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A METHOD FOR ESTIMATING THE LOCAL AREA ECONOMIC DAMAGES OF SUPERFUND WASTE SITES

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ABSTRACT

A METHOD FOR ESTIMATING THE LOCAL AREA ECONOMIC DAMAGES OF SUPERFUND WASTE SITES

By

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National Priority List (NPL) sites, or more commonly called Superfund sites, are hazardous waste sites (HWS) deemed by the Environmental Protection Agency (EPA) to impose the greatest risks to human health or welfare or to the environment. HWS are placed and ranked for cleanup on the NPL based on a score derived from the Hazard Ranking System (HRS), which is a scientific assessment of the health and environmental risks posed by HWS.

A concern of the HRS is that the rank of sites is not based on benefit-cost analysis. Because of this concern, the main objective of this dissertation is to develop a method for estimating the local area economic damages associated with Superfund waste sites. Secondarily, the model is used to derive county-level damage estimates for use in ranking the county level damages from Superfund sites.

The conceptual model used to describe the damages associated with Superfund sites is a household-firm location decision model. In this model it is assumed that households and firms make their location choice based on the local level of wages, rents and amenities.

The model was empirically implemented using 1980 Census microdata on households and workers in 253 counties across the United States. The household sample includes data on the value and structural characteristics of homes. The worker sample

includes the annual earnings of workers and a vector worker attributes. The microdata was combined with county level amenity data, including the number of Superfund sites.

The hedonic pricing technique was used to estimate the effect of Superfund sites on average annual wages per household and on monthly expenditures on housing. The two equations were specified in log-linear form and estimated using the seemingly unrelated regressions model.

The results show that Superfund sites impose statistically significant damages on households. The annual county damages from Superfund sites for a sample of 151 counties was over 14 billion dollars. In addition, the ranking of counties using the damage estimates is correlated with the rank of counties using the HRS.

I dedicate this dissertation to my wife Hirae whose love and inspiration was valuable beyond measure.

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CHAPTER ONE: AN INTRODUCTION TO SUPERFUND WASTE SITES

1. INTRODUCTION

Hazardous waste is generated by industry, municipalities, mining operations and by hospitals and laboratories among other sources (Andelman and Underhill, 1987). The quantity of hazardous waste material generated annually by these groups is substantial. For example, in 1981, industry in the United States generated 264 million metric tons of hazardous waste (71.3 billion gallons) (CEP, 1986). In the past, these wastes would have been disposed of in open dumps or underground containers (Grisham, 1986). Presently over 99 percent is eventually placed in the ground in deep wells, surface impoundments, and lined landfills (CEP, 1986). In 1988, 2.3 billion pounds of toxic chemicals from major manufacturing facilities were transferred or released to air, water, or land (EPA, 1990). As of December 1990, 32,506 potentially hazardous waste sites were identified across the United States (EPA, 1990).

Among hazardous waste sites, National Priority List sites (NPL) or more commonly called Superfund sites, are considered by the United States Environmental Protection Agency (EPA) to be the most hazardous sites. These sites are considered to pose the most threat to human health, natural resources and the environment. Superfund sites are eligible to receive Federally mandated monies for cleaning up the site and repairing, restoring or acquiring equivalent natural resources. There are over 1,200 sites listed on the NPL as of January 1991.

The main objective of this study is to develop a method for estimating the local area economic damages caused by Superfund waste sites. Damage estimates can be used to prioritize the cleanup of Superfund sites and to provide measures of the interim damages caused by Superfund sites.

The remainder of this chapter describes recent legislation and regulation of Superfund waste sites, economic issues regarding Superfund waste sites, and finally the research objectives of this study.

2. RECENT LEGISLATION AND REGULATION OF SUPERFUND SITES

Congress in 1980 passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to deal, inter alia, with the hazardous waste problem. CERCLA enabled the federal government to respond to actual or threatened releases of dangerous substances at sites and facilities by undertaking cleanup actions, to administratively or judicially abate releases posing an imminent or substantial danger to public health or welfare or to the environment, and to recover damages for the destruction of or damage to natural resources. CERCLA also allows Trustees to conduct a cleanup or remedial action at a site and then recover the costs from responsible parties or from the Hazardous Substances Superfund or more commonly called Superfund (Wolf, 1988).

CERCLA was amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). SARA expanded and toughened the cleanup authority of the federal government and provided an increase in funds for the Superfund (Wolf, 1988). SARA set new standards for cleaning up contaminated and polluted sites and mandated the federal government to begin work at 375 sites within five years (Wolf, 1988). In addition, SARA stressed the use of permanent cleanup methods such as detoxifying hazardous wastes whenever possible, rather than burying wastes in landfills, or transferring them from one site to another (Wolf, 1988).

SARA increased the power of the federal government (EPA) in a number of ways. For example, the President may order a polluter to remove or control any hazardous substance endangering public health, welfare, or natural resources. SARA also retained and strengthened the authority of the federal government and members of the public to enforce the act's provisions and compel responsible parties to pay the costs of response actions and to reimburse the Superfund for initially financing these response actions (Wolf, 1988).

CERCLA requires the EPA to maintain a National Priority List (NPL) of hazardous waste sites with known or threatened releases. The NPL identifies abandoned or uncontrolled hazardous waste sites that warrant further investigation to determine if they pose a threat to human health or the environment (EPA, 1989).

The criteria for placing sites on the NPL is based on the hazard ranking system (HRS). This system is used by the EPA and others to evaluate the relative risk to human health and the environment posed by a site. The factors used in the HRS for ranking sites include: relative hazard to public health or the environment, taking into account the population at risk; hazardous potential of the substances at the site; potential for contamination of drinking water supplies; direct contact or destruction to sensitive ecosystems; damage to natural resources which may affect the human food chain; ambient air pollution; and a state's preparedness to assume the costs and responsibilities of cleanups (Hall et al. 1987).

A total score is derived for each site using the HRS. A higher score implies greater risk to human health and natural resources. Until recent regulation was passed, a minimum score of 28.5 was required to place a waste site on the NPL[1].

The purpose of Superfund is to finance government and private cleanup actions of Superfund sites and to pay claims for damages to natural resources (Hall et al. 1987). The claims for natural resource damage can only be claimed or recovered by a Trustee. The Trustee may be a federal, state or local official, or representative of an Indian tribe acting on behalf of the general interest of the public. Claims for natural resource damages cannot be recovered by an individual. Up to 85 percent of Superfund is to be devoted to the costs of removal and remedial actions while the remaining 15 percent can be directed to natural resource damages (Hall et al. 1987).

Trustees are entitled to recover up to $50 million above response costs for natural resource damages for each incident involving releases of hazardous substances. However, Congress can prohibit the use of Superfund monies for recovering natural resource damages if the EPA determines that all the money in the fund is needed for response actions (Hall et al. 1987).

In addition, Superfund monies can only be used to recover natural resources that are publicly held or for natural resources that are privately held but where the public has a substantial statutory, common law, or regulatory interest (Department of the Interior, 1991).

To assess natural resource damages, CