87 (0.20)	4.04 (0.20)	4.70	-0.40	-4.15[a]	-3.30[a]
EDUC	11.66 (0.10)	12.40 (0.64)	12.20	-1.00	-5.40[a]	0.31
COLLEGE	10.12 (0.59)	11.00 (0.55)	13.70	0.77	-6.07[a]	-4.91[a]
HOME	35,326 (1,439)	38,336 (1,107)	43,036	-1.18	-5.36[a]	-4.24[a]
RENT	173 (6)	187 (5)	214	-1.32[c]	-6.73[a]	-5.59[a]

Standard errors in parentheses.
[a]Significance at 5 percent level.
[b]Significance at 10 percent level.
[c]Significance at 20 percent level.

typical zip code areas. This is, of course, expected since zip code areas are geographically smaller and therefore less populated. We utilize the zip code data in order to capture any variations that might exist within the parish but dissappear in parish aggregates. Visual inspection of the sample means in Table 3.5 columns (1) and (2) reveals some differences between parish and zip code level data. For example, the percentage of blacks in TRI reporting zip code areas is slightly higher than the percentage of blacks in TRI reporting parishes; the opposite is true for percentage of whites. Parish sample means of median household income, average household income, and per capita income seem to be slightly lower than the zip code sample means.

To determine whether these observed differences are statistically significant, we calculate a t-statistic based on the null hypotheses that the parish and zip code sample means are equal. For each variable in Table 3.5, we calculate the difference between the parish mean ($\bar{X}_p$) and the zip code mean ($\bar{X}_z$). Then we calculate the standard error for the difference of the means, $S_{\bar{x}_p - \bar{x}_z}$, according to the following formula:

$$S_{\bar{x}_p - \bar{x}_z} = \sqrt{\frac{s_p^2}{n_p} + \frac{s_z^2}{n_z}} \tag{3.1}$$

where s_p^2 and s_z^2 are the parish and zip code sample variances respectively, and n_p and n_z represent the number of observations for each sample. The t-statistic is then calculated as follows:

$$(3.2) \qquad t = \frac{\overline{X}_p - \overline{X}_z}{S_{\overline{X}_p - \overline{X}_z}}$$

The calculated t values are listed in column (4) of Table 3.5. The tests, at 5 percent level of significance, resulted in rejecting the equality of sample means for population (POP) and number of households (HSHLD). At the 20 percent level of significance, however, we reject the equalities of sample means for median income (MEDINC), percent families with incomes below $10,000 (INC A), percent families with incomes between $25,000 and $34,999 (INC D), and median rent (RENT). These tests suggest that there are no substantial differences between parish and zip code communities.

We arrive at different conclusions when comparing parish and zip code sample means, $\overline{X}_p$ and $\overline{X}_z$, to the state's benchmark values, μ. The characteristics of the population in TRI reporting zones appear to be different from the state's general population characteristics. All income and income related variables, such as education and property values, have higher statewide benchmark values than either parish or zip code sample means. To determine whether these observed differences are statistically significant, we compare the mean values of parish and zip code variables ($\overline{X}_p$ and $\overline{X}_z$), separately, with the benchmark values (μ) by computing a t-statistic based on the null hypotheses that the values are equal. The t-statistic is calculated as follows:

$$(3.3) \qquad t = \frac{\overline{X} - \mu}{S_{\overline{X}}}$$

where $\overline{X}$ is the sample mean and $S_{\overline{X}}$ is the standard error of the mean. Columns (5) and (6) in Table 3.5 present the calculated t values for parish and zip code samples, respectively. For the parish level variables, the tests at the 10 percent level of significance or higher, resulted in rejecting the null hypotheses for nearly all income variables. In other words, income distribution in TRI reporting parishes are statistically different from Louisiana's benchmark values. The mean values of median household income (MEDINC), average household income (AVGINC) and per capita income (CAPINC) are all significantly lower in TRI reporting parishes than the state averages. The mean percentages of families with incomes below $15,000 (INC A and INC B) are higher in these parishes, and the percentages of those with incomes above $35,000 is significantly lower (INC E, INC F and INC G). Other income related parish level variables reveal significant divergences from state benchmarks. The mean values of median years of education (EDUC), the percent of the population that is a college graduate (COLLEGE), median home values (HOME), and the median rent (RENT) are all significantly lower in TRI reporting parishes. Race variables represent an exception in that there are no observed differences in parish and statewide racial distributions.

The divergences from the state benchmarks appear to be of a smaller magnitude for the zip code level variables. The tests, at 5 percent level of significance, resulted in rejecting the null hypotheses for CAPINC, INC G, COLLEGE, HOME, and RENT. On average, compared to the state, TRI reporting zip code areas have lower per capita incomes, fewer families with incomes greater than $75,000, fewer college graduates, and lower home and rent values. The null hypothesis of equality of AVGINC is rejected at the 10 percent level of significance. The difference between zip code and state racial composition is greater than that between parish and the state as a whole. The mean percent black in the TRI reporting zip code areas is 30.34% which is above the state's benchmark of 27.7%. The null hypothesis of equality is rejected at the 20 percent significance level. It is interesting to note that income variables show less divergence and race variables more divergence with lower degrees of geographic aggregation. The significance of divergent racial distributions becomes more evident when we consider block groups, the lowest level of aggregation, below.

b. Community Characteristics and Toxic Exposure

Is potential exposure to toxics in Louisiana systematically related to socioeconomic characteristics of the community? We address this question by examining the correlation coefficient between alternative measures of potential toxic exposure and the socioeconomic variables introduced above for both parish and zip code area communities. Note that this approach is not intended to explain cause and effect relationships, it merely shows the degree of spatial association between the two sets of variables. Nevertheless, the findings do provide an additional insight into the characteristics of the communities surrounding the toxic sources.

Table 3.6 presents the Pearson's correlation coefficients between 1989 total annual toxic releases (TOTAL), per capita annual releases (TRI-PC), number of TRI reporting facilities (FIRMS) and socioeconomic variables at both parish (columns 1-3) and zip code (columns 4-6) levels. TOTAL, TRI-PC, and FIRMS are used as proxies for potential toxic exposure. The larger the volume of releases, both total and per

Table 3.6

Correlation* Between Socioeconomic Variables And Alternative Measures of Toxic Exposure

	PARISH LEVEL			ZIP CODE LEVEL		
	TOTAL (1)	TRI-PC (2)	FIRMS (3)	TOTAL (4)	TRI-PC (5)	FIRMS (6)
POP	.423[a]	.001	.710[a]	.138[b]	-.113	.214[a]
HSHLD	.401[a]	-.009	.689[a]	.110	-.113	.203[a]
WHITE	.157	.054	.031	-.053	-.128	-.114
BLACK	-.170	-.047	-.050	.047	.129	.089
MEDINC	.326[a]	.302[a]	.585[a]	.018	.012	.124
AVGINC	.302[a]	.262[b]	.594[a]	-.014	-.042	.120
CAPINC	.313[a]	.164	.644[a]	-.068	-.092	.060
INC A	-.311[a]	-.230[b]	-.547[a]	-.044	.055	-.143[b]
INC B	-.316[a]	-.253[b]	-.521[a]	-.021	-.073	-.082
INC C	-.197	-.409[a]	-.351[a]	.056	-.166[a]	.016
INC D	.251[b]	.078	.307[a]	.151[b]	.125	-.009
INC E	.381[a]	.422[a]	.536[a]	.057	.063	.160
INC F	.271[a]	.371[a]	.568[a]	-.055	-.034	.112
INC G	.117	.049	.494[a]	-.110	-.155[b]	.037
EDUC	.227[b]	.155	.505[a]	-.017	-.008	.008
COLLEGE	.128	-.099	.498[a]	-.110	-.052	-.081
HOME	.357[a]	.243[b]	.600[a]	-.009	-.055	.047
RENT	.321[a]	.066	.584[a]	-.002	-.196[a]	.123

*Pearson's correlation coefficients.
[a]Significance at 5 percent level.
[b]Significance at 10 percent level.

capita, and the greater the number of firm in a given geographic area, the higher the potential for exposure to toxic chemicals.

At the parish level, total toxic releases (TOTAL) and total number of firms (FIRMS) are positively and significantly (at 5 percent level) related to median household income (MEDINC), average household income (AVGINC), and per capita income (CAPINC). Per capita toxic releases (TRI-PC) is also positively related to the income variables, although less significantly. All three measures of potential toxic exposure reveal the same relationship with income distribution variables. While the percentages of families in the two lower income classes (incomes less than $15,000) are negatively related to total releases, the percentages in middle and upper middle classes (incomes between $35,000 and $75,000) are positively related. These positive relationships between incomes and potential exposure levels are not consistent with findings reported in other pollution studies.[3] Usually, the relationships between these two sets of variables are found to be negative. However, we are not alarmed with the findings because the variables used as proxies for exposure also describe the intensity of the industrial activity in a parish, a relatively large geographic area. Toxic releases are by-products of industrial activity. Higher releases indicate higher production levels and higher production may translate into more jobs and higher incomes. Although income levels in TRI reporting parishes are, on average, lower than the state's overall benchmarks, among TRI reporting parishes incomes are higher in parishes

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[3] See Freeman (1972), Asch and Seneca (1978), Brajer and Hall (1992).

with more facilities and higher levels of discharges. More industrial activity may generate higher incomes, or may require higher labor compensation to attract workers. Our findings are consistent with those of Napton and Day (1992).

The wealth enhancing feature of industrial activity at the parish level is further evidenced by the relationships between total number of firms and other income related variables. Median years of education and percentage of population with a college degree are positively and significantly related to the number of firms. Median home values and median rents tell a similar story. Race variables, on the other hand, do not have any significant association with the potential exposure variables.

We obtain a very different picture when calculating correlation coefficients between alternative measures of potential exposure and socioeconomic variables in TRI reporting zip code areas. Table 3.6 reveals few significant associations between the two sets of variables. For example, the rental value of housing is negatively related to per capita toxic releases, with the correlation coefficient of RENT significant at the 5 percent level. The percentage of families in the highest income class (INC G) is negatively and significantly related to TRI-PC. It is interesting to note that at this lower aggregation level the signs of the correlation coefficients are consistent with other pollution studies. For instance, the percentage of blacks (BLACK) is positively related to all measures of potential exposure. AVGINC and CAPINC are negatively related to TOTAL and TRI-PC. However, these relations are not significant.

TRI related industrial activity may be income enhancing at high (parish) aggregation levels due to spillovers or need for compensating wage differentials due to hazards or quality of life. However, it may also be related to depressed "localized" pockets observable only at the lower (zip code) aggregation levels.

c. Community Characteristics and Distance

Exposure to toxics is assumed to be, among other things, a function of distance from pollution sources. The closer a community is to a pollution source, the higher the risk of potential exposure. Block groups are geographically much smaller than either parishes and zip code areas. Therefore, block group data provide high resolution information about communities immediately adjacent to toxic polluters. Block groups are used to test for possible localized distance effects on the community's social and economic make-up. Distances of block groups from their nearest polluting facilities are calculated and used as the basis for identifying spatial differences in community characteristics and potential exposure levels.

The *Census of Population and Housing, 1990: Summary Tape File A* (STF-A) is the source of the block group data. A block group consists of a cluster of blocks having the same first digit of their three-digit identifying numbers within a census tract or block numbering area. Block groups generally contain between 250 and 550 housing units, with the ideal size being 400 housing units.[4] The STF-A provides data on the population distribution in a block group by race, age and sex. It

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4 U.S. Bureau of Census, *Census of Population and Housing, 1990: Summary Tape File A*, Appendix A.

provides data on total housing units and distribution of housing units by race, ownership, housing values, and rental values. The only limitation of the STF-A is the fact that it does not provide information on income and education.

In order to use STF-A, we need to associate the information it provides with the TRI data. TRI data do not have block group specific information on facility locations. Fortunately, STF-A provides a set of latitude and longitude coordinates that identify the center of each block group. This allows us to construct a data base that provides distance specific information about the characteristics of communities that may be exposed to potential toxic risks. The development of a data base that identifies communities based on their distance from TRI reporting facilities is one of the major contributions of this research. Using the latitudes and longitudes of TRI sources and STF block groups, we calculate a matrix of distances between each of the 307 Louisiana facilities that reported toxic releases in 1987 or 1989 and the 8,055 block groups in Louisiana. This is a 307 x 8055 matrix of distances which is used to link sources to communities. Appendix B explains the procedure used for the distance calculations.

In order to capture possible distance effects, communities are classified into eleven distinct distance groups, C_1 through C_{11}. The procedure for classifying communities requires an examination of the distances between each block group and all 307 TRI reporting facilities. Using the distance matrix described above, we identify the distance between each block group and its nearest TRI facility. We then keep the distance variable and use it as community identification factor. C_j defines all block groups that are located within a distance of d_j and d_{j-1} miles of TRI reporting facilities. It is expected that exposure potential will eventually diminish with distance. We arbitrarily choose ten miles to be the maximum distance. One mile intervals are used to define the community groups C_1 through C_{10}, C_{11} represents the block groups that are located more than 10 miles from the nearest TRI source.

Is proximity to toxic sources in Louisiana independent of a community's social and economic status? To answer this question, we calculate the means of various socioeconomic variables for community groups C_1 through C_{11} and test whether there are any statistical differences between them. Table 3.7 describes the socioeconomic variables used in the analysis and explains the community group definitions in detail. Table 3.8 presents the sample means for each variable. Community groups are listed in column (1): C_1 represents those block groups that have the nearest TRI firm within a distance of one mile; C_2 represents the block groups that have the nearest TRI firm within a distance of at least one and at most two miles; etc. The total number of block groups (N) for each community category is listed in column (2). Of the 8,055 total block groups in Louisiana, 6,116 are located within a distance of 100 miles from TRI reporting facilities. Of which, 5,297 are located within a distance of 10 miles. C_2 has the highest number of block groups. The number of block groups falls as we go further from TRI facilities. However, over 52% of the block groups in Louisiana are located within a distance of 5 miles from the nearest TRI reporting facility.

The mean population in a community group, column (3), shows a general decreasing trend as the distance to the nearest facility

Table 3.7

Variable and Notation Definition

Variable	Definition
POP	Total Population
DENSITY	Population Density
WHITE	Percent Population, White
BLACK	Percent Population, Black
OTHER	Percent Population, Non-White/Non-Black
FEMALE	Percent Population, Female
YOUNG	Percent Population, 15 Years Old and Below
OLD	Percent Population, 62 Years Old and Above
HOME	Median Home Value
RENT	Median Rent
C_1	Block Groups located 0-1 miles from Nearest TRI Facility
C_2	Block Groups located 1-2 miles from Nearest TRI Facility
C_3	Block Groups located 2-3 miles from Nearest TRI Facility
C_4	Block Groups located 3-4 miles from Nearest TRI Facility
C_5	Block Groups located 4-5 miles from Nearest TRI Facility
C_6	Block Groups located 5-6 miles from Nearest TRI Facility
C_7	Block Groups located 6-7 miles from Nearest TRI Facility
C_8	Block Groups located 7-8 miles from Nearest TRI Facility
C_9	Block Groups located 8-9 miles from Nearest TRI Facility
C_{10}	Block Groups located 9-10 miles from Nearest TRI Facility
C_{11}	Block Groups located > 10 miles from Nearest TRI Facility

Table 3.8

Community Characteristics Given Distance to TRI Reporting Facilities

COMMUNITY (1)	N (2)	POP (3)	DENSITY (4)	WHITE (5)	BLACK (6)	OTHER (7)	FEMALE (8)	YOUNG (9)	OLD (10)	HOME (11)	RENT (12)
C_1	755	753	4,457	57.88%	40.29%	1.84%	52.71%	24.71%	16.76%	$55,253	$259
		(21)	(179)	(1.39)	(1.41)	(.13)	(.17)	(.28)	(.33)	(997)	(4)
C_2	1,354	730	4,646	60.72	37.56	1.72	52.63	24.27	16.06	62,840	270
		(16)	(131)	(0.99)	(1.00)	(.10)	(.13)	(.21)	(.24)	(1,135)	(3)
C_3	1,055	748	4,038	65.35	32.92	1.73	52.13	24.48	15.63	61,990	271
		(18)	(144)	(1.04)	(1.05)	(.09)	(.15)	(.24)	(.29)	(1,009)	(4)
C_4	629	728	1,955	75.37	23.31	1.32	51.72	25.27	14.65	59,853	269
		(26)	(109)	(1.21)	(1.22)	(.14)	(.17)	(.29)	(.38)	(1,072)	(6)
C_5	379	654	1,248	75.99	22.69	1.32	51.54	26.76	13.42	57,434	245
		(31)	(92)	(1.51)	(1.51)	(.22)	(.23)	(.33)	(.43)	(1,698)	(7)
C_6	310	623	867	78.29	20.69	1.02	51.19	27.00	13.77	52,907	225
		(36)	(78)	(1.53)	(1.53)	(.17)	(.22)	(.38)	(.46)	(1,298)	(7)
C_7	256	640	805	75.69	23.38	0.93	51.08	27.66	13.20	49,896	201
		(38)	(85)	(1.79)	(1.79)	(.14)	(.27)	(.37)	(.44)	(1,546)	(6)
C_8	232	581	474	74.08	24.89	1.03	51.39	27.65	14.24	47,295	201
		(33)	(72)	(1.96)	(1.98)	(.16)	(.28)	(.38)	(.49)	(1,540)	(7)
C_9	187	489	595	78.72	20.56	0.71	51.49	26.36	16.12	44,452	178
		(32)	(99)	(2.11)	(2.12)	(.11)	(.44)	(.50)	(.62)	(1,492)	(5)
C_{10}	140	626	372	80.44	18.76	0.79	50.79	26.36	15.44	47,386	178
		(45)	(64)	(2.03)	(2.04)	(.12)	(.35)	(.50)	(.69)	(1,679)	(6)
C_{11}	819	539	505	74.77	23.81	1.41	51.23	26.34	16.26	40,979	165
		(21)	(41)	(0.99)	(1.00)	(.13)	(.16)	(.21)	(.25)	(654)	(2)
OVERALL[1]	6,116	681	2,744	68.52	29.99	1.48	51.94	25.38	15.47	55,636	240
		(8)	(52)	(0.43)	(0.43)	(.04)	(.06)	(.09)	(.11)	(405)	(2)
ANOVA F[2]		11.61	142.81	32.70	29.75	5.45	10.43	16.30	9.31	38.09	71.9
K-W H[3]		161.75	2,089	272.33	237.62	250.10	305.35	177.73	152.30	581.45	937.9

Standard errors in parentheses.
C_1 is 0-1 miles, C_2 is 1-2 miles, etc., C_{11} is greater than 10 miles.
[1]This represents the total sample.
[2]Fisher's F-statistic.
[3]Kruskal-Wallis H-statistic.

increases. On average, more people live closer to TRI facilities than further away. This is further evidenced by the values of the mean population density (DENSITY) in column (4). A wide range of variation is observed for DENSITY, with the highest values reported in C_2. The variable shows a decreasing trend with distance. This finding indicates that industrial activity in Louisiana is highly concentrated in densely populated areas. There are reasons to expect that industrial activity would induce nearby population growth, and industries would tend to locate near population centers for labor supply purposes. However, the implication is that population exposure to environmental risks is also higher due to this location pattern.

The racial composition of the community changes with distance, columns (5)-(7). The percentage of blacks in the population (BLACK) is highest in communities that live within a distance of one mile from toxic sources. While the overall percentage of blacks in the study areas, C_1 - C_{11}, is 29.99%, the mean value in C_1 is 40.29%. Furthermore, the mean values of BLACK in communities within 3 miles of the nearest TRI facility (C_1- C_3) are significantly greater than the percentage of blacks in the state as a whole, 27.7% (Table 3.5, column 3). The data clearly show that the percentage of blacks systematically falls as distance increases. The lowest value of 18.76% for this variable is reported in communities that live between 9 and 10 miles from the nearest TRI facility. The percentage of whites in the population (WHITE) shows the opposite relation, as one would expect since the percentage of other minorities constitute a small percentage of Louisiana's overall population.

Distance is also related to the sex and age composition of the community. The percentage of females (FEMALE) ranges from 52.71% in C_1 to 50.79% in C_{10}. Inspection of column (8) shows a modest but steady decline with distance. The percentages of young people (YOUNG), ages below 15, show an increasing trend with the lowest value of 24.47% reported in C_1 and the highest value of 27.66 reported in C_8. The percentages of older persons (OLD), ages 62 and above, show a decreasing trend over a limited distance range, with percentages ranging from a high of 16.76% in C_1 to a low of 13.2% in C_7.

The means of median home values (HOME) and rents (RENT) show variations across the defined communities. As one would expect these two averages seem to move in the same general direction. While HOME has its highest value in C_2, RENT reaches its highest in C_3. The data indicate that home and rent values are generally higher in communities that are located closer to the toxic sources. This finding appears to be inconsistent with studies that predict property values to be lower in areas of lower environmntal quality. However, TRI facilities are mostly located in urban and densely populated areas. The distance to a facility may be acting as a proxy for the distance to the central business district used in property value studies. The closer the property is located to the central business district, the higher its value. Therefore, the relationship is not necessarily inconsistent.

The natural question is whether these observed differences can be attributed to chance, or whether they are indicative of actual differences among the means of the corresponding populations. If $\bar{z}_1$, $\bar{z}_2$, ... , $\bar{z}_k$ are the true mean values of the variables in each community, we want to test the null hypothesis $\bar{z}_1 = \bar{z}_2 = \ldots = \bar{z}_k$ against the alternative hypotheses that they are not all equal. Two statistical approaches are used to explore these hypotheses. First, we use one way analysis of variance (ANOVA). ANOVA assumes that the data can be treated as random samples from a normal populations having the same variance and differing, if at all, only in their means. Formally, the ANOVA model is represented as follows:

$$z_{ij} = \bar{z} + \alpha_i + \varepsilon_{ij} \tag{3.4}$$

where i = 1,2,...,k community classes, and j = 1,2,...,n block groups. This model assumes that any observed value can be decomposed into three parts:

1. An overall mean, $\bar{z}$, obtained by treating all community classes as though they constitute a single sample.
2. A deviation associated with community classes, α_i, where $\alpha_i = \bar{z} - \bar{z}_i$, $\bar{z}_i$ being the mean of the variable in the ith class.
3. A random element from a normally and independently distributed population, $\varepsilon_{ij} = N(0,\sigma)$.

ANOVA provides a single test of the null hypothesis that the mean of the k community classes are equal. The variance ratio

$$F = \frac{\text{Mean square among community classes}}{\text{Error Mean Square}} \tag{3.5}$$

is considered to be a good criterion for testing the null hypotheses. The value of F is 1 when the null hypothesis holds, and is larger when the class means differ significantly. The test of significance is performed by comparing the value obtained for F with critical values of

F. The null hypotheses are rejected at α level of significance if the calculated F > $F_{\alpha}(k-1,N)$. The calculated F statistics for our sample of block group communities are presented in Table 3.8 (ANOVA F). According to these values the observed differences in the class means cannot be attributed to chance. The tests for each socioeconomic variable resulted in rejecting the null hypotheses at the 5 percent level of significance or higher.

The F-test is very specific about the assumption of normality. Our sample of over 6,000 observations could be treated as a random sample from a normal population. However, to make sure that the results are statistically significant we use a second approach to test the same hypotheses. A nonparametric alternative to Fisher's ANOVA is the Kruskal Wallis H-test. Unlike ANOVA, this test does not require the assumption that the samples come from a normal distribution and have equal variances. The H test is based on the statistic

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i}{n_i} - 3(N+1) \tag{3.6}$$

The k classes are ranked as though they constituted a single sample. R_i is the sum of the ranks assigned to the n_i observations in the ith sample, and $N = \sum_{i=1}^{k} n_i$. If the null hypothesis is true, the sampling distribution of H is approximated by a Chi-Square distribution with k-1 degrees of freedom. The null hypothesis is rejected at the significance level α if $H > \chi^2_{\alpha}$ (k-1 d.f.). Table 3.8 presents the values of the H statistic calculated for our sample. According to these values, we are able to reject the null hypotheses at the 5 percent level of significance, or higher, for all socioeconomic variables.

Regression models in which each of the variables listed in Table 3.7 is a quadratic function of the precise distance of the block group to the nearest TRI reporting facility provides further evidence of the above relationships. Table 3.9 presents the regression results obtained from the following model:

$$(3.7) \qquad z = \alpha + \beta x + \gamma x^2 + \varepsilon$$

where z is the block group specific socioeconomic variable (BLACK, HOME, OLD, etc.); x is the distance measured to the nearest 0.01 mile; and ε is a normally distributed error term.

The explanatory power of the individual regressions in Table 3.9, as measured by the value of $\bar{R}^2$, range from a low of 0.026 for OTHER to a high of 0.1486 for DENSITY. All coefficient estimates have the expected signs and are statistically significant. The results basically confirm that as distance from the nearest TRI facility increases, population, population density, the percentage of blacks, other minorities, females, and elderly decrease. The percentage of whites and young children increase, and median home and rent values decrease as the distance increases.

IV. Conclusions

Toxic chemical releasing facilities are not distributed evenly across Louisiana. Most TRI facilities are conveniently located in the southern portion of the state along the lower Mississippi River. Jefferson and Ascension parishes alone accounted for over 70% of Louisiana's total toxic releases in 1989. The distribution pattern of these facilities suggests that some communities may be

Table 3.9

Distance Regression

Dependent Variable	Coefficient Estimates α	β	γ	$\bar{R}^2$	F-Value
POP	771.51	-22.41	0.38	0.0163	51.72
	(12.76)	(3.10)	(0.11)		
DENSITY	4,814.56	-573.96	13.98	0.1486	534.52
	(80.32)	(19.53)	(0.68)		
WHITE	59.78	2.65	-0.08	0.0382	121.45
	(0.71)	(0.17)	(0.01)		
BLACK	38.51	-2.59	0.08	0.0355	113.66
	(0.71)	(0.17)	(0.01)		
OTHER	1.72	-0.06	0.001	0.0026	8.92
	(0.07)	(0.02)	(0.0006)		
FEMALE	52.76	-0.25	0.008	0.0169	53.53
	(0.10)	(0.02)	(0.0008)		
YOUNG	24.25	0.31	-0.007	0.0141	44.78
	(0.15)	(0.04)	(0.001)		
OLD	15.88	-0.16	0.007	0.0030	10.19
	(0.19)	(0.04)	(0.001)		
HOME	64,017	-2,140.09	41.00	0.0465	150.27
	(663.53)	(161.31)	(5.61)		
RENT	286.02	-11.75	0.23	0.0919	310.33
	(2.50)	(0.61)	(0.02)		

Standard Errors in Parentheses.
Number of Observations: 6,116.

disproportionately exposed to potential toxic risks, assuming that toxic releases represent potential environmental risk to the communites. This chapter tested whether the characteristics of the population in TRI reporting areas were different from Louisiana's general population characteristics. Our analysis showed that income levels (median household income, average household income, and per capita income), on average, were significantly lower in TRI reporting parishes and zip code areas. Furthermore, the percentage of families with incomes below $10,000 was significantly higher and the percentage of families with incomes above $50,000 was significantly lower in TRI reporting areas. Other income related variables such as education and property values were also lower than the state averages.

This chapter tested whether potential exposure to toxics in Louisiana is systematically related to socioeconomic characteristics of the community. The evidence examined indicates that TRI related industrial activity may be income enhancing at the parish level. The correlations between income variables and alternative measures of potential exposure are consistently and significantly positive, indicating that income levels are higher in parishes with greater total discharges, greater per capita discharges, and more TRI facilities. Similar relationships are revealed between potential exposure measures and other income related variables such as property values and education. These relationships, however, are not evident at the zip code level. Our analysis suggests that potential exposure to toxics in zip code areas may be distributed regressively. Per capita discharges are negatively correlated with the percentage of families in the highest income class and positively correlated with the percentage of the families in the lowest income class. A strong negative association is also found between per capita discharges and the median rental value of housing.

The relationships between alternative measures of potential toxic exposure and race are not strong at high levels of spatial aggregation. The percentage of blacks is negatively correlated with parish level exposure data and positively correlated with zip code level, with the correlation coefficients statistically insignificant. However, an interesting trend is observed for the race variable with lower levels of spatial aggregation. While the racial composition of the population in the TRI reporting parishes, the highest aggregation level, is statistically the same as the general population's, the percentage of blacks in TRI reporting zip code areas is slightly higher. Using distance specific information on local communities around the toxic sources, the lowest aggregation level, we found that the percentage of blacks in communities living within a three mile distance to the nearest TRI facility is significantly above the state's average. Generally, as distance from the nearest pollution source increases, the percentage of blacks in the community decreases and the percentage of whites increases, which suggests that blacks, more than whites may be disproportionately exposed to potential toxic risks in Louisiana. We do not use dispersion models of pollutants, so the distance-exposure relation may not be exact.

Overall, our findings indicate that proximity to toxic sources is not independent of a community's social and economic status. Most toxic sources are located in urban and densely populated areas. Relatively more elderly people and more females live in the immediate proximity of toxic sources. As distance from the nearest toxic releasing facility increases, the percentage of older people, ages 62 and above, and the percentage of females in the community decreases. On the other hand, the percentage of young people, ages below 15, increases as distance increases. Finally, property values are relatively higher in the immediate proximity of toxic releasing facilites, with the values declining as distance from toxic sources increases.

Chapter 4

Theoretical Model

I. Introduction

Research indicates that environmental risks are not evenly distributed across the population. "Community Exposure" models suggest that low income and minority groups are disproportionately exposed to poorer environmental quality conditions (Freeman, 1972; Ash and Seneca, 1978; Brajer and Hall, 1992; U.S. General Accounting Office, 1983). The previous chapter also presented evidence of systematic relationships between alternative pollution exposure measures and community charactersitics. These findings raise the question whether there is a persistent set of forces, perhaps resulting from the normal optimizing behavior of individuals, businesses, and government, that may lead to "disproportionate" exposure. Residential and industrial location choices of household and firms may help explain why some neighborhoods bear relatively higher exposure burden than others. However, the environmental control behavior of firms and the response behavior of communities to the environmental stressors may also be critical in determining the distribution of environmental risk.

This chapter develops a public choice theoretic model that captures the relationship between hazard production behavior of a profit maximizing firm and the socioeconomic characteristics of communities surrounding the firm. The model assumes that the firm's location decisions were determined by product and input market conditions as well as transportation costs, regulatory environments and public services available. An attempt is made to model the firm's behavior apart from location decisions. The production process is assumed to generate both a marketable product and negatively valued by-products, pollutants. The firm is assumed to maximize profits by establishing the optimal amounts of output and hazard production.

Communities surrounding the firm are the recipients of the negative externalities. The model assumes that individual households in the community choose consumption to maximize utility subject to budget constraints. Since pollution represents a potential hazard or a source of disutility, consumers may respond by expending "efforts" to compensate for or to reduce the potential hazard. In turn, the behavior of the affected consumers is expected to have an effect on the pollution control behavior of the profit maximizing firm. In anticipation of the community response which could translate into potential cost such as increased regulatory burden, the firm may find it profitable to increase expenditures on pollution control in order to reduce hazard levels and, thereby, reduce the potential governmental or community opposition.

The proposed model provides several important insights which will be applied to the empirical study of the environmental hazards distribution. The model will be used to empirically test whether the environmental control behavior of toxic chemical releasing firms are related to socioeconomic characteristics of surrounding communities. For example, would firms' decisions to reduce environmental risks, through reductions in toxic discharges, be related to a community's racial and economic status?

This chapter is organized as follows: section II presents the consumer/household model; section III presents the firm model; section IV presents the equilibrium model and section V presents the conclusions.

II. Consumer Behavior

Consider the behavior of an individual household who chooses consumption to maximize utility subject to a budget constraint. Living at a location l, d miles from a pollution source, the household, after ex-post realization of potential or actual hazards, adjusts consumption such that some of the budget may be allocated to remedy the situation. The household could choose from several options for remedial actions:

1. Change location (mobility)
2. Insulate the house (adaptation)
3. Organize and demand strong regulations (advocacy)
4. Demand punitive damage awards (litigation)

The response behavior depends on household's constrained utility maximization decisions. Socioeconomic, cultural and psychological constraints determine the household's opportunities and costs of decisions.

The propensity for mobility is a function of personal characteristics as well as opportunities, income, and the transferability of human capital. Economically well endowed individuals have more options for leaving a polluted area to a better environment or have the financial ability to avoid lower ambient environmental quality in their neighborhood by taking vacations, insulating their homes, or by installing pollution reducing devices.

If propensities for mobility are low, for social, economic or cultural reasons, individuals may resort to organizing and demanding a better quality of life. Regulatory initiatives are driven by the public's efforts to enhance quality of life. Communities organize and form opposition groups if the expected payoff is positive. The expected payoff to each member of the group is different, and is a function of individual perception of the imposed risk as well as the cost of effecting change. A perception of the harmful effects of the chemicals they are exposed to is an important determinant of advocacy. It is postulated that the likelihood of active participation in the opposition is directly related to personal efficacy and resource availability.[1] Personal efficacy deals with the individual's perceptions of his or her abilities to affect the social and/or political environment. High efficacy individuals are more likely to become politically involved than low efficacy individuals (Orum, 1974; Smith et al., 1980).

Let r represent the remediation efforts available to the household. In response to the realized hazard h, the household's objective is to maximize the utility function U(y,c) where y represents a composite bundle of all consumption goods with $U_y > 0$, and c

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[1] Mohai, Paul, "Public Concern and Elite Involvement in Environmental-Conservation Issues", *Social Science Quarterly*, Volume 66, Number 4, December 1985, 820-838.

represents the environmental "disamenity" or the impact of net hazard after all remediation efforts with $U_c < 0$. Subscripts denote derivatives. The household chooses y and r to maximize:

$$(4.1) \qquad \max_{y,r} \; U = U(y,c)$$

$$\text{s.t. } I = P_y y + P_r r \text{ , and}$$

$$c = c(h,r)$$

where I is the income level, P_y is the price of composite good y, and P_r is the price of remediation efforts. The environmental disamenity c(h,r) is assumed to be an increasing function of the hazard level, $c_h > 0$, and a decreasing function of the remediation efforts, $c_r < 0$.

Normalizing P_y to 1 without loss of generality, the first order conditions for a household's objective function in (4.1) are

$$(4.2) \qquad \begin{aligned} U_y - \lambda &= 0 \\ U_c c_r - \lambda P_r &= 0 \\ I - y - P_r r &= 0 \end{aligned}$$

where λ is the Langrange multiplier. The second order conditions require that the bordered Hessian determinant be positive, or

$$(4.3) \qquad |H_c| = 2P_r U_{yc} c_r - (U_{cc} c_r^2 + U_c c_{rr}) - U_{yy} P_r^2 > 0.$$

The subscript in $|H_c|$ is included in order to differentiate the consumer model Hessian determinant from the firm model's that will be introduced later in this chapter. Assuming that the second order conditions for utility maximization are satisfied, that is, assuming that preferences are regular strictly quasi concave in y and r, the optimal solutions to the system of equations in (4.2) are given by

$$(4.4)\qquad \begin{aligned} y^{*} &= y(P_r,\ I,\ h) \\ r^{*} &= r(P_r,\ I,\ h) \end{aligned}$$

where y^{*} and r^{*} represent the household's demand for consumption goods and remediation efforts, respectively, at a given location, *l*. The first-order conditions reveal that y and r are chosen such that the marginal rate of substitution equals the price ratio:

$$(4.5)\qquad MRS_{r,y} = \frac{U_{c}c_{r}}{U_y} = \frac{MU_r}{MU_y} = P_r$$

where $U_{c}c_{r}$ and U_y represent the marginal utilities of remediation effort and consumption respectively. Figure 4.1 illustrates consumer equilibrium graphically, with condition (4.5) satisfied at the point of tangency between the indifference curve $U|_h$ and the budget constraint facing the household.

Several questions are of immediate interest to this research. Primary among them is the impact of changes in the level of hazards present in the community on the household demand for remediation efforts. Before exploring this issue, and to facilitate later discussions, comparative statics on exogenous income and price will be performed.

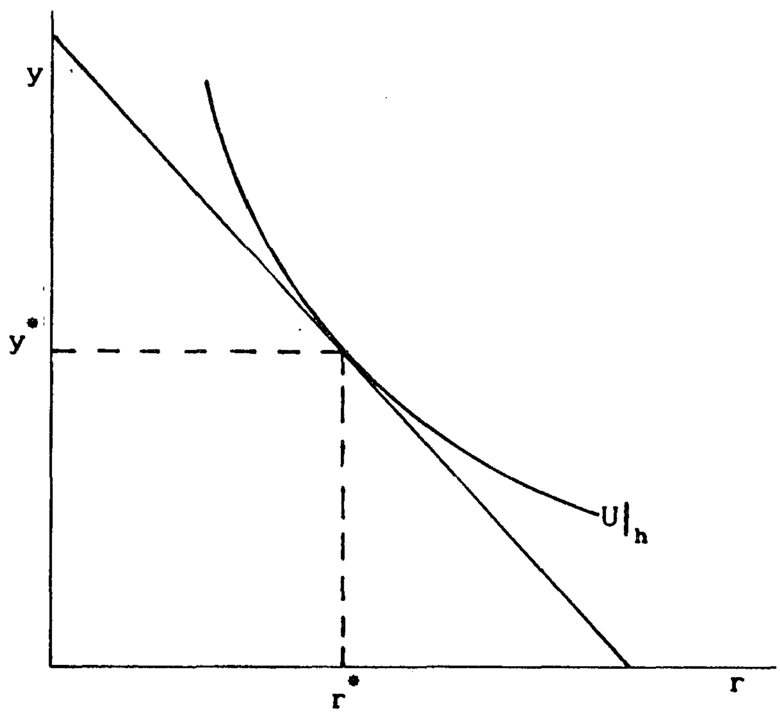

Figure 4.1

Consumption Equilibrium at Location *l* and Hazard Level *h*

a. Income Changes

The impact of a change in household income on the level of remediation effort is found by substituting the optimal solutions from (4.4) into the first order conditions in (4.2), and totally differentiating the system of equations with respect with respect to I. Solving using Cramer's Rule yields a description of the exogenous income effect:

$$(4.6) \qquad \frac{\partial r^*}{\partial I} = \frac{1}{|H_c|}\left[U_{cy}c_r - P_rU_{yy}\right] > 0$$

where $|H_c| > 0$ from the second order conditions; $c_r < 0$; $P_r > 0$; $U_{yy} < 0$ assuming diminishing marginal utility; and $U_{cy} \gtreqless 0$ depending on the relationship between c and y. It is reasonable to assume that r is a normal good; in fact, environmental activism is usually assumed to be a luxury good. As income level increases, the household's willingness and ability to expend efforts for enhanced environmental quality will also increase. If $U_{cy} < 0$ (c and y are substitutes) which is intuitively easy to see, then the expected relationship between r and I will hold and $\partial r^*/\partial I$ will be positive; or if $U_{cy} = 0$ (c and y are independent), then $\partial r^*/\partial I$ will also be positive.

High income individuals pose the greatest cost on the polluting firm. They are the ones with the greatest access to lawyers and politicians and may claim the greatest damage awards.[2] Research

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[2] It is also possible that people view the legal process as a lottery with high gains, and may engage in frivolous suits for high damage awards.

confirms that "environmental activists tend to be drawn disproportionately from the upper-middle class." (Mohai, 1985, p. 821). One explanation for this trend could be that low income groups have always been exposed to relatively poorer physical conditions so they are less aware that they live in polluted environment and breathe polluted air.[3] However, it should be noted that upper middle class involvement in environmental issues may be due to factors other than taste differences. Research has shown that environmental quality deterioration lowers the property values in the affected areas.[4] In fact, a study by Gianessi, Peskin and Wolff (1977) concluded that in terms of per capita damage costs of pollution, high income groups suffered the greatest damages. Hence, a higher degree of concern and increased effort to enhance environmental quality is observed.

b. Remediation Price Changes

To analyze the impact of a change in own-price on the amount of remediation effort undertaken, substitute the optimal solutions in the first order conditions and totally differentiate with respect to P_r, solve using Cramer's rule and get

$$(4.7) \qquad \frac{\partial r^*}{\partial P_r} = - \frac{1}{|H_c|} \left[\lambda + r\left(U_{cy} c_r - P_r U_{yy} \right) \right]$$

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[3] Taylor, Dorceta E., "Blacks and the Environment: Toward an Explanation of the Concern and Action Gap Between Blacks and Whites", *Environment and Behavior*, Volume 21, Number 2, March 1989, 175-205.

[4] Nelson, Jon P., "Airport Noise, Location Rent, and the Market for Residential Amenities", *Journal of Environmental Economics and Management*, 6, 1979, 320-331. Frankel, Marvin, "Aircraft Noise and Residential Property values: Results of a Survey Study", *The Appraisal Journal*, Volume 59, Number 1, January 1991, 96-110.

Insert the income effect from (4.6) for the second term in (4.7),

$$(4.8) \qquad \frac{\partial r^*}{\partial P_r} = - \frac{\lambda}{|H_c|} - r \frac{\partial r^*}{\partial I} < 0$$

The first term in (4.8) is the substitution effect of a price change; $\lambda = U_y > 0$ from the first order condition and therefore the substitution effect is negative as expected. The second term is the income effect of the price change. If remediation effort r is a normal good, or if c and y are independent or substitutes ($U_{cy} \leq 0$), then the income effect is positive and r would have a downward sloping demand curve, that is $\partial r^*/\partial P_r < 0$.

c. Hazard Level Changes

When the level of observed hazard changes, the household is expected to respond. Differentiating (4.2) with respect to h, and solving the system yields

$$(4.9) \qquad \frac{\partial r^*}{\partial h} = \frac{1}{|H_c|} \left[U_{cc} c_r c_h + U_c c_{rh} - P_r U_{yc} c_h\right]$$

To sign $\partial r^*/\partial h$, we need to sign the bracketed term. Totally differentiating $MRS_{r,y}$ (4.5) with respect to h yields the following

$$(4.10) \qquad \frac{dMRS_{r,y}}{dh} = \frac{U_y\left[U_{cc} c_r c_h + U_c c_{rh}\right] - U_c U_{yc} c_r c_h}{U_y^2}$$

Substitute P_r for $MRS_{r,y}$ from (4.5),

$$(4.11) \qquad \frac{dMRS_{r,y}}{dh} = \frac{1}{U_y} \left[U_{cc} c_r c_h + U_c c_{rh} - P_r U_{yc} c_h\right]$$

Substituting (4.9) for the term in the brackets

$$(4.12) \qquad \frac{dMRS_{r,y}}{dh} = \frac{1}{U_y} |H_c| \frac{\partial r^*}{\partial h}$$

Signing (4.12) is therefore equivalant to signing

$$(4.13) \qquad \frac{\partial r^*}{\partial h} = \frac{U_y}{|H_c|} \frac{dMRS_{r,y}}{dh} > 0.$$

$MRS_{r,y}$ represents the amount of good y the household is willing to give up to obtain an additional unit of r, such that it will maintain a constant level of satisfaction. Assuming that greater hazard increases the consumer's relative willingness to tradeoff consumption for remediation, the $MRS_{r,y}$ will also increase and the indifference curve $U|_h$ in Figure 4.2 will rotate and become steeper. From the diagram it is clear that the household will consume more r and less y, the demand for remediation effort is therefore expected to increase with the level of hazard yielding the positive sign in (4.13).

d. Taste Changes

In order to evaluate taste effects on consumer behavior, introduce a shift parameter α which alters household's preferences for environmental quality. Higher values for α signify stronger tastes for environmental amenities or stronger dislike for disamenity c. Differentiating (4.2) with respect to α following the procedures outlined above yields

$$(4.14) \qquad \frac{\partial r^*}{\partial \alpha} = \frac{1}{|H|} \left[U_{cc} c_r c_\alpha + U_c c_{r\alpha} - P_r U_{yc} c_h \right]$$

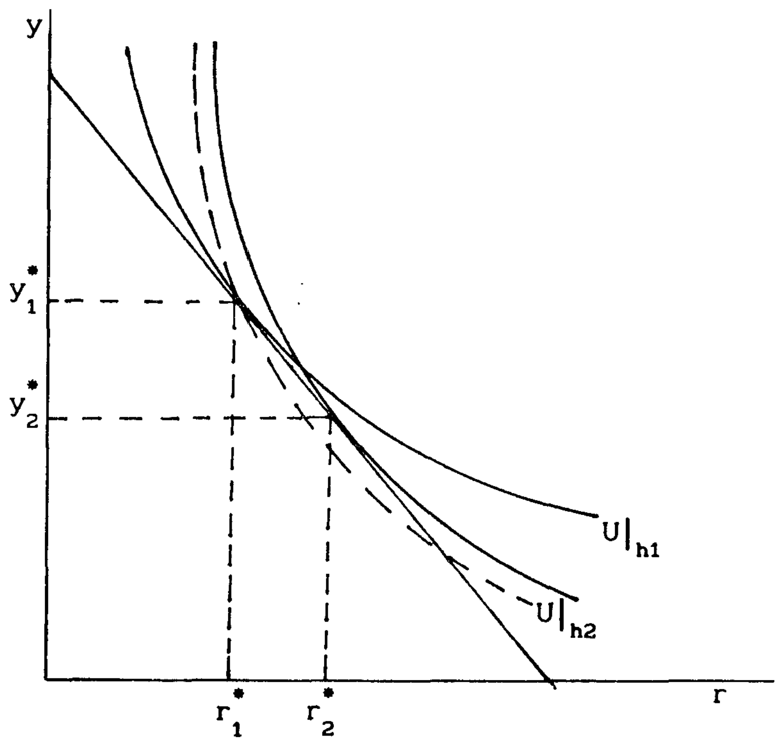

Figure 4.2

Consumption Equilibrium Adjustment to Increased Hazard

Stronger taste for environmental amenities will change $MRS_{r,y}$ just as increased hazard does. Totally differentiating $MRS_{r,y}$ with respect to α, and making the necessary substitutions yields

$$\text{(4.15)} \qquad \frac{dMRS_{r,y}}{d\alpha} = \frac{1}{U_y}\left[U_{cc}c_r c_\alpha + U_c c_{r\alpha} - P_r U_{yc} c_h\right] > 0$$

The sign of (4.15) is expected to be positive assuming that stronger taste for environmental amenities increases the consumer's relative willingness to tradeoff consumption for remediation. The consumer will sacrifice more y for an extra unit of remediation as α increases.

III. Firm Behavior

Consider a profit maximizing competitive firm producing a marketable product x. A negativly valued by-product of x is hazard h. The production technology can be described implicitly by $J(x,h,z,a) = 0$, where z is the production input and a is the hazard abatement input. Assume the production technology is separable into the product production function $x(a,z)$ and the hazard production function $h(a,z)$. Since the marketable product x and hazard h are joint products of the production input z, then it is plausible to expect that as the firm employs more of z, the production of x and h will increase simultaneously; hence, $x_z > 0$ and $h_z > 0$. Holding abatement effort constant, hazard increases as output increases. Since h is a nondesirable output or a negative by-product, abatement input is defined as one that reduces the hazard output, ($h_a < 0$). On the other hand, no a priori restrictions are placed on the derivative of product output with respect to the abatement input, ($x_a \gtreqless 0$). It is possible for the abatement input to augment or hinder the production of marketable product x. For instance, if the hazard produced is waste heat, the abatement input is a heat-exchanger and the production input is fuel oil, then as a increases more waste heat is recaptured for use in the production of x. Hence, the marginal product of a in the production of x is positive ($x_a > 0$). Alternatively, if h is smoke, a is an electrostatic precipitator and z is electricity, then a requires electricity to remove the particulates from stack emissions. Hence, input a diverts electricity away from production of x and the marginal product of a in the production of x is negative ($x_a < 0$).[5]

The firm is required by law to contain the level of hazard it produces, within a given time period, to a specific amount. Assuming that pollution standards are perfectly enforceable, if the level of hazard produced by the firm exceeds the maximum allowable limit, then penalties and/or taxes will be imposed. Let C(h,r) represent the total non-compliance cost of hazard production. Hazard produced is, of course, equivalent to hazard not abated. Generally it is expected that any fine or penalty will be a positive function of the size of violation such as strict liability for damages, and the total cost of non-compliance will be increasing at an increasing rate as the hazard level increases. Hence, It is assumed that C(h,r) is an increasing convex function of h; that is, $\partial C/\partial h \equiv C_h > 0$ and $\partial^2 C/\partial h^2 \equiv C_{hh} > 0$.

Aside from the direct cost of non-compliance, the firm confronts an indirect cost associated with hazard production. The firm

[5] The example and the basic framework presented are from Martin (1986).

acknowledges the possibility that the household's remediation efforts could translate into public or regulatory opposition, the cost of which could take the form of additional regulatory burden such as higher penalties, stringent enforcement actions, and/or tighter standards on hazard production. Households' remediation efforts could take the form of law suits, requiring the firm to incur defense costs or punitive damage awards. Thus, the risk neutral profit maximizing firm is assumed to account for possible responses by nearby residents. C(h,r) is assumed to be an increasing convex function of r ($C_r > 0$ and $C_{rr} \geq 0$). Furthermore, C_{hr} is assumed positive. This is consistent with the discussion above; since an increase in households' remediation efforts could result in increased regulatory burden, it is expected that marginal cost to the firm of hazard non-abatement will increase with r.

In light of the discussion above, the firm's decision on the optimal product and hazard output involves maximization of the profit function with respect to z and a. The risk neutral firm's objective function is given by

$$(4.16) \qquad \max_{z,a} \pi = Px - P_z z - P_a a - C(h,r)$$

$$\text{s.t.} \qquad x = x(a,z)$$

$$h = h(a,z)$$

where P is the market price of product x assumed to be exogenous to the firm, P_z is the price of the production input z, P_a is the price of the abatement input a, C(h,r) is the total non-compliance cost of hazard production.

The maximization requires that the following first order conditions be satisfied

(4.17)
$$\pi_z = Px_z - P_z - C_h h_z = 0$$
$$\pi_a = Px_a - P_a - C_h h_a = 0$$

The second order conditions for profit maximization are

(4.18)
$$\pi_{zz} = Px_{zz} - C_{hh} h_z^2 - C_h h_{zz} < 0,$$
$$\pi_{aa} = Px_{aa} - C_{hh} h_a^2 - C_h h_{aa} < 0,$$
$$\pi_{za} = Px_{za} - C_{hh} h_z h_a - C_h h_{za} \gtreqless 0, \text{ and}$$
$$|H| = \pi_{zz}\pi_{aa} - \pi_{za}^2 > 0$$

Assuming that the second-order conditions are satisfied, the optimal solutions to (4.16) are $z^* = z(P,P_z,P_a,r)$ and $a^* = a(P,P_z,P_a,r)$, where z^* and a^* are the production and abatement input demand functions, respectively. The first-order conditions reveal that the firm chooses z and a such that the marginal rate of technical substitution between abatement input and production input equals the ratio of marginal input costs:

(4.19)
$$\frac{x_a}{x_z} = \frac{P_a + C_h h_a}{P_z + C_h h_z}$$

The marginal cost of abatement input a in the production of x is equal to its price, P_a, plus the reduction in marginal non-compliance cost realized by abatement, $-C_h h_a > 0$. The marginal cost of the production input z in the production of x is equal to its price, P_z, plus the marginal non-compliance cost incurreded by increased hazard output, $C_h h_z > 0$.

Substituting z^* and a^* into the product production function and hazard production function, we get the optimal production levels

$$(4.20) \qquad x^* = x(z^*, a^*)$$

$$(4.21) \qquad h^* = h(z^*, a^*).$$

System of equations (4.20) and (4.21) can be used to derive comparative statics results describing firm behavior. Although several questions may be of interest, primary among them is the effect of households' remediation effort on the optimal hazard produced by the firm.[6] The impact of changes in households' remediation efforts on the firm's hazard production or hazard control behavior is obtained by totally differentiating (4.21) with respect to r which yields

$$(4.22) \qquad \frac{dh^*}{dr} = h_z \frac{\partial z^*}{\partial r} + h_a \frac{\partial a^*}{\partial r}$$

where $h_z > 0$ and $h_a < 0$ by assumption. The effect of changes in household remediation efforts on optimal input demands, $\partial z^*/\partial r$ and $\partial a^*/\partial r$, are obtained by substituting z^* and a^* into the first order

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[6] Comparative statics on all exogenous variables is performed in Appendix C in order to facilitate later discussions.

conditions (4.17), totally differentiating the system of equations with respect to r, and solving by implementation of Cramer's rule to get

$$\frac{\partial z^*}{\partial r} = \frac{1}{|H|} C_{hr} \left[h_z \pi_{aa} - h_a \pi_{az} \right] \gtreqless 0 \tag{4.23}$$

$$\frac{\partial a^*}{\partial r} = \frac{1}{|H|} C_{hr} \left[h_a \pi_{zz} - h_z \pi_{az} \right] \gtreqless 0 \tag{4.24}$$

Substitute (4.23) and (4.24) into (4.22) to obtain

$$\frac{dh^*}{dr} = \frac{1}{|H|} C_{hr} \left[h_z^2 \pi_{aa} - 2 h_z h_a \pi_{za} + h_a^2 \pi_{zz} \right] < 0 \tag{4.25}$$

where $|H|$ is the determinant of the profit Hessian, $|H| > 0$, and $C_{hr} > 0$ by assumption. The second order conditions imply that the collective sign of the bracketed terms is negative (since it can be shown that the bracketed term is negative definite quadratic form).[7] Hence, the optimal hazard level will fall as household remediation effort increases in a locality. The firm may respond by increasing expenditures on pollution control or reducing production scale to reduce the hazard level in the community and, thereby, reduce community opposition.

IV. Equilibrium Remediation Efforts and Hazard Level

In equilibrium both households and firms are maximizing utility and profits, respectively. The observed outcome will be a Cournot-Nash equilibrium if the household maximizes utility based on the assumption that the hazard level produced by the firm is invariant with respect to

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[7] This is demonstrated in Appendix C.

its own remediation efforts, and the firm maximizes profits based on the premise that the household's decision to expend remediation effort is invariant with its own hazard production decision. A Stackelberg outcome will be observed if at least one party (possibly both) will behave assuming that his or her behavior will alter the behavior of the other party. This section presents an analysis of the possible outcomes using both the Cournot and the Stackelberg formulations and compares the results.

a. Cournot-Nash Equilibrium

Cournot-Nash equilibrium is observed when each party maximizes its objective function under the assumption that the response of the other party is fixed. An alternative "Nash" view is that each party attempts to find the best response to the other agent's action. Mathematically, the equilibrium values of hazard $\hat{h}$ and remediation effort $\hat{r}$ are the solutions to the following system of equations

(4.26) $$r - r^{*}(h, I, P_r) = 0$$

(4.27) $$h - h^{*}(r, P, P_z, P_a) = 0$$

Equation (4.26), the household's reaction function, gives a relationship between r and h with the property that for any specified value of h, the corresponding value of r maximizes household's utility. The properties of (4.26) have been established in section II. Equation (4.27), the firm's reaction function, gives a relationship between r and h such that for any value of r, the corresponding value of h maximizes the firm's profit. The properties of (4.27) have been established in the preceeding section of this chapter. The equilibrium solution is a pair of values for r and h which satisfy both equations simultaneously.

The Jacobian of the system is found by differentiating each equation with respect to the endogenous variables r and h.

(4.28) $$|J| = \begin{bmatrix} 1 & -\frac{\partial r^*}{\partial h} \\ -\frac{dh^*}{dr} & 1 \end{bmatrix} = 1 - \left(\frac{\partial r^*}{\partial h}\right)\left(\frac{dh^*}{dr}\right) > 0$$

The sign of (4.28) is clearly positive since $\partial r^*/\partial h > 0$ from (4.13) and $dh^*/dr < 0$ from (4.25). Since the Jacobian does not vanish, an equilibrium solution exists and these solutions are $\hat{r} = r(P_r, I, P, P_z, P_a)$ and $\hat{h} = h(P_r, I, P, P_z, P_a)$. Figure 4.3 presents the Nash equilibrium graphically.

Equilibrium values $\hat{r}$ and $\hat{h}$ change when the parameters of the model change. Substituting $\hat{r}$ and $\hat{h}$ in the system of equations (4.26) and (4.27), differentiating with respect to the parameter of interest, and solving using Cramer's Rule yields the comparative statics results summarized below.

i. Household Income Changes

The impact of a change in household income is given by

(4.29) $$\frac{\partial \hat{r}}{\partial I} = |J|^{-1}\frac{\partial r^*}{\partial I} > 0$$

(4.30) $$\frac{\partial \hat{h}}{\partial I} = |J|^{-1}\left(\frac{\partial r^*}{\partial I}\right)\left(\frac{dh^*}{dr}\right) < 0$$

In the consumer model above, it was shown that when household income increases, the demand for remediation efforts increases, that is $\partial r^*/\partial I$

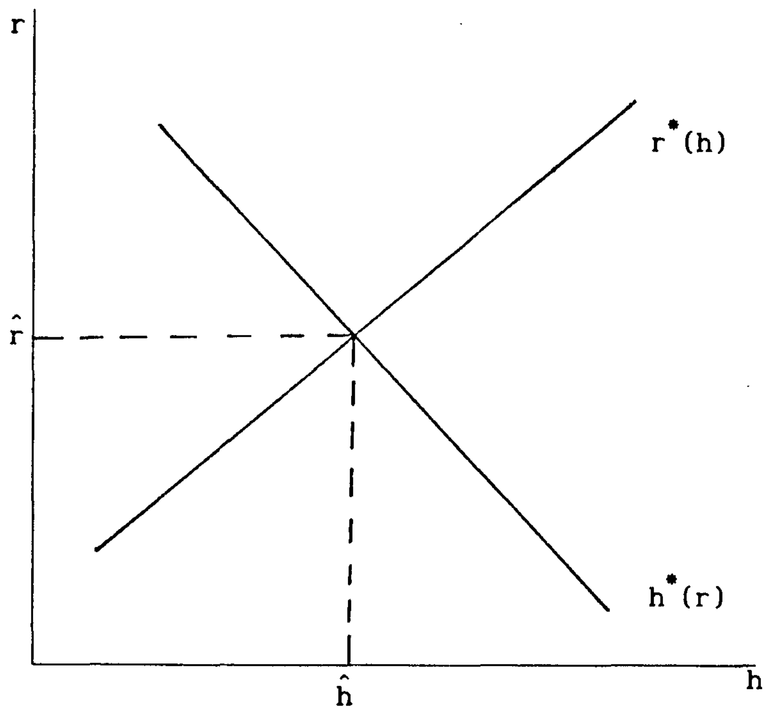

Figure 4.3

Nash Equilibrium

> 0 from (4.6). Hence, when income level increases, the household's reaction function $r^*(h)$ in Figure 4.3 shifts upward and as a result $\hat{r}$ increases and $\hat{h}$ decreases.

ii. Remediation Price Changes

The impacts of a change in the price of remediation effort, P_r, on equilibrium values of r and h are given by

$$(4.31) \qquad \frac{\partial \hat{r}}{\partial P_r} = |J|^{-1} \frac{\partial r^*}{\partial P_r} < 0$$

$$(4.32) \qquad \frac{\partial \hat{h}}{\partial P_r} = |J|^{-1} \left(\frac{\partial r^*}{\partial P_r} \right) \left(\frac{dh^*}{dr} \right) > 0$$

The signs of the above equations are established using (4.8). When the price of remediation effort increases, the household's reaction function $r^*(h)$ in Figure 4.3 shifts downward and as a result the optimal level of $\hat{r}$ decreases and $\hat{h}$ increases.

iii. Taste Changes

The impact of a change in household preferences for environmental quality, α, on equilibrium r and h are given by

$$(4.33) \qquad \frac{\partial \hat{r}}{\partial \alpha} = |J|^{-1} \frac{\partial r^*}{\partial \alpha} > 0$$

$$(4.34) \qquad \frac{\partial \hat{h}}{\partial \alpha} = |J|^{-1} \left(\frac{\partial r^*}{\partial \alpha} \right) \left(\frac{dh^*}{dr} \right) < 0$$

Stronger taste for environmental amenities indicates an upward shift in the household reaction function using (4.15). The result, of course, is a decreased hazard production and increased remediation.

iv. Output Price Changes

Following the procedure outlined above, the impact of product price changes on optimal remediation effort and hazard level are given by

(4.35) $$\frac{\partial \hat{r}}{\partial P} = |J|^{-1}\left(\frac{dh^*}{dP}\right)\left(\frac{\partial r^*}{\partial h}\right)$$

(4.36) $$\frac{\partial \hat{h}}{\partial P} = |J|^{-1}\frac{dh^*}{dP}$$

where $$\frac{dh^*}{dP} = \frac{1}{|H|}\left[2PC_h\right]^{-1}\left\{\left[\pi_{aa}P_z^2 + \pi_{zz}P_a^2 - 2\pi_{za}P_zP_a\right]\right.$$

$$- P^2\left[\pi_{aa}x_z^2 + \pi_{zz}x_a^2 - 2\pi_{za}x_zx_a\right]$$

$$\left. - C_h^2\left[\pi_{aa}h_z^2 + \pi_{zz}h_a^2 - 2\pi_{za}h_zh_a\right]\right\} \gtreqless 0$$

(see Appendix C (C.6-C.11) for derivation). The sign of dh^*/dP depends on the collective sign of the terms in brackets, {.}. The second order conditions imply that the first set of terms in brackets is negative, the second set is positive, and the third set is positive. Although the above expression has an indeterminate sign, it is nevertheless expected to be positive. When the price of marketable product x increases more x will be produced (see Appendix C (C.5) for details). Since x and h are joint products, it is expected that h will also increase as the price of the output increases, holding everything else constant. Consequently, a sufficient condition for $dh^*/dP > 0$ is that the absolute value of the first term must be less than the absolute value of the sum of the second and third set of terms. The firm's reaction function $h^*(r)$ is expected to shift rightward when the price of marketable product x increases. Hence, an increase in both $\hat{r}$ and $\hat{h}$.

v. Input Prices Change

The effect of a changes in price of abatement input a and production input z on r and h are given by

$$(4.37) \qquad \frac{\partial \hat{r}}{\partial P_a} = |J|^{-1} \frac{dh^*}{dP_a} r_h$$

$$(4.38) \qquad \frac{\partial \hat{h}}{\partial P_a} = |J|^{-1} \frac{dh^*}{dP_a}$$

$$(4.39) \qquad \frac{\partial \hat{r}}{\partial P_z} = |J|^{-1} \frac{dh^*}{dP_z} r_h$$

$$(4.40) \qquad \frac{\partial \hat{h}}{\partial P_z} = |J|^{-1} \frac{dh^*}{dP_z}$$

where
$$\frac{dh^*}{dP_z} = \frac{1}{|H|} \left[h_z \pi_{aa} - h_a \pi_{za} \right] \gtreqless 0, \text{ and}$$

$$\frac{dh^*}{dP_a} = \frac{1}{|H|} \left[h_a \pi_{zz} - h_z \pi_{za} \right] \gtreqless 0$$

(See Appendix C for derivation). The signs of (4.37)-(4.40) clearly depend on π_{za} since π_{zz} and π_{aa} are negative by the second order conditions for profit maximization, and $h_z > 0$ and $h_a < 0$ by assumption. If $\pi_{za} \le 0$, that is z and a are substitute or independent inputs, then the expected signs of (4.37) and (4.38) are positive and those of (4.39) and (4.40) are negative. That is, when price of input a increases, the firm's reaction function $h^*(r)$ in Figure 4.3 shifts to the right and as a result $\hat{r}$ and $\hat{h}$ both increase, and when price of input z increases, the firm's reaction function shifts to the left and both $\hat{r}$ and $\hat{h}$ decrease.

The comparative statics results clearly indicate that both households and firms respond to each other's behavior. For instance, a change in household income triggers a change in both remediation effort and hazard reduction effort. However, it may seem inappropriate to assume Cournot type solution for this particular environmental problem since "environmental activism" implicitly implies that the household feels that it can make a difference and the firm recognizes that its environmental control behavior will impact the community and cause reactions. If equilibrium is expected to be reached through a sequence of finite adjustments, the hazard level produced by the firm will induce the community to adjust the level of remediation effort, which in turn (depending on the mode of remediation effort: mobility, adaptation, advocacy, or litigation) will prompt the firm to adjust control behavior, and so on. It is rather unlikely that each party will assume that its decisions do not effect the other party's behavior if each of the adjustments is immediately followed by a reaction on the part of the other party.[8]

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[8] Daughety (1985) considers Cournot by endogenizing the conjectural variations and letting the model determine them instead of assuming the ad-hoc behavior. setting up an infinite regress problem, he presents "a purely static model that generates the Cournot equilibrium without reference to conjectures or quasi dynamics."(p. 368). He proves that Cournot equilibrium is consistent in the 'as if' sense.

Nash equilibrium might not be observed if at least one party (possibly both) will behave assuming that his or her behavior will alter the behavior of the other party. If the household assumes the role of the leader, then it will maximize utility taking the firm's reaction function into consideration. If the firm, on the other hand, assumes the role of the leader, then it will maximize its profits subject to the household's reaction function. Basically, a Stackelberg equilibrium is observed when one of the parties chooses to play Cournot while the other plays consistent conjectural variations. The following section presents one possible Stackelberg equilibrium.

b. Stackelberg Equilibrium

A von Stackelberg equilibrium is observed when either the firm or the household behaves assuming that its behavior will alter the behavior of the other and builds the conjectural variation into the marginal conditions. In the following analysis, the firm is assumed to behave as the leader and the household as the follower. The household maximizes utility by adjusting r given the hazard level produced by the firm. In this model, the household adapts Cournot behavior and follows its own reaction function (4.26). The firm, on the other hand, does not follow its own reaction function (4.27), instead maximizing profit given the household's marginal adjustments implied by the reaction function (4.26). The firm's profit function is given by

(4.41) $$\max_{z,a} \pi' = Px - P_z z - P_a a - C(h,r)$$

$$\text{s.t.} \quad x = x(a,z)$$

$$h = h(a,z)$$

$$r = r^*(h,I,P_r)$$

The notations are as defined previously with the exception that the firm's profit function now includes the household's response to the realized level of hazard. The firm anticipates the reaction of household and, therefore, incorporates this reaction in the profit maximizing decision. The first order conditions for profit maximization are:

$$\pi'_z = Px_z - P_z - \left(C_h + C_r\frac{\partial r^*}{\partial h}\right)h_z = 0$$

(4.42)

$$\pi'_a = Px_a - P_a - \left(C_h + C_r\frac{\partial r^*}{\partial h}\right)h_a = 0$$

Assuming that the second-order conditions are satisfied, the optimal solutions to (4.42) are $\tilde{z} = z(P,P_z,P_a,r^*(.))$ and $\tilde{a} = a(P,P_z,P_a,r^*(.))$. Substituting $\tilde{z}$ and $\tilde{a}$ into the product production function and hazard production function, we get the optimal production levels

(4.43) $$\tilde{x} = x(\tilde{z},\tilde{a})$$

(4.44) $$\tilde{h} = h(\tilde{z},\tilde{a}).$$

The optimal hazard production level in Stackelberg equilibrium is expected to be lower than in Cournot equilibrium. The first-order conditions reveal that the firm chooses z and a such that the marginal rate of technical substitution equals the ratio of marginal input costs:

(45) $$\frac{x_a}{x_z} = \frac{P_a + \left[C_h + C_r r^*_h\right]h_a}{P_z + \left[C_h + C_r r^*_h\right]h_z}$$

Note that $r^*_h \equiv \partial r^*/\partial h$. The above relationship can be directly compared with (4.19). Since the firm implicitly incorporates the possible household reaction to the level of hazard it produces, the marginal cost of abatement input a in the production of x (the numerator in (4.45)) is lower than its counterpart in (4.19) by the amount of $C_r r^*_h h_a$. The marginal cost of the production input z in the production of x (the denominator), on the other hand, is higher by $C_r r^*_h h_z$. The marginal rate of technical substitution between a and z is lower here (4.45) than in the previous case (4.19). This indicates that the production process will be relatively more abatement intensive than would be the case if the firm did not consider household responses. The amount of input z the firm hires will depend on x_a.

The firm in Stackelberg model will employ relatively more of the abatement input a than in Cournot model because, for a given z, the marginal benefit of hazard abatement or the marginal cost savings from hazard abatement is higher under Stackelberg formulation. Figure 4.4 illustrates the difference between the two. The marginal cost of abatement input is given by MC. Under both Cournot and Stackelberg models, MC is given by $Px_a - P_a$. MB_C is the marginal benefit of hazard abatement under Cournot. MB_C is equivalent to $C_h h_a$. MB_S is the marginal benefit of hazard abatement under Stackelberg. MB_S is equivalent to $C_h h_a + C_r \frac{\partial r^*}{\partial h} h_a$. The firm employs $\hat{a}$ level of abatement input in Cournot equilibrium, and $\tilde{a} > \hat{a}$ in Stackelberg equilibrium. As a result, the hazard production by the firm is lower in Stackelberg equilibrium, given $h_a < 0$.

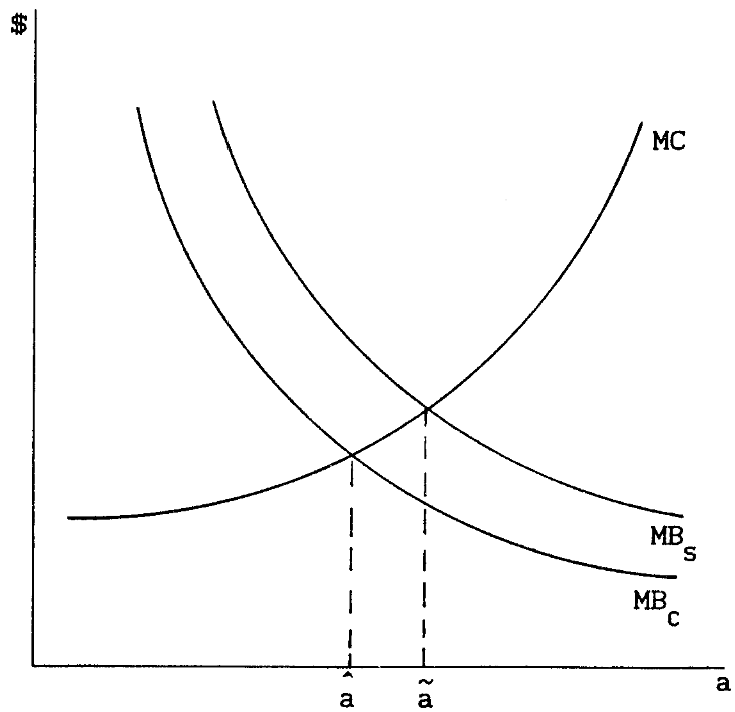

Figure 4.4

Abatement Input Employment in Cournot and Stackelberg Equilibriums

Equilibrium hazard, $\tilde{h}$, changes when the parameters of the model change. Totally differentiating (4.44) with respect to the parameter of interest yields the comparative statics results summarized below.

i. Household Income Changes

The impact of a change in households income on the firm's hazard production or hazard control behavior is given by

$$(4.46) \qquad \frac{d\tilde{h}}{dI} = h_z \frac{\partial \tilde{z}}{\partial I} + h_a \frac{\partial \tilde{a}}{\partial I}$$

$\partial\tilde{z}/\partial I$ and $\partial\tilde{a}/\partial I$, are obtained by substituting $\tilde{z}$ and $\tilde{a}$ in the first order conditions (4.42), totally differentiating the system of equations with respect to I, and solving by implementation of Cramer's rule to get

$$(4.47) \qquad \frac{\partial \tilde{z}}{\partial I} = \frac{1}{|H'|} \left[\left(C_{hr} + C_{rr} r^*_h\right) r^*_I + C_r r^*_{hI}\right]\left[h_z \pi'_{aa} - h_a \pi'_{az}\right]$$

$$(4.48) \qquad \frac{\partial \tilde{a}}{\partial r} = \frac{1}{|H'|} \left[\left(C_{hr} + C_{rr} r^*_h\right) r^*_I + C_r r^*_{hI}\right]\left[h_a \pi'_{zz} - h_z \pi'_{az}\right]$$

Substitute (4.47) and (4.48) into (4.46) and get

$$(4.49) \quad \frac{d\tilde{h}}{dI} = \frac{1}{|H'|} \left[\left(C_{hr} + C_{rr} r^*_h\right) r^*_I + C_r r^*_{hI}\right]\left[h^2_z \pi'_{aa} - 2h_z h_a \pi'_{za} + h^2_a \pi'_{zz}\right] < 0$$

where $|H'| > 0$ is the determinant of the profit Hessian. The first bracketed terms in (4.49) is positive since $C_{hr} > 0$ and $C_{rr} > 0$ by assumption, $r^*_h > 0$ from (4.13), $r^*_I > 0$ from (4.6), and r^*_{hI} is expected to be positive. The collective sign of the second bracketed terms is negative as implied by the second order conditions. Thus as household income increases the firm recognizes the possibility of increased threat of opposition by the community and responds by reducing the hazard level. The firm may respond by increasing expenditures on pollution control or reducing production scale to reduce the level of hazard in the community and, thereby, reduce community opposition. It is possible that the firm will reduce hazard production even below the maximum allowable limits if the threat of opposition is sufficiently high. In a dynamic, intertemporal context the firm may see exceeding standards now as a means to placate the community and avoid stricter standards in the future.

ii. Remediation Price Changes

Following the above outlined procedures, the impact of a change in price of remediation is given by

$$(4.50)\quad \frac{d\tilde{h}}{dP_r} = \frac{1}{|H'|}\left[\left(C_{hr} + C_{rr} r^*_h\right) r^*_{P_r} + C_r r^*_{hP_r}\right]\left[h_z^2 \pi'_{aa} - 2h_z h_a \pi'_{za} + h_a^2 \pi'_{zz}\right] > 0$$

The sign of (4.50) is expected to be positive since $r^*_{Pr} \equiv \partial r^*/\partial P_r < 0$ from (4.8) and r^*_{hPr} is expected to be negative. This is of course intuitively correct, when price of remediation effort increases, r decreases and the threat to the firm goes down. The firm responds by increasing hazard production.

V. Conclusions

Several important insights are obtained from the above analysis. It is apparent that the usual optimizing behavior of firms and households does explain to a certain extent the distribution of environmental risk across communities. The polluting firm's hazard production behavior is modelled as being responsive to the political influence of the local populations. Ability and willingness of households to pursue remediation to alleviate or compensate for the environmental disamenity is shown to have a direct effect on the environmental control behavior of firms. The firm acknowledges the possibility that the household's remediation efforts could translate into public or regulatory opposition, the cost of which could take the form of additional regulatory burden such as higher penalties.

The income effect is specifically clear. Assuming that environmental activism is a normal good, as income level increases, the household's ability to expend efforts for enhanced environmental quality also increases. Which in turn, prompts the risk neutral profit maximizing firm to increase expenditures on pollution control and avoid any possible regulatory burden. The household's reaction to a change in cost of remediation, the price effect, is also clearly illustrated. The demand for remediation effort is inversely related to its own-price.

Willingness of households to pursue remediation is a function of the actual hazard level they are exposed to. As the level of observed hazard increases, the demand for remediation also increases. The individual firm's control behavior may also be a function of the total number of other polluting firms in the area. Higher releases of toxics in the community either from the firm in question or from other firms in the proximity may trigger opposition. It is expected that as the number of firms increase in the community, the willingness of people to voice opposition will increase, and to avoid regulatory burdens individual firms may increase abatement efforts.

Stronger tastes for environmental amenities also increases the demand for remediation. How do we measure tastes for environmental amenities? Membership in environmental advocacy groups is often used as an indicator of involvement in environmental issues. Research indicates that such groups draw their support mostly from the upper-middle class (Mohai, 1985). Differences in black/white involvement in environmental issues have also been observed over time. Research indicates the existence of both a "concern gap" and an "action gap" between blacks and whites (Taylor, 1989). The concern gap is explained partially by socioeconomic status and hierarchy of needs. Environmental issues are assumed to be luxury items that can be attended to only after more pressing basic needs are satisfied. The action gap is explained by political inefficacy, failure to recognize advocacy channels, and low level of political participation.

If the firm's pollution control behavior is a function of the political activism of the communities, then hazard production levels would be greater in neighborhoods with predominantly low income and black populations.

Chapter 5

Evidence on Recent Toxic Level Changes

I. Introduction

Since 1987 there has been a significant reduction in toxic releases to the environment. Between 1987 and 1989, reported releases and transfers of all toxic chemicals in the United States decreased by about 18 percent (EPA, 1991). In the same period, Louisiana reported an overall reduction of 54.8 percent (Chapter 3, Table 3.1). If toxic releases represent potential environmental risk to communities, then reductions in those releases represent a potential improvement in risks. This chapter attempts to explain the observed reduction in toxic discharges and concomitant toxic risks between 1987 and 1989 in the State of Louisiana.

The theoretical model presented in the previous chapter indicates that community characteristics and activism may impact the behavior of the polluting firms; releasing potentially harmful chemicals triggers community opposition and, therefore, a discharger response to this opposition. Firms have a profit motive to reduce pollution when community opposition increases regulatory and compliance cost. The purpose of this chapter is to provide a direct test of the hypothesis that environmental control behavior of toxic releasing firms are related to the socioeconomic characteristics of surrounding communities. The central question is whether or not changes in potential exposure to toxic risks are nondiscriminatory, that is, whether toxic discharge reductions are statistically related to the socioeconomic makeup of affected communities.

This chapter is organized as follows: section II specifies the empirical model; section III presents the estimation results, and section IV presents the conclusions.

II. Empirical Models

a. Model Specifications

Maintaining the hypothesis that community characteristics and activism does impact the behavior of polluting firms, we propose to estimate two types of discharge reduction functions: collective, and individual. The collective discharge reduction function refers to aggregated reductions in toxic releases by all firms within a defined geographic area. The individual discharge reduction function refers to reductions in toxic releases by individual firms at each given location.

By specifying these two types of discharge reduction functions, we hope to sort out how community characteristics affect individual and collective firm behavior. The theory presented in the previous chapter illustrates why community characteristics are a factor in explaining the behavior of a firm or a collection of firms that release toxic chemicals. Given the theoretical consideration, the following empirical model is specified.

(5.1) $$\Delta RELEASE = \alpha_1 + \alpha_2 RELEASE_{87} + \alpha_3 FIRMS + \sum_i \phi_i Z_i + \varepsilon$$

where the dependent variable, $\Delta RELEASE = RELEASE_{89} - RELEASE_{87}$, is the simple arithmetic difference between 1989 toxic releases and 1987 toxic releases. $RELEASE_{87}$ is included in the model as an explanatory variable to control for initial level of releases. We expect its coefficient to be negative, due to lower marginal cost of control for facilities with high initial releases or due to high control benefits in the form of lower penalties. Vector Z includes the socioeconomic characteristics of the communities exposed to the potential environmental risks. Z is included in the model to determine the effects of neighborhood factors in explaining discharge reductions; and ε is the normally distributed error term. FIRMS is defined as the total number of toxic chemical releasing firms in the locality and is included in the model to control for the level of industrial activity in the area. It is reasonable to expect that an area heavily populated by toxic releasing facilities will be an obvious target to any regulatory initiative. Therefore, we might expect the coefficient of FIRMS to be negative; i.e., discharges are expected to be reduced by a greater magnitude when the total number of toxic releasing facilities increases in an area, due to the 'hot spot' phenomenon. However, it is also possible that firms believe they can avoid regulatory burdens by simply keeping a low profile as the number of firms increases. In this case, discharges will be reduced by a smaller magnitude, and the coefficient of FIRMS will be positive.

i. Parish and Zip Code Level Analysis

The dependent variable in the collective discharge reduction function is the difference in toxic releases aggregated over all facilities in a given geographical area. Parishes and Zip Code areas are used to represent alternative geographic aggregation levels. At the parish level, ΔRELEASE is calculated by taking the change in total reported releases in a given parish. Only those parishes that report releases in both years, 49 out of 55 reporting parishes, are considered in the parish level empirical estimation. The variable FIRMS represents the total number of toxic releasing facilities located in each parish; and vector Z represents parish population characteristics. Vector Z includes population density (DENSITY), percentage of the population that is black (BLACK), median family income (INCOME), median home value (HOME), percentage of population that is a college graduate (COLLEGE), and the ratio of registered to eligible voters in the parish (REGVOTE).

At the zip code level, the dependent variable is calculated by aggregating discharges of all facilities that reported releases in both years, 112 out of 153 reporting zip code areas. FIRMS represents the total number of toxic releasing facilities in each zip code area. Vector Z represents zip code area population characteristics. It includes all variables used in parish level analysis with the exception of the ratio of registered to eligible voters (REGVOTE) since zip code areas do not represent individually identifiable political jurisdictions. Furthermore, population (POP) is substituted for DENSITY because zip code areas do not have easily defined area measurements.

ii. Firm Level Analysis

The dependent variable in the individual discharge reduction function is the difference in toxic releases for individual facilities that reported releases in both 1987 and 1989, 157 out of 308 reporting facilities. Vector Z represents the socioeconomic variable describing the characteristics of communties based on their proximity to these individual facilities. Vector Z in the individual discharge reduction model is constructed from data at the block group level. Block group level data have one limiting factor; they do not provide information about income levels in the community. The variables included in Z are population density (DENSITY), percentage blacks (BLACK), median home value (HOME), percentage females (FEMALE), and percentage of population 62 years old and above (OLD).

It is reasonable to expect that communities living closer to toxic releasing facilities are the ones most affected by an adverse environmental condition. They are the ones that have the most to gain from environmental improvement, although, perhaps, the most to lose in terms of possible negative emloyment impacts. In order to obtain the characteristics of proximate communites and capture possible neighborhood factors in explaining discharge reductions by individual firms, circles of increasing radii are drawn around each facility and the characteristics of the communities that live within the circle are aggregated and used as explanatory variables. The smallest circle has a radius of one mile; the size of the circle is increased by increments of one mile, and the largest circle has a radius of five miles. Communities living at a distance of zero to two miles from a polluting firm are likely to be most vulnerable to the toxic emissions, and are likely to be most relevant to the polluting firm's pollution control decisions. Hence we expect a greater response by the firms to nearby communities than to more distant communities. As the size of the circle increases, the level of community aggregation increases and we expect that aggregated community characteristics would have less impacts on firm behavior. The largest circle considered has a radius of five miles, representing a fairly large geographic area.

In order to capture incremental effects of neighborhood factors on the firm's pollution control decisions, we also estimate a modified model in which communities are classified into two groups based on their distance from the pollution source. The circle with the five mile radius delineated for each facility is transformed into a circle with two rings. Ring 1 represents the immediately impacted communities living within a distance of two miles from the pollution source; and Ring 2 represents the distant communities living within a distance of at least two and at most five miles from the source; The modified model is:

$$(5.2) \qquad \Delta RELEASE = \alpha_1 + \alpha_2 RELEASE_{87} + \sum_r \beta_r FIRM_r + \sum_i \sum_r \phi_{ir} Z_{ir} + \varepsilon$$

where r = Ring 1 and Ring 2, and i = ith socioeconomic variable. $FIRM_1$ and $FIRM_2$ represent the number of polluting firms in Ring 1 and Ring 2 respectively. Individual ring community characteristics are included in vector Z. We expect that distant community effects will be different from proximate community effects in explaining the observed reductions in discharges. i.e., we expect stronger response by the firms to Ring 1 communities than to Ring 2 communities.

iii. Discharges by Type of Emission

The collective and individual discharge reduction functions are estimated for three discharge sources using (5.1) and (5.2). The Total Model represents the aggregated discharge reduction function in which the change in total toxic releases is used as the dependent variable.

Total releases include emissions into the air, releases into the water, underground injections, releases to land, and transfers of waste between facilities. The Air Model represents the air discharge reduction function where the change in air releases is used as the dependent variable. The Land Model represents the land discharge reduction function where the change in land releases is used as the dependent variable.

We expect communities to react differently to alternative types of risk sources. Air and land releases are more visible than total releases, and air releases may be more spatially dispersed than land releases. Community response is expected to be strong when the threat of potential exposure is highly visible or spatially concentrated. The firm's discharge control behavior is expected to reflect the response behavior of the community. We expect strong "local" community opposition to land discharges because the impact of these discharges are highly localized. The impact of air releases, on the other hand, is not only felt by communities living in the immediate proximity of the firm, but also by those living further away. Hence, we expect strong "spatially aggregated" community opposition to air discharges.

b. Data

Several data bases are used in this study. The United States Environmental Protection Agency's *Toxics Release Inventory*, 1987 and 1989, is the data source on toxic discharges and is described in Chapter 3 and Appendix A. Parish level socioeconomic variables are obtained from *The Sourcebook of County Demographics*, 1990; data on eligible voters in Louisiana are obtained from the *Census of Population and Housing, 1990: PL-94.171 Reapportionment and Redistricting Data* for the State of Louisiana; and data on registered voters in the state are obtained from the Louisiana Department of Elections and Registration. *The Sourcebook of Zip Code Demographics* is the source of zip code level variables, and the *Census of Population and Housing: 1990 Summary Tape File A* is the source of block group level data used to construct distance specific information (see Appendix B).

c. Estimation Technique

Multiple regression wass selected as the appropriate statistical tool because of its ability to control for many factors in the analysis. All specified linear models are estimated using Ordinary Least Squares. Although detecting and treating econometric problems are not the main purposes of this study, the potential problems of multicollinearity and heteroskedasticity are examined and accounted for whenever possible.

Multicollinearity occurs when there is a linear relationship among some or all explanatory variables of a regression model. In the presence of high or perfect multicollinearity, it becomes difficult, if not impossible, to disentangle the separate influences of each independent variable. If a moderate degree of multicollinearity is present, the regression coefficients, although determinate, possess large standard errors, which means that the coefficients cannot be estimated with great precision. Several rules of thumb are suggested to detect the presence and degree of multicollinearity in a given data set. For instance, if the coefficient of determination, R^2, is high and the F test rejects the hypothesis that the partial slope coefficients are simultaneously equal to zero, but the individual t-tests show that none or very few partial slope coefficients are statistically different from zero, then multicollinearity is a problem. High pair wise correlations among the regressors is also a signal of the presence of multicollinearity. Another procedure to detect the problem is to regress each of the independent variables on the other regressors. If the value of R^2 in the auxiliary regressions is high, a near exact linear dependence among the explanatory variables is indicated.

A moderate to strong degree of multicollinearity was detected in our data using SAS diagnostic option COLLIN based on the work of Belsley, Kuh, and Welsch (1980). The sole purpose of our analysis is establishing whether or not a relationship exists between community characteristics and the behavior of polluting firms. We are not overly concerned with precise estimates of the parameters, but rather their significance. Multicollinearity may result in the rejection of significance of a relation when, in fact, the relation exists. Estimates will be biased if a relevant variable is omitted and inefficient if a nonrelevant variable is included. The extent of the bias depends on the degree of the correlation between the misspecified variable and the variables with significant coefficients.[1]

Heteroskedasticity occurs when the condition of constant variance in the disturbance term, ε, is violated. The problem of heteroskedasticity often occurs in cross-sectional studies. In fact, "in cross sectional data involving heterogeneous units, heteroskedasticity may be the rule rather than the exception" (Gujarati, 1988, p. 327) This study involves the relation between

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[1] For a detailed discussion on multicollinearity see Gujarati (1988), pp.283-309, and Judge et al. (1988), pp. 859-886.

reductions in discharges and socioeconomic characteristics. Heteroskedasticity is expected since small, medium, and large size firms are sampled together. Several methods of detecting heteroskedasticity are available. The simplest of which is the graphical method. Using this approach, the residuals of the OLS regression are plotted against the dependent variable, and the shape of the residual distribution pattern would suggest whether the variance of the error term is constant. Park (1966), Glajser (1969), Goldfeld and Quandt (1972), and Breusch and Pagan (1979) discussed alternative methods of detecting heteroskedasticity. The common treatment of this problem is to use the weighted regression method designed to reduce the nonhomogeneity of the variance. However, a prerequisite for using weighted least squares is that the nature of heteroskedasticity be known. For our sample, the presence of an unknown form of heteroskedasticity was detected in the data. The consequence of heteroskadasticity is to render least squares estimates inconsistent. It is important to properly adjust the least squares result for this fact. Instead of using the covariance matrix of the least squares estimator, the standard errors of the estimates were obtained by constructing the asymptotic variance-covariance matrix. The square root of the diagonal elements of this matrix provide correct and consistent estimates of the standard errors when heteroskedasticity of an unknown form is present in the data (White, 1980).

III. Discharge Reduction Function Estimates

a. Collective Discharges

Parish level discharge reduction function estimates for total, air, and land releases are reported in Table 5.1. The variable

Table 5.1

Parish Level Discharge Reduction Function Estimates

	TOTAL MODEL	AIR MODEL	LAND MODEL
INTERCEPT	165,721,273[a]	22,005,301[b]	216,530
	(2.941)	(1.706)	(0.528)
$RELEASE_{87}$	-0.72[a]	0.19	-0.99[a]
	(-7.304)	(1.299)	(-1637)
DENSITY	4,126.72	165.67	-243.80[a]
	(0.321)	(0.245)	(-2.926)
BLACK	-1,119,254[a]	-112,568[c]	-1,753
	(-2.990)	(-1.492)	(-0.647)
INCOME	-3,544.23[a]	-363.50[b]	-60.12[a]
	(-2.329)	(-1.817)	(-2.548)
HOME	664.39	19.92	17.92[a]
	(1.024)	(0.392)	(2.325)
COLLEGE	-2,453,257[a]	-116,350	-18,537[b]
	(-2.496)	(-1.123)	(-1.869)
REGVOTE	-898,144[a]	-142,319[b]	8,023[a]
	(-2.419)	(-1.679)	(2.308)
FIRMS	3,389,126[a]	46,624	36,989[a]
	(2.981)	(0.309)	(2.979)
N	49	49	27
F-value	28.719	2.527	124,476
$\bar{R}^2$	0.8221	0.2029	0.999

t-statistic in parentheses.
a Significance at 5% level.
b Significance at 10% level.
c Significance at 15% level.

$RELEASE_{87}$ in Table 5.1 is defined as 1987 total, air, and land releases, respectively, in the three models.

The Total Model regression results reveal that the proposed model explains roughly 82 percent of the variance in observed reductions in total discharges. The negative and statistically significant coefficient estimate of $RELEASE_{87}$ indicates that the greater the level of discharges in 1987, the greater the reductions in those releases in 1989; that is, the difference between 1989 and 1987 releases is algebraically greater. This relation is expected since it may be easier for firms to reduce discharges when their initial volumes are high if there are increasing marginal control costs. We suspect that $RELEASE_{87}$ is acting as a proxy for control cost.

The negative and highly significant coefficient estimate for BLACK represents an important result for this study. It indicates that the greater the percentage of blacks in a parish, the greater the reductions in toxic discharges. This relation may be explained by the increased attention that has arisen in recent years about blacks and other racial minorities being disproportionately exposed to potential environmental risk. Historically, environmental advocacy in black communities has been somehow dormant; tolerance, perhaps due to limited economic means, fear of job loss, and poor access to power, has been the norm in black communities. The emergence of environmental activism in these communities is a recent phenomenon. Greater empowerment and greater political awakening of blacks can help explain why firms may have responded by lowering discharges. In fact, a similar relationship is observed in a recent study by Gelobter (1992). Gelobter's findings indicated that non-whites experience slightly greater reductions in exposure to pollutants than whites. The implications of his findings, however, are not clear since they may have resulted from the fact that marginal cost of pollution control is lower in the areas that are heavily polluted. The advantage of the present study is that it controls for this cost effect by including the $RELEASE_{87}$ variable.

Parish median income (INCOME) has the expected sign and is highly significant. The higher the income levels in a given parish, the greater the reduction in total toxic discharges. The percentage of population who are college graduates (COLLEGE) and the ratio of registered to eligible voters (REGVOTE) in a parish both have the expected relationships. The more educated and the more politically active the community, the greater the discharge reductions over time. Median home value (HOME) is not statistically significant. This result may be attributable to the high degree of collinearity between median family income and median home value. The pairwise correlation coefficient between the two variables is 0.827. When the HOME variable is taken out of the regression equation, all other variables retain their sign and significance. When INCOME is taken out, the coefficient estimate of HOME changes to the anticipated sign and becomes significant.

Table 5.1 shows that the more firms there are in a parish, the smaller the reduction in toxic discharges over time. Theoretically, it is expected that community opposition will be greater when many polluters are located in a given area. Increased community opposition will, in turn, trigger the firms to respond by lowering discharges in order to avoid additional regulatory costs. However, with many polluting firms the probability of proving a particular firm is at fault may be reduced, making it easier for a polluter to hide. This potential pollution "hiding effect" on control behavior may explain the positive coefficient estimate for FIRMS.

A frequently raised question in the literature on environmental equity is whether it is race or income which explains environmental data. In response to this concern, we use the method of *beta coefficients*, or standardized regressions, to make direct comparisons between variables. The beta coefficient is directly related to the OLS coefficient; it is calculated by multiplying the OLS coefficient estimate by the standard error of its regressor and dividing by the standard error of the regressand. The beta coefficient can be interpreted as measuring the degree of change in the standard error of the dependent variable resulting from one standard error change in the independent variable (Kennedy, 1986, p.213). The results of this standardization reveal that income is more important than race in explaining the observed reductions in total toxic discharges. While a change of 1 standard deviation in INCOME results in a 0.39 standard deviation change in total discharge reduction, the same change in BLACK results in a 0.29 standard deviation change in ΔRELEASE. The results also reveal that the most important regressor in the Total Model is $RELEASE_{87}$, followed by FIRMS, INCOME, BLACK, COLLEGE and REGVOTE, respectively.

The coefficient estimates for the air discharge reduction function in Table 5.1 Air Model are qualitatively similar to the Total Model estimates, with the exception of $RELEASE_{87}$. Nevertheless, the positive coefficient estimate for $RELEASE_{87}$ is statistically insignificant. BLACK, INCOME, and REGVOTE are the only variables with statistically significant coefficient estimates. The standardized regression model indicates that income is also more important than race in explaining the obseved reductions in air discharges. Overall, the Air Model has less explanatory power than the Total Model as indicated by lower F and $\bar{R}^2$ values.

The land discharge reduction model (Land Model), on the other hand, has a greater explanatory power then either the Total or Air Models; it has an almost perfect $\bar{R}^2$ value. Inspection of the data revealed that the strong fit may be explained by the high degree of correlation between the dependent variable ΔRELEASE and $RELEASE_{87}$. Reported land releases in 1989 were dramatically smaller than the reported releases in 1987, so the difference in discharges was basically similar to the values of 1987 releases with a negative sign attached to them. Nevertheless, some interesting relationships are observed and are worth noting.

Population density (DENSITY) is an important determinant of land discharge reductions. The reductions are greater the higher the population density. This is consistent with both regulatory risk based enforcement and potential costs to firms of polluting behavior. This variable is only significant in the Land Model. The coefficient estimate for BLACK is negative but insignificant. Median home value (HOME), on the other hand, has a positive and highly significant coefficient estimate indicating that the higher the home values, the lower the observed reductions in land discharges. This is inconsistent with theory and common sense. A similar inconsistent result is observed with REGVOTE. A positive and significant coefficient estimate for REGVOTE raises further concerns about the credibility of this model.

These unusual results may be attributed to the fact that land discharges are highly localized and, therefore, cannot be effectively estimated using the characteristics of the parish population. If this is true, we expect the land discharge reduction function to yield more meaningful results when the function is estimated at a lower aggregation level.

The Zip Code level discharge reduction function estimates are reported in Table 5.2. The Total Model coefficient estimates are qualitatively similar to the parish level estimates although not as statistically significant. While the coefficient estimate of INCOME retains its negative sign, it is only significant at the 20% level. Furthermore, the parameter estimate of BLACK is insignificant even at the 20% level. The results of the Air Model indicate that income is a more significant determinant of air discharge reduction than race, education and home values. Furthermore, among the significant coefficients, namely, $RELEASE_{87}$, INCOME and FIRMS, INCOME ranks the most important factor in explaining reductions in air discharges, followed by $RELEASE_{87}$ and FIRMS, respectively.

The Land Model shows race to be a significant factor in determining land discharge reductions. However, the Land Model estimate of BLACK is positive and significant at the 10% level, indicating that the higher the percentage blacks in a zip code area, the <u>lower</u> the <u>reductions</u> in land discharges, which is contrary to prior results. The population variable, POP, is significantly negative, and could be acting as a proxy for DENSITY, yielding results consistent with the Land Model in Table 5.1. The estimated coefficient for $RELEASE_{87}$ is negative one, suggesting that all releases to land were terminated by

Table 5.2

Zip Code Level Discharge Reduction Function Estimates

	TOTAL MODEL	AIR MODEL	LAND MODEL
INTERCEPT	6,023,864	439,271[a]	-233,024[c]
	(0.974)	(2.179)	(-1.471)
$RELEASE_{87}$	-0.63[a]	-0.06[a]	-1.00[a]
	(-2.847)	(-2.368)	(-1057)
POP	249.87	-1.48	-4.57[b]
	(1.358)	(-0.318)	(-1.937)
BLACK	-43,020	-2,582	3,605[b]
	(-0.803)	(-0.779)	(1.693)
INCOME	-459.18	-45.36[a]	16.58
	(-1.294)	(-2.455)	(1.148)
HOME	84.76	11.06	-5.57
	(0.827)	(1.053)	(-1.049)
COLLEGE	-148,508	4,681	-23.41
	(-1.196)	(0.348)	(-0.008)
FIRMS	817,938	79,954[a]	11,542
	(1.320)	(2.209)	(0.883)
N	112	105	43
F-value	33.995	2.144	55,084
$\bar{R}^2$	0.6754	0.0715	0.999

t-statistic in parentheses.
a Significance at 5% level.
b Significance at 10% level.
c Significance at 15% level.

1989. If this were true, or roughly true, other variables are not likely to explain much of the release reductions.

A comparison of results in Tables 5.1 and 5.2 reveal that community characteristics are not as significant determinants of zip code level reductions as they are of parish level reductions. These results seem to suggest that strong aggregated community effects and weak local community effects in determining the behavior of firms.

b. Individual Discharges

The individual discharge reduction function estimates using one, two, three, four and five mile radius circles for Total, Air and Land Models are reported in Tables 5.3 through 5.5, respectively. In estimating individual discharge reduction functions, only those facilities located in populated areas are considered. The sample size, N, depends on the radius of the circle drawn around the facilities. For instance, when a circle of one mile radius is drawn around each facility that reported toxic releases in both 1987 and 1989, the sample includes only 92 facilities in estimating the Total Model, 88 facilities in the Air Model, and 23 in the Land Model; with a radius of two miles, the sample size grows to 136, 130, and 40 facilities in Total, Air, and Land Models, respectively; etc.

Inspection of the results in Tables 5.3-5.5 reveals again the importance of $RELEASE_{87}$ in explaining the observed reductions in total, air, and land discharges. The coefficient estimates of $RELEASE_{87}$ are consistently negative and significant for all specifications. This relationship indicates that what is true for the collective discharge reductions is also true for individual discharges. Individual facilities that reported high discharges in 1987 are the ones that

Table 5.3

Individual Total Discharge Reduction Function Estimates
Total Model

	CIRCLES WITH RADII OF				
	ONE MILE	TWO MILES	THREE MILES	FOUR MILES	FIVE MILES
INTERCEPT	465,787	10,314,342	6,923,585	-7,124,902	-17,225,496
	(0.056)	(1.096)	(1.144)	(-0.858)	(-1.271)
$RELEASE_{87}$	-0.52[b]	-0.63[a]	-0.63[a]	-0.64[a]	-0.63[a]
	(-1.789)	(-2.824)	(-2.788)	(-2.842)	(-2.842)
DENSITY	534.28	115.20	90.03	-132.37	-280.64
	(1.185)	(0.284)	(0.253)	(-0.396)	(-0.695)
BLACK	40,494[c]	26,353[c]	-17,829	-48,244	-44,772
	(1.517)	(1.420)	(-0.730)	(-1.226)	(-1.019)
FEMALE	27,233	-127,635	-115,652	128,001	251,411
	(0.249)	(-0.715)	(-0.987)	(0.937)	(1.302)
OLD	-279,980	-278,467[a]	-18,554	112,097	252,437
	(-0.988)	(-2.018)	(-0.339)	(0.979)	(1.046)
HOME	3.89	-9.98	-8.06	-6.11	30.79
	(0.133)	(-0.647)	(-0.444)	(-0.230)	(0.775)
FIRMS	-949,757	-142,706	236,599	382,117[b]	315,796[b]
	(-1.126)	(-0.704)	(1.410)	(1.723)	(1.657)
N	92	136	150	153	156
F-value	17.360	41.944	45.892	47.599	48.839
$\bar{R}^2$	0.5572	0.6798	0.6784	0.6821	0.6836

t-statistic in parentheses.
a Significance at 5% level.
b Significance at 10% level.
c Significance at 15% level.

Table 5.4

Individual Air Discharge Reduction Function Estimates
Air Model

	CIRCLES WITH RADII OF				
	ONE MILE	TWO MILES	THREE MILES	FOUR MILES	FIVE MILES
INTERCEPT	346,404[c]	378,250	711,111	568,846	175,098
	(1.438)	(0.579)	(1.075)	(0.941)	(0.111)
$RELEASE_{87}$	-0.60[a]	-0.29[a]	-0.29[a]	-0.29[a]	-0.29[a]
	(-4.588)	(-23.019)	(-22.845)	(-23.801)	(-23.396)
DENSITY	4.16	-23.10	-23.41	-27.39	-9.96
	(0.268)	(-1.403)	(-1.319)	(-1.376)	(-0.271)
BLACK	794.79	-1,950.14	-1,426.30	1,432.76	128.45
	(0.776)	(-1.261)	(-0.718)	(0.882)	(0.061)
FEMALE	-8,522.31[c]	-1,769.51	-8,780.16	-9,181.14	2,136.50
	(-1.507)	(-0.148)	(-0.746)	(-0.887)	(0.067)
OLD	2,859.52	-5,827.10	-4,946.01	-5,240.03	-7,026.16
	(0.415)	(-0.686)	(-0.628)	(-0.380)	(-0.421)
HOME	2.18	-2.71	-2.94	-1.02	-4.43
	(1.065)	(-1.318)	(-0.847)	(-0.485)	(-1.039)
FIRMS	-3,385	11,574	10,177	2,402	5,211
	(-0.171)	(0.624)	(0.971)	(0.306)	(0.684)
N	88	130	141	144	147
F-value	38.506	91.528	98.331	99.906	109.190
$\bar{R}^2$	0.7511	0.8309	0.8295	0.8288	0.8291

t-statistic in parentheses.
a Significance at 5% level.
b Significance at 10% level.
c Significance at 15% level.

Table 5.5

Individual Land Discharge Reduction Function Estimates
Land Model

	CIRCLES WITH RADII OF				
	ONE MILE	TWO MILES	THREE MILES	FOUR MILES	FIVE MILES
INTERCEPT	2,559,341[a]	-394,082	38,606	122,257	1,102,065[c]
	(2.279)	(-0.957)	(0.184)	(0.348)	(1.535)
$RELEASE_{87}$	-1.08[a]	-0.99[a]	-1.00[a]	-1.00[a]	-1.00[a]
	(-18.29)	(-4499)	(-2924)	(-2598)	(-3152)
DENSITY	23.97	-53.55[c]	-34.54	-32.01	-2.81
	(1.069)	(-1.543)	(-1.171)	(-1.003)	(-0.092)
BLACK	-1,617[c]	923.10	441.25	2,693.34	4,355.76
	(-1.577)	(0.492)	(0.274)	(0.987)	(1.173)
FEMALE	-40,657[a]	9,074	2,115	-2,644.80	-23,312.62
	(-2.253)	(1.269)	(0.740)	(-0.442)	(-1.473)
OLD	-14,471[b]	3,832.55	-2,436.95	-3,614.07	-5,487.48
	(-1.940)	(0.657)	(-0.813)	(-0.718)	(-0.803)
HOME	-2.74[c]	-1.13	-1.60	1.19	2.99
	(-1.498)	(-0.845)	(-0.993)	(0.668)	(0.710)
FIRMS	-68,489[b]	-5,780	6,810	-3,205	-11,716
	(-1.918)	(-0.416)	(0.786)	(-0.313)	(-0.950)
N	23	40	45	45	46
F-value	16.805	48,420	54,647	56,836	62,303
$\bar{R}^2$	0.834	0.999	0.999	0.999	0.999

t-statistic in parentheses.
a Significance at 5% level.
b Significance at 10% level.
c Significance at 15% level.

reduced reductions by a greater magnitude, possibly because of lower marginal control costs or higher expected enforcement related costs.

With the exception of $RELEASE_{87}$, the estimated coefficients differ in sign and significance across alternative ring aggregation levels. One and Two mile radius estimates are of particular importance because they isolate the characteristics of communities closest to the toxic sources. In the Total Model (Table 5.3), the coefficient estimates for BLACK are positive and weakly significant at the 15% level for One and Two mile rings, indicating that the greater the percentage of blacks living in close proximity to toxic releasing facilities, the lower the level of observed reductions. This result lends support to the hypothesis that blacks are disproportionately more exposed to potential environmental risks over time. However, this relationship is no longer valid as the level of community aggregation increases. The coefficient estimates are negative but insignificant with rings of Three to Five miles.

The percentage of persons aged 62 and above, OLD, in the immediate community seems to be an important determinant of the observed reductions in total discharges. The negative and highly significant coefficient estimate of OLD in the Two mile radius regression indicates that the greater the percentage of elderly in the community the greater the reductions in total discharges. As the community aggregation level increases, this variable becomes insignificant. The coefficient estimates for FIRMS become positive and significant as the size of the circle increases. This provides continued support for the "hiding" hypothesis: individual firm's discharges are reduced by a smaller magnitude when the number of other firms in its proximity increases. This is consistent with the results reported in Tables 5.1 and 5.2.

The estimated coefficients for the air discharge reduction function show slightly different relations. In general, the Air Model shows little significance of the socioeconomic variables. DENSITY in the Air Model (Table 5.4) has negative coefficient estimates, albeit significant only at the 20% level. There is some evidence that the more densely populated the area the greater the efforts by the firm to reduce air discharges. This relationship was not observed in the Total Model estimation. The coefficient estimates of BLACK alternate in sign as the size of the circle increases but are insignificant. The percentage of females (FEMALE) in the immediate vicinity of the firm is an important determinant of air discharge reductions. The higher the percentage of females the greater the reduction in air discharges. It has been documented that women have "established social networks available for quick action, and they are more likely to recognize patterns of ill health in the neighborhood" (Edelstein, 1988, p. 141). Hamilton (1985) reported that concern about toxic wastes and contamination problems is highest among women and among those who have children under the age of 18. Furthermore, he suggested that "opposition to toxic wastes could eventually become a "motherhood issue", impossible for a politician not to support." (p. 479).

The land discharge reduction function is shown in Table 5.5. Coefficient estimates at the One mile radius are of special interest. Land releases are highly localized and impact the immediate communities. Table 5.5 results are very interesting. Note that in explaining the observed reductions in land discharges, the One Mile population characteristics have many significant coefficient estimates. The results are generally consistent with prior expectations. Unlike the Total Model, BLACK in the Land Model has a negative and statistically significant coefficient estimate. FEMALE and OLD are also strong determinants of the land discharge reduction functions; the higher the percentages of females and elderly in the community the greater the reductions in land discharges. Home values in the immediate vicinity have the expected negative sign. Only in the land discharge reduction function and only at the lowest level of community aggregation is the coefficient estimate of HOME negative and significant at the 15% level. It may be that local communities are more sensitive to land discharges than total toxic discharges. The FIRMS variable is significantly negative, differing from prior results. This makes some sense, as hiding may not be a feasible strategy at such a localized level. The FIRMS variable may represent a localized "hot spot" effect, causing greater enforcement intensity.

The standardized coefficient estimates for the Land Model at the One Mile level reveal that $RELEASE_{87}$ is the most important factor and BLACK is the least important factor in explaining the observed reductions in land discharges. If HOME is acting as a proxy for income, then income is more important than race in the Land Model also.

The above results indicate that there is a definite trend in the sign and significance of the coefficient estimates as the community aggregation level increases. There are more significant socioeconomic effects for proximate communities than for larger aggregated communities. The One or Two mile ring effects, which represent the lowest level of community aggregation, may be different from the more aggregated rings, perhaps indicating the differences in community responses as the distance from the pollution source increases.

Spatially aggregating community characteristics may not be valid if it is expected that distant communities will behave differently or have different effects from the proximate communities. In response to this concern, communities were classified into two groups, or rings, based on their distance from the pollution source. Those living within a two mile distance from the source are considered the immediate, or Ring 1, communities; and those living within at least two and at most five miles from the source are considered the distant, or Ring 2, communities. Table 5.6 presents the independent ring approach to estimating total, air, and land discharge reduction functions.

The results of the independent ring analysis are disappointing. First, the adjusted R^2's are not higher than those for the Five mile radius regressions in Table 5.3-5.5, which suggests that segmenting the circles into two separate parts does not enhance explanatory power. Second, most coefficient estimates are statistically insignificant, which may be due to the high correlations between Ring 1 and Ring 2 characteristics. For instance, the pairwise correlation coefficient between DENSITY1 and DENSITY2 is in excess of 0.8; the correlation between FIRM1 and FIRM2 is above 0.6, and that between BLACK1 and BLACK2 is above 0.5.

Only the Total Model in Table 5.6 shows meaningful statistically significant coefficient estimates, namely the female, age, and firm variables. The FEMALE1 coefficient estimate, which is significant at the 10% level, is inconsistent with the FEMALE coefficient pattern in Table 5.3. The OLD1 and OLD2 coefficients are consistent with the OLD

Table 5.6

Ring Level Discharge Reduction Function Estimates

	TOTAL MODEL	AIR MODEL	LAND MODEL
INTERCEPT	-2,399,073 (-0.845)	-4,999 (-0.036)	38,554 (0.779)
$RELEASE_{87}$	-0.64[a] (-3.105)	-0.29[a] (-21.903)	-1.00[a] (-1916)
DENSITY1	-2,715.24 (-1.132)	-71.99 (-1.008)	-33.50 (-0.917)
DENSITY2	2,184.22 (0.920)	86.55 (0.931)	-12.38 (-0.380)
BLACK1	49,657 (1.199)	-3,997[a] (-1.922)	-1,123 (-0.988)
BLACK2	-55,518 (-0.923)	2,180 (1.064)	3,650 (1.273)
FEMALE1	109,651[b] (1.620)	3,825 (0.994)	5,862 (1.303)
FEMALE2	-193,303 (-1.214)	7,246 (1.099)	-6,158 (-0.777)
OLD1	-475,618[b] (-1.835)	3,822 (0.415)	5,310 (-0.727)
OLD2	690,200[c] (1.523)	-16,043 (-0.876)	-761 (-0.071)
HOME1	-33.72 (-0.777)	-1.99 (-0.855)	-2.23 (-1.375)
HOME2	120.00 (1.361)	-5.96 (-1.271)	4.29 (0.925)
FIRM1	-1,086,598 (-1.410)	-3,896 (-0.112)	-5,765 (-0.454)
FIRM2	725,745[b] (1.639)	11,788 (0.586)	-8,717 (-0.581)
N	157	148	47
F-value	28.484	55.565	30,889
$\bar{R}^2$	0.6961	0.8283	0.9999

t-statistic in parentheses.
a Significance at 5% level.
b Significance at 10% level.
c Significance at 15% level.

coefficient patterns in Table 5.3. Finally, the FIRM2 coefficient suggests that the larger the total number of firms located far from the firm under observation, the lower the firm's discharge reduction. This may result from a transfer of regulatory enforcement effort, or concern, away from the firm under observation to distant "hot spots" with a large number of firms. The Air Model shows a significantly negative BLACK1 effect, as generally expected, and is consistent with Table 5.4 patterns. The Land Model in Table 5.6 has no meaningfully significant socioeconomic variables, contrary to results in Table 5.5. Again, the coefficient for $RELEASE_{87}$ is negative one, suggesting complete elimination of land releases.

c. Collective versus Individual Discharges

To directly compare aggregated versus disaggregated reductions in releases across parish, zip code and block groups, we ran regressions including only those variables that are common to all the data sets for all the community aggregation levels. The results for the Total Model are presented in Table 5.7. A careful examination of the results reveals that the coefficient estimates retain at least their signs, if not their significance levels, when we exclude the non-common variables. The only exception is the sign and significance of the HOME coefficient estimate at the parish level. When INCOME is excluded from the parish regression, median home value may act as a proxy for income. Note that median income and median home value are highly positively correlated with a pairwise correlation coefficient in excess of 0.8. A negative sign for the coefficient estimate of HOME indicates that the higher the home value in a given locality, the greater the reductions

Table 5.7
Total Discharge Reduction Function Estimates

	Coefficient Estimates						
Variable	One Mile	Two Miles	Three Miles	Four Miles	Five Miles	Zip Code	Parish
INTERCEPT	-1,880,784	-40,156	737,503	1,020,631	-371,392	180,984	23,113,386[c]
	(0.804)	(-0.037)	(0.765)	(0.911)	(-0.302)	(0.080)	(1.619)
$RELEASE_{87}$	-0.51[b]	-0.63[a]	-0.63[a]	-0.64[a]	-0.64[a]	-0.63[a]	-0.72[a]
	(-1.778)	(-2.793)	(-2.791)	(-2.844)	(-2.833)	(-2.869)	(-5.307)
POP	416.73	41.22	3.43	-2.39	-2.66	259.84	58.38
	(1.385)	(0.669)	(0.162)	(-0.277)	(-0.353)	(1.352)	(0.685)
BLACK	36,939[c]	15,431	-21,662	-42,471	-35,030	-11,670	-581,213[b]
	(1.528)	(1.056)	(-0.867)	(-1.101)	(-0.892)	(-0.327)	(-1.907)
HOME	-6.59	-8.72	-6.42	-9.96	19.76	-113.62	-550.90[c]
	(-0.220)	(-0.416)	(-0.329)	(-0.412)	(0.643)	(-1.175)	(-1.603)
FIRMS	-1,084,409	-99,072	233,352	374,086[b]	261,361[b]	717,937	1,898,027
	(-1.193)	(-0.420)	(1.384)	(1.752)	(1.770)	(1.133)	(1.419)
N	92	136	150	153	157	112	49
F-value	24.714	58.798	65.090	67.416	68.605	47.529	35.027
$\bar{R}^2$	0.5658	0.6816	0.6826	0.6860	0.6856	0.6770	0.7800

t-values in parantheses.
a Significance at 5% level.
b Significance at 10% level.
c Significance at 15% level.

in toxic releases. Note that this variable is significant only at the parish level.

The results in Table 5.7 reveal an interesting converging pattern in the signs of the coefficient estimates for BLACK and FIRMS as the level of community aggregation increases. For instance, while BLACK has a positive and weakly significant coefficient estimates at low levels of community aggregation (one and two mile radius), the sign changes with three mile radius and stays consistently negative as the community aggregation increases. At the parish level, the coefficient estimate is negative and significant at the 10% level. FIRMS, on the other hand, has negative, but insignificant, coefficient estimates at low levels of aggregation and these change to significantly positive coefficient estimates at higher levels of community aggregation.

Table 5.8 presents the air discharge reduction function estimates for alternative levels of community aggregation. While the coefficient estimate of POP at the parish level is positive and significant at the 10% level indicating that the more populated the parish the smaller the reductions, the coefficient estimates of POP in Two, Three and Four Mile rings are negative, indicating that reductions are greater in more populated areas. These differences may be attributed to the fact that at the parish level, population may proxy economic activity and growth, suggesting smaller reductions in discharges with more economic activity. However, in spatially constrained radius regressions POP proxies density and we get results consistent with DENSITY patterns in Table 5.4: i.e., higher density implies greater reductions. BLACK maintains a negative and weakly significant coefficient in the Air Model. FIRMS maintains a significantly positive coefficient only at the

Table 5.8
Air Discharge Reduction Function Estimates

Variable	Coefficient Estimates One Mile	Two Miles	Three Miles	Four Miles	Five Miles	Zip Code	Parish
INTERCEPT	-26,668	201,507	191,429	20,418	162,442	-127,934	3,134,370
	(-0.278)	(1.189)	(0.856)	(0.159)	(0.838)	(-0.688)	(1.112)
$RELEASE_{87}$	-0.60[a]	-0.29[a]	-0.29[a]	-0.29[a]	-0.29[a]	-0.06[a]	0.19
	(-4.526)	(-22.59)	(-22.61)	(-23.52)	(-22.78)	(-2.131)	(0.997)
POP	0.44	-2.39[c]	-1.22[c]	-0.88[b]	-0.23	0.06	8.80[b]
	(0.061)	(-1.543)	(-1.506)	(-1.918)	(-0.541)	(0.011)	(1.814)
BLACK	517.21	-2,079[c]	-1,892	967.08	158.49	984.99	-47,028
	(0.579)	(-1.439)	(-0.991)	(0.619)	(0.082)	(0.291)	(-0.859)
HOME	1.97	-2.51	-2.64	-0.59	-3.88	-3.81	-74.81
	(1.016)	(-1.176)	(-0.748)	(-0.300)	(-1.147)	(-1.159)	(-1.240)
FIRMS	-4,596.34	14,009	11,830	4,052.70	6,471.25	61,545[b]	-104,426
	(-0.238)	(0.836)	(1.244)	(0.595)	(1.015)	(1.737)	(-0.733)
N	88	130	141	144	147	105	49
F-value	54.499	129.697	139.154	141.538	144.779	2.095	1.723
$\bar{R}^2$	0.7546	0.8330	0.8315	0.8309	0.8312	0.0500	0.0701

t-values in parantheses.
a Significance at 5% level.
b Significance at 10% level.
c Significance at 15% level.

zip code level of aggregation. The Air Model regression results at the parish and zip code level reveal that the model does not have good explanatory power; the coefficients of determination, $\bar{R}^2$, are 0.05 and 0.07, respectively, and the F tests do not reject the hypothesis that the partial slope coefficients are simultaneously equal to zero.

The land discharge reduction function estimates are presented in Table 5.9. The coefficient estimates in the parish and zip code regressions are qualitatively similar to Table 5.1 and Table 5.2 results, respectively. We had emphasized the importance of one mile radius level analysis in estimating land discharge reduction functions because of the highly localized characteristic of the externality. However, a comparison of Tables 5.9 and 5.5 provides a substantially different interpretation of socioeconomic effects. In Table 5.9, none of the variables are significant, while Table 5.5 shows considerable significance and anticipated signs for the very localized One mile ring regressions.

IV. Conclusions

This chapter is a preliminary attempt to explain the pollution control behavior of a toxic releasing firms as a function of community socioeconomic characteristics. Maintaining the hypothesis that a community's characteristics and political activism impact the behavior of a risk neutral profit maximizing firm, we estimated collective and individual discharge reduction functions for three types of discharges, total, air and land, using alternative community aggregation levels. Collective discharge reduction functions pertained to the behavior of all toxic releasing firms in a given geographical area. In estimating collective discharge reduction functions, we aggregated the total, air,

Table 5.9
Land Discharge Reduction Function Estimates

Variable	Coefficient Estimates: One Mile	Two Miles	Three Miles	Four Miles	Five Miles	Zip Code	Parish
INTERCEPT	254,041	111,409	98,051	-74,536	-167,446	30,956	-13,514
	(1.138)	(1.229)	(1.066)	(-0.661)	(-0.742)	(0.267)	(-0.128)
$RELEASE_{87}$	-1.03[a]	-0.99[a]	-1.00[a]	-1.00[a]	-1.00[a]	-0.99[a]	-0.99[a]
	(-30.96)	(-5911)	(-3217)	(-2503)	(-2942)	(-4318)	(-2143)
POP	-5.33	-3.70	-1.49	-0.77	-0.59	-3.80[b]	-0.83[b]
	(-0.842)	(-1.263)	(-1.172)	(-1.279)	(-1.252)	(-1.891)	(-1.761)
BLACK	-1,357.19	1,311.74	520.39	2,614.15	3,271.52	2,167,80[a]	1,551.04
	(-1.094)	(0.676)	(0.318)	(0.998)	(1.009)	(2.030)	(1.019)
HOME	-2.77	-1.29	-1.36	1.53	3.52	-0.70	-1.43
	(-1.080)	(-0.979)	(-0.935)	(0.850)	(0.861)	(-0.386)	(-0.514)
FIRMS	-40,666	-5,706	7,707	-3,094	-5,754	12,251	21,531[b]
	(-1.107)	(-0.397)	(0.848)	(-0.308)	(-0.551)	(0.906)	(1.981)
N	23	40	45	45	46	43	27
F-value	11.749	71,258	80,298	83,320	88,979	76,659	157,326
$\bar{R}^2$	0.7095	0.9998	0.9998	0.9998	0.9998	0.9998	0.9999

t-values in parantheses.
a Significance at 5% level.
b Significance at 10% level.
c Significance at 15% level.

and land discharges of all toxic releasing firms located in a given parish or zip code area and used the characteristics of these aggregated communities to explain the reductions in discharges. The individual discharge reduction function examined the behavior of single toxic releasing firms as a function of distance specific community characteristics.

The results of our analysis indicate that community socioeconomic characteristics are relatively important factors in explaining the observed reductions in toxic discharges. While the significance of the coefficient estimates vary across alternative community aggregation levels, a general pattern is observed. The parish level analysis, Table 5.1, revealed that the higher the income levels in a parish the greater the reductions in total, air, and land discharges over time. Also, the more educated and the more politically active the community is the greater the reductions in discharges. One of the more interesting results, at the parish level, was the significance of the race variable in explaining the Total and the Air Models. The results indicated that the greater the percentage of blacks in the community the greater the reductions in total and air toxic discharges. This relationship may provide support to the observation that blacks are becoming more active in environmental issues. However, in terms of relative importance in explaining the collective discharge reductions, income was a more important factor than race. Another interesting relationship in the parish level regression relates to the number of firms variable. The results indicated that when the number of toxic releasing firms increases, the reductions in discharges are smaller. This seems to be a reasonable relationship since the variable measures the level of industrial activity in the area. The greater the industrial activity, the greater the production of discharges in an area. With many firms concentrated in an area, pinpointing particular firm discharges over time is difficult task to the regulator. Hence, firms located in industrial complexes have both the incentive and the ability to "hide" from regulators.

The zip code level analysis, Table 5.2, produced estimates qualitatively similar to parish results, albeit not as significant statistically. It was surprising to note that at this lower level of community aggregation, the estimated models were not superior to the parish models. The only significantly different relationship between the two was observed in the land discharge reduction model. In the Land Model, the coefficient estimate of BLACK was positive indicating that the greater the percentage of blacks in the area, the lower the reductions in land discharges.

Individual discharge reduction function estimates, Tables 5.3-5.5, reveal that the coefficients are very sensitive to the specification of the model. When we consider the characteristics of the communities living within a distance of one mile from a toxic releasing facility, the coefficient estimates are dramatically different from estimates based on the characteristics of communities living within three miles of the facilities. In estimating the total discharge reduction model, Table 5.3, the coefficient estimate for the percentage of blacks was positive indicating that the greater the percentage of blacks in the immediate vicinity of the firm the lower the reductions in the firm's total discharges. This relationship lends support to the hypothesis that blacks are disproportionately more exposed to environmental risk.

However, this relationship was not observed with more aggregated community characteristics. The percentage of elderly people in the community was also a significant factor in explaining the observed reductions in individual discharges. The estimates of the number of firms variable in the Total Model provided continued support for the hiding hypothesis. The Air Model, Table 5.4, revealed the significance of the female variable in explaining the reductions in air discharges.

The Land Model, Table 5.5, produced a very interesting set of estimates when the One Mile radius population variables were used as regressors. The results indicated that the greater the percentages of blacks, females and elderly in the community and the higher the median home value, the greater the observed reductions in land discharges. Furthermore, the estimate for the number of firms variable in the One Mile analysis was significantly negative indicating that the greater the number of toxic releasing facilities in the immediate proximity of the firm under observation the greater the reductions in the firm's land discharges. Obviously, the firm's behavior reflects the highly localized nature of the externality it created. Hence, the implication is that the firm is in a "hot spot" and hiding is not a feasible strategy with a spatially concentrated externality.

In general, the estimation results revealed that the models are very sensitive to the level of aggregation. While parish level analysis provided very interesting results, the zip code level analysis was basically uninformative. Furthermore, the individual regressions showed how the signs and significance of the coefficient estimates differed across alternative community aggregation levels and alternative types of discharge measures. Tables 5.7 through 5.9 provided ample evidence on that. The results are also sensitive to the inclusion and exclusion of variables.

Chapter 6

Conclusions

This dissertation tested whether the location and environmental control behavior of toxic chemical releasing facilities (TRI facilities) in Louisiana were systematically related to the socioeconomic and racial characteristics of the surrounding communities. Following the "site distribution" models in the literature, the location of toxic releasing facilities was used as an indicator of environmental quality. The distribution pattern of toxic releasing facilities in Louisiana suggested that some communities may be disproportionately exposed to potential toxic risks.

Most toxic sources were located in the southern portion of the state along the lower Mississippi River. Using alternative community aggregation levels, Chapter 3 identified who lives near the toxic sources in Louisiana, and determined whether, and how, the characteristics of these communities differ from those of Louisiana's general population. The results of the parish level analysis, the highest level of community aggregation, indicated that there were significant differences between the characteristics of the parish population in which toxic sources were located and the state's general population characteristics. Income, income related variables, such as education, and property values were significantly lower in TRI hosting parishes than the state averages. There were no statistical differences in the racial composition of the population at this aggregation level.

The zip code level analysis, a lower level of community aggregation, revealed similar divergences from the state averages as the parish data for income variables, but of a smaller magnitude. Compared to the state, zip code area communities had lower per capita income, fewer families with incomes above $75,000, fewer college graduates, and lower home and rent values. A major difference from the parish level analysis was the statistical differences in the racial composition of the population. The mean percentage of blacks in TRI facility hosting zip code area populations was above the state's average. One of the more significant findings of Chapter 3 was that income variables showed less divergence and race variables more divergence with lower degrees of community aggregation. For example, in 1990 mean per capita incomes in the state, TRI hosting parishes, and TRI hosting zip code areas were $9,949, $8,979 (± $199), and $9,399 (± $164), respectively. The difference between host parish and state per capita incomes was significantly greater than that between host zip code and state. The mean percentage of blacks in the state, host parish, and host zip code areas, on the other hand, were 27.7%, 28.61% (± 1.81), and 30.34% (± 1.69), respectively. While the difference between host parish and state racial composition was statistically insignificant, that between host zip code and state was significant at the 15 percent significance level.

The significance of divergent racial distributions at lower aggregation levels was more evident when distance specific data were used in the analysis. A major contribution of this dissertation was the explicit recognition of the role distance from a toxic source may play in determining the burden of potential environmental risks. One of the significant contributions of the current study was the development of a data base that identifies communities based on their distances from toxic sources. This data base was used to detemine whether socioeconomic and racial characteristics of communities change as distance from the toxic sources increases. A distance gradient analysis in Chapter 3 indicated that as distance from the nearest toxic source increases, the percentage of blacks in the community decreases and the percentage of whites increases. The percentages of blacks were significantly higher than the state average in communities that live within a distance of one to three miles from toxic sources. While the mean percentage of blacks in the study area (all block groups that are within 100 mile of TRI facilities) was 29.99% (± 0.43), the mean values in communities that live within one, two, and three miles of the nearest TRI facility were 40.29% (± 1.41), 37.56% (± 1.0), and 32.92% (± 1.05), respectively. These findings suggest that blacks, more than whites, may be disproportionately exposed to potential toxic risks.

The sex and age composition of the communities also change as distance from toxic sources increases. Compared to the 100 mile study area, relatively more females, more elderly people (ages 62 and above), and fewer younger people (ages below 15) live in the immediate proximity of toxic sources. The mean percentages of females, elderly people, and younger people in the study area were 51.94% (±.06), 15.47%

(± .11), and 25.38% (±.09), respectively. The corresponding percentages in communities living within one mile of the nearest TRI facility were 52.71% (± .17), 16.76% (±.33), and 24.71% (± .28), respectively. The mean percentage of females shows a modest but steady decline with distance from a source. The mean percentage of older people shows a decreasing trend over a limited distance range; and the mean percentage of younger people shows an increasing trend with distance.

The results also indicated that property values (measured by the means of median house and median rent values) are relatively higher in the immediate proximity of toxic sources, with the values declining as distance from the source increases. While the mean of the median home values in the study area was $55,636 (± $405), the highest mean home value of $62,840 (± $1,135) was observed in communities located within a distance of two miles from the nearest TRI facility. The lowest value of $40,979 (± $654) was observed in communities located within ten miles from the nearest TRI facility. These findings are contrary to expectations. Property value studies predict that land prices will be lower in environmentally undesirable areas. Poor environmental quality is expected to drive away high-income households while attracting lower-income groups, partly through the housing price mechanism.

Is the housing market in Louisiana failing to capture the negative externality created by these toxic sources? Not necessarily. TRI facilities in Louisiana are mostly located in urban and densely populated areas. In fact, the mean population density systematically declines as the distance from toxic sources increases. The distance from a TRI facility may be acting as a proxy for the distance from the central business district used in property value studies. The closer the property is located to the central business district, the higher its value.

Discrimination and prejudice in the housing markets may provide an alternative explanation for the observed relationships. The results indicate that more blacks pay higher prices to live near toxic sources. This could only be true if housing markets are highly segregated. King and Mieszkowski (1973) analyzed the effects of racial variables on apartment rents in New Haven, Connecticut. Their study concluded that compared to a white in predominantly white neighborhood, a black in predominantly black neighborhood pays 9.3 percent more in rent for comparable housing. Yinger (1979) presents a comprehensive review of studies that have examined the relationship between racial composition and the price of housing.

Following the "community exposure" models in the literature, this study used the number of toxic releasing firms and the total and per capita toxic discharges as proxies for potential exposure. Correlation analysis was performed for these alternative exposure measures and the socioeconomic characteristics of the population surrounding the toxic sources. The results of the parish level analysis indicated that there were strong associations between income and other socioeconomic variables, and potential exposure measures, but not always in the same direction suggested by the literature. The results revealed that "exposure" to toxics is relatively higher in parishes with high income characteristics. The relationships between income variables and all three measures of potential exposure were consistently and significantly positive. Other socioeconomic variables, such as education and property values revealed similar associations. These positive relationships between income, and income related variables and potential exposure measures are contrary to findings reported in Freeman (1972), Asch and Seneca (1978), and Brajer and Hall (1992). They are, however, consistent with findings reported in Napton and Day (1992). Evidently, the variables used as proxies for potential exposure also describe the level of industrial activity in a parish. The number of TRI facilities, and the amount of discharges are expected to be positively related to the levels of industrial production. Higher production levels may generate higher incomes, or may require higher compensation to attract workers.

The observed relationships were very sensitive to the degree of spatial aggregation. While TRI related industrial activities may be income enhancing at the parish level due to spillovers or need for compensating wage differentials, the results of the zip code level analysis revealed that such activities may also be related to depressed "localized" pockets. The results indicated that exposure to toxics was relatively lower in zip code areas characterized by high income characteristics. The percentage of families in the highest income class (incomes above $75,000) was negatively and significantly related to the level of per capita releases. There was also a significantly negative relationship between the rental value of housing and per capita releases at the zip code level.

The observed relationships between exposure measures and socioeconomic characteristics of populations reveal little about underlying causation. Residential and industrial location choices of households and firms are jointly related decisions, partially determining who bears the burden of environmental hazards. While market factors, profits, tastes, etc. play a large role in the joint location decisions, other factors may also be important in explaining risk distributions and changes in these risks over time. The theoretical model presented in Chapter 4 suggested that environmental hazards in any community may be explained partially by the political activism of the local communites. The environmental control behavior of a risk neutral profit maximizing firm was modeled as being responsive to the political influence of local populations. The model presumed that releasing potentially harmful pollutants may trigger community opposition and, therefore, a discharger response to this opposition. Willingness and ability of households (factors reflected in income, race, education, and participation in political issues) to pursue remediation efforts to alleviate or compensate for the environmental disamenity created by the polluting firms are shown to have a direct effect on the pollution control behavior of firms. Firms have a profit motive to reduce pollution when community opposition is expected to increase regulatory and compliance cost. Individual firm's behavior is also expected to be a function of the total number of other polluting firms in the area. An area heavily populated by polluting firms will be an obvious target for any regulatory initiative.

Chapter 5 provided direct tests of the hypothesis that environmental control behaviors of toxic releasing firms are related to the socioeconomic charactersitics of surrounding communities. A single equation model of toxic discharge reductions was posited as a function of several variables describing the people and the general area where firms are located. Using parish and zip code samples, this chapter estimated aggregated discharge reduction functions for total toxic releases, relases into the air, and releases onto the land by all firms within a defined geographic area. The estimation results revealed that some community socioeconomic characteristics were significant factors in explaining observed reductions in toxic discharges. The parish level estimates indicated that the higher the income levels, the more educated, and the more politically active the community, the greater the reductions in all three types of discharges over time. Furthermore, the results indicated that the greater the percentage of blacks in a parish, the greater the reductions in total and air discharges. This relationship may provide support to the observation that blacks are becoming more active in environmental issues (Bullard and Wright, 1987). However, in terms of relative importance, income was a more important factor than race in explaining aggregated reductions in discharges.

The results revealed that the more TRI firms there are in a parish, the smaller the reductions in discharges over time. This seems to be a reasonable relationship since the number of TRI facilities may be describing the intensity of industrial activity in the area. The greater the industrial activity, the greater the production of discharges, and the smaller the relative impact of one source's reduction in discharges. It is a difficult task to the regulator to pinpoint particular firm discharges over time when many firms are concentrated in an area. Therefore, firms located in industrial complexes may have the ability to "hide" from regulators.

Compared to the parish results, and contrary to expectations, the zip code level estimates suggested a weaker degree of local community effects on firms' pollution control behavior. Income was the only significant variable in the air discharge reduction model. The results indicated that the higher the income levels, the greater the reductions in air discharges. The estimates of other socioeconomic variables, such as education and median home values, retained their signs, but not their significance. These results seem to suggest that more aggregated community characteristics better explain the pollution control behavior of firms. The estimation for the land discharge reduction model revealed the only significantly different relationship between parish and zip code results. The zip code estimates indicated that the higher the percentage of blacks in a zip code area, the smaller the reductions in land discharges over time.

Chapter 5 also estimated discharge reduction functions by individual firms. The individual firm's discharge reduction behavior was modeled as a function of the characteristics of communities in their immediate proximity. Circles of increasing radii, indicating increasing levels of community aggregation, were alternatively drawn around each facility and the characteristics of the people who live within the circle were used as explanatory variables. The estimation results were very sensitive to the level of community aggregation and discharge type. The estimates of the reduction in total discharges, using one mile population characteristics, revealed that the greater the percentage of blacks in the immediate vicinity of the firm, the smaller the reductions in the firm's total discharges. This finding is consistent with the claim that blacks are disproportionately exposed to greater environmental hazards than whites and may be less able or willing to do anything about it. However, this very localized relationship was not observed with more aggregated population characteristics, in this case for circles of larger radii. The percentage of older people (ages 62 and above) in the immediate community was a significant determinant of the observed reduction in total toxic discharges: the greater the percentage of older people in the community, the greater the reductions in total discharges. Furthermore, the results consistently confirmed the "hiding" hypothesis: individual firm's discharges are reduced by a smaller amount when the number of other polluting firms in their proximity increases.

The estimates of a land discharge reduction function, using one mile community characteristics, showed a significantly different set of relationships. The results indicated that the greater the percentages of blacks, females, and elderly in the community, the greater the observed reductions in land discharges. Furthermore, the results revealed that the greater the number of other polluting firms in the immediate proximity of a firm, the greater the reductions in land discharges. Obviously, "hiding" is not a feasible strategy with a spatially concentrated externality. Firms' behaviors may also reflect a major focus of federal and state policies, under the Resource Conservation and Recovery Act (RCRA), on reducing land discharges.

The air discharge reduction function estimates, on the other hand, did not reveal any interesting relationships. There was some evidence that the more densely populated the community, the greater the efforts of the firm to reduce air discharges, although the relationship was not highly significant. There were no significant relationships between racial composition and the firm's air discharge reduction behavior. The percentage of females in the immediate vicinity of the firm was the single socioeconomic variable with a highly significant cefficient estimate, indicating that the higher the percentage of females the greater the reductions in air discharges.

This dissertation presented ample evidence suggesting that potential exposure to toxics are systematically related to the socioeconomic and racial characteristics of the population. This study focused only on the distribution of toxic sources in Louisiana. The results are very specific to this type of hazard. A comprehensive study of the social distribution of cumulative environmental hazards, including commercial hazardous waste disposal facilities, landfills, and Superfund sites, across the population will prove invaluable to policymakers.

The distance-exposure relationships may have not been exact, since we did not employ dispersion models. Furthermore, the exposure measures were based on the assumption that people stayed at their places of residence. A logical extension of this study would require the use of human exposure modelling (such as the REHEX model employed by Brajer and Hall, 1992) that would account for the location and mobility of residents.

The findings of this dissertation revealed that the results are very sensitive to the level of community aggregation. Future research should emloy, if possible, localized and distance specific information about the population when studying the distribution of environmental risks.

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Appendix A

Criteria for Reporting Toxic Releases

Section 313 of Title III of Superfund Amendments and Reauthorization Act, the Emergency Planning and Community Right-to-Know Act, requires certain manufacturing firms to submit to U.S. EPA data on their emissions of some 300 toxic chemicals. EPA lists a chemical as toxic if it meets the following criteria:

1. it is expected to cause a significant adverse acute effects (short term) on human health;
2. it is expected to cause chronic (long term) health effects; or,
3. it is expected to cause significant adverse effects on the environment.

A manufacturing firm is required to submit a TRI report form if it meets the following criteria:

1. it has ten or more full-time employees;
2. it is included in Standard Industrial Classification codes 20 through 39; and
3. a) it manufactured or processed a reportable toxic chemical in quantities exceeding the reportable limits established by EPA for that calander year, or

   b) it used 10,000 pounds of reportable toxic chemicals that calander year.

Reporting requirements are subject to change over time. A TRI report form must be filed for each listed chemical that is manufactured or processed over the course of a year in amounts equal to or greater than:

75,000 pounds for calander year 1987

50,000 pounds for calander year 1988

25,000 pounds for calander year 1989 and subsequent years.

EPA publishes this data in the *Toxics Release Inventory* (TRI) and, by law, makes the information accessible to the public. The information collected in TRI is "intended to inform the general public and the communities surrounding covered facilities about releases of toxic chemicals, to assist research, to aid in the development of regulation, guidelines, and standards." (EPA, 40 CFR Ch. I(7-1-90 Edition), p. 372.3).

Appendix B

Distance Matrix Calculations

Consider points $A(x_a,y_a)$ and $B(x_b,y_b)$ where x and y represent the latitudes and longitudes of points A and B, respectively. To calculate the distance between A and B, we need to measure the length of a degree of latitude and the length of a degree of longitude.

Because the earth approximates an oblate spheroid, a north-south line has more curvature near the equator and less near the poles. Consequently, degrees of north-south arc on the earth are not quite the same lengths in units of uniform surface distance but vary from about 69.4 miles near the poles to about 68.7 miles near the equator. For the United States, these numbers vary from 68.833 miles in Washington State to 69.121 miles near Florida State. For the purpose of this study, the length of a degree of latitude is approximated by the average for the United States which is 68.9713. The latitude of the distance between A and B is calculated as follows:

(B.1) $$LAT = (x_a - x_b)(68.9713)$$

The length of the equator is nearly the same as the length of a meridian circle but, as we go toward the poles, all other parallels become smaller and smaller circles; yet each is divided into 360 degrees. The length of a degree of longitude is equal to the cosine of the latitude times length of a degree of latitude. Formally, the longitude of the distance between A and B is calculated as:

(B.2) $$LONG = (y_a - y_b)(\cos((x_a + x_b)/2))(68.9713)$$

Finally, the distance between points A and B is calculated as:

(B.3) $$DISTANCE = Sqrt(LAT^2 + LONG^2)$$

Appendix C

Comparative Statics

I. Product Price Changes

To study the effect of changes in the price of product x on optimal input demands, substitute z^* and a^* in the first-order conditions (4.17), totally differentiate the system of equations with respect to P, and solve by implementing Cramer's Rule to get

(C.1) $$\frac{\partial z^*}{\partial P} = -\frac{1}{|H|}\left[\pi_{aa}x_z - \pi_{za}x_a\right] \gtreqless 0$$

(C.2) $$\frac{\partial a^*}{\partial P} = -\frac{1}{|H|}\left[\pi_{zz}x_a - \pi_{za}x_z\right] \gtreqless 0$$

The effect of changes in the price of marketable produce x on the demand for production input z and the demand for abatement input a are clearly indeterminate. The behavior of product x with respect to its own-price is obtained by totally differentiating (4.20) with respect to P which yields

(C.3) $$\frac{dx^*}{dP} = x_a\frac{\partial a^*}{\partial P} + x_z\frac{\partial z^*}{\partial P}$$

Substituting (C.1) and (C.2) into (C.3)

(C.4) $$\frac{dx^*}{dP} = -\frac{1}{|H|}\left[x_a^2\pi_{zz} - 2x_a x_z \pi_{za} + x_z^2\pi_{aa}\right]$$

to sign (C.4), complete the square and rewrite

$$\text{(C.5)} \qquad \frac{dx^*}{dP} = -\frac{1}{|H|}\left\{\pi_{zz}\left[x_a - x_z\frac{\pi_{za}}{\pi_{zz}}\right]^2 + \frac{x_z^2}{\pi_{zz}}\left[\pi_{aa}\pi_{zz} - \pi_{za}^2\right]\right\} > 0$$

The sign of (C.5) is determined from the second order conditions for profit maximization (4.18). Output x is positively related to its own price (upward sloping supply function for x).

Totally differentiating (4.21) with respect to P yields the effect of a change in price of x on the optimal amount of hazard produced:

$$\text{(C.6)} \qquad \frac{dh^*}{dP} = h_a\frac{\partial a^*}{\partial P} + h_z\frac{\partial z^*}{\partial P} \gtreqless 0$$

Substituting (C.1) and (C.2) into (C.6) yields

$$\text{(C.7)} \qquad \frac{dh^*}{dP} = -\frac{1}{|H|}\left[\pi_{aa}h_z x_z - \pi_{za}\left(h_z x_a + h_a x_z\right) + \pi_{zz}h_a x_a\right]$$

It is apparent that (C.7) can not be signed directly; nevertheless, it is possible to infer the sign by some mathematical manipulations. Note that x and h are joint products. Increased production of x, holding abatement effort constant, is expected to increase the level of hazard production which means that dh^*/dP is expected to be positive. From the first order conditions in (4.17) obtain $P_z = Px_z - C_h h_z$ and $P_a = Px_a - C_h h_a$, square both sides of these two equations, solve for $h_z x_z$ and $h_a x_a$, respectively. Multiply the first equation (P_z) by the second (P_a) and solve for $(h_a x_z + h_z x_a)$. Performing these operations yield the following sets of equations:

(C.8) $$h_z x_z = -\frac{1}{2PC_h}\left[P_z^2 - P^2x_z^2 - C_h^2h_z^2\right]$$

(C.9) $$h_a x_a = -\frac{1}{2PC_h}\left[P_a^2 - P^2x_a^2 - C_h^2h_a^2\right]$$

(C.10) $$h_a x_z + h_z x_a = \frac{1}{PC_h}\left[P^2x_z x_a + C_h^2h_z h_a - P_z P_a\right]$$

Substitution for these terms in (C.7) yields

(C.11) $$\frac{dh^*}{dP} = \frac{1}{|H|}\left[2PC_h\right]^{-1}\left\{\left[\pi_{aa}P_z^2 + \pi_{zz}P_a^2 - 2\pi_{za}P_zP_a\right] - P^2\left[\pi_{aa}x_z^2 + \pi_{zz}x_a^2 - 2\pi_{za}x_zx_a\right] - C_h^2\left[\pi_{aa}h_z^2 + \pi_{zz}h_a^2 - 2\pi_{za}h_zh_a\right]\right\} \gtreqless 0$$

By the second order conditions the first set of terms in brackets is negative, the second set of terms which is equivalent to $P^2(dx^*/dP)$ from (C.4) is positive, and the third set is positive. Consequently, a sufficient condition for $dh^*/dP > 0$ is that the absolute value of the first term must be less than the absolute value of the sum of the second and third set of terms.

II. Input Prices Change

The effects of changes in price of production inputs z and a, P_z and P_a, on the demand for z and a are given by:

(C.12) $$\frac{\partial z^*}{\partial P_z} = \frac{\pi_{aa}}{|H|} < 0$$

(C.13) $$\frac{\partial z^*}{\partial P_a} = - \frac{\pi_{az}}{|H|} \gtreqless 0 \qquad \text{as } \pi_{az} \lesseqgtr 0$$

(C.14) $$\frac{\partial a^*}{\partial P_a} = \frac{\pi_{zz}}{|H|} < 0$$

(C.15) $$\frac{\partial a^*}{\partial P_z} = - \frac{\pi_{za}}{|H|} \gtreqless 0 \qquad \text{as } \pi_{za} \lesseqgtr 0$$

Own price effects (C.12) and (C.14) are negative from the second order conditions for profit maximization. When price of production input z increases, utilization of z will decrease, *ceteris paribus*; and when price of abatement input a, P_a, increases, abatement effort will decrease, *ceteris paribus*. Cross price effects (C.13) and (C.15), on the other hand, are indeterminate. By Young's Theorem, the cross price effects are equivalant ($\pi_{za} = \pi_{az}$). If the two inputs, z and a, are substitutes, then $\pi_{za} < 0$; if they are independent then $\pi_{za} = 0$, and if they are complements $\pi_{za} > 0$.

The impact of a change in price of production input z on the production of x is obtained by totally differentiating (4.20) with respect to P_z which yields:

(C.16) $$\frac{dx^*}{dP_z} = x_z \frac{\partial z^*}{\partial P_z} + x_a \frac{\partial a^*}{\partial P_z}$$

Substituting for $\partial z^*/\partial P_z$ and $\partial a^*/\partial P_z$ from (C.12) and (C.15), respectively, rewrite (C.16) as

(C.17) $$\frac{dx^*}{dP_z} = \frac{1}{|H|} \left[x_z \pi_{aa} - x_a \pi_{za} \right]$$

Note that using (C.1), $dx^*/dP_z = -\ \partial z^*/\partial P$; if z is a normal input then $\partial z^*/\partial P > 0$ and hence, the sign of (C.17) is expected to be negative.

The impact of a change in price of z on the production of h is obtained by totally differentiating (4.21) with respect to P_z which yields:

$$\text{(C.18)} \qquad \frac{dh^*}{dP_z} = h_z \frac{\partial z^*}{\partial P_z} + h_a \frac{\partial a^*}{\partial P_z}$$

Substituting for $\partial z^*/\partial P_z$ and $\partial a^*/\partial P_z$ from (C.12) and (C.15) respectively, rewrite (C.18) as

$$\text{(C.19)} \qquad \frac{dh^*}{dP_z} = \frac{1}{|H|} \left[h_z \pi_{aa} - h_a \pi_{za} \right] \gtreqless 0$$

When price of the production input z increases, less z will be used since $\partial z^*/\partial P_z < 0$ from (C.12). If (C.17) is negative, an increase in the price of z results in a decrease in production of x. Given that h is a by-product of x, it is expected that the production of h will decrease as a result of higher production input prices. A sufficient condition for (C.19) to be negative is that z and a be independent or substitute inputs ($\pi_{za} \le 0$).

The impact of a change in price of abatement input a on the production of x is obtained by totally differentiating (4.20) with respect to P_a which yields:

$$\text{(C.20)} \qquad \frac{dx^*}{dP_a} = x_z \frac{\partial z^*}{\partial P_a} + x_a \frac{\partial a^*}{\partial P_a}$$

Substituting for $\partial z^*/\partial P_a$ and $\partial a^*/\partial P_a$ from (C.13) and (C.15) respectively, rewrite (C.20) as

$$\text{(C.21)} \qquad \frac{dx^*}{dP_a} = \frac{1}{|H|}\left[x_a\pi_{zz} - x_z\pi_{za}\right] \gtreqless 0$$

Using (C.2) note that $dx^*/dP_a = -\,\partial a^*/\partial P$; if a is an inferior input in the production of x, then $\partial a^*/\partial P < 0$, and (C.21) is expected to be positive.

The impact of a change in price of a on the production of h is obtained by totally differentiating (4.21) with respect to P_a which yields:

$$\text{(C.22)} \qquad \frac{dh^*}{dP_a} = h_z\frac{\partial z^*}{\partial P_a} + h_a\frac{\partial a^*}{\partial P_a}$$

Substituting for $\partial z^*/\partial P_a$ and $\partial a^*/\partial P_a$ from (C.13) and (C.15) respectively, rewrite (C.22) as

$$\text{(C.23)} \qquad \frac{dh^*}{dP_a} = \frac{1}{|H|}\left[h_a\pi_{zz} - h_z\pi_{za}\right] \gtreqless 0$$

When P_a increases, the firm will employ less a given (C.14). A sufficient condition for (C.23) to be positive would be if the absolute value of $h_z\pi_{za}$ is less than the absolute value of $h_a\pi_{zz}$ or if $\pi_{za} \le 0$, that is z and a are substitutes or independent inputs.

III. Changes in Households' Remediation Efforts

A question of particular interest in this study is the impact of changes in households' remediation efforts on the firm's output and hazard production or hazard control behavior. The impact of changes in r on demand for z is given by

$$\text{(C.24)} \qquad \frac{\partial z^*}{\partial r} = \frac{1}{|H|} C_{hr} \left[h_z \pi_{aa} - h_a \pi_{az} \right] = C_{hr} \frac{dh^*}{dP_z} \gtreqless 0$$

$$\text{(C.25)} \qquad \frac{\partial a^*}{\partial r} = \frac{1}{|H|} C_{hr} \left[h_a \pi_{zz} - h_z \pi_{az} \right] = C_{hr} \frac{dh^*}{dP_a} \gtreqless 0$$

where $C_{hr} > 0$ by assumption; although (C.24) and (C.25) can not be signed as expressed, (C.25) is expected to be positive, if $\pi_{za} \leq 0$.

Differentiating (4.20) with respect to r yields

$$\text{(C.26)} \qquad \frac{dx^*}{dr} = x_z \frac{\partial z^*}{\partial r} + x_a \frac{\partial a^*}{\partial r}$$

Substituting for $\partial z^*/\partial r$ and $\partial a^*/\partial r$ from (C.24) and (C.25), rearranging the terms, and further substituting from (C.17) and (C.20) yields the following expression

$$\text{(C.27)} \qquad \frac{dx^*}{dr} = C_{hr} \left[h_z \frac{dx^*}{dP_z} + h_a \frac{dx^*}{dP_a} \right] < 0$$

given the assumptions about input normality and inferiority.

Vita

Salpie Sarkis Djoundourian was born in Beirut, Lebanon, on March 20, 1964. After graduating from high school in 1982, she started a course of study in Business Administration at Haigazian College. The civil war in Lebanon forced her to come to the United States to complete her education. She enrolled in Louisiana State University in the Spring of 1985. In May 1987, she received the Bachelor of Science degree in International Trade and Finance. In May 1989, she earned the Masters of Science degree in Economics. In December 1993, Ms. Djoundourian will be awarded the doctoral degree in Economics. Her primary area of expertise is Applied Microeconomics with strong emphases in Environmental and Natural Resource Economics and Public Finance.

DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Salpie Sarkis Djoundourian

Major Field: Economics

Title of Dissertation: The Distribution of Toxic Sources in Louisiana: An Analysis of Community Socioeconomic Characteristics and Industry Behavior

Approved:

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Dean of the Graduate School

EXAMINING COMMITTEE:

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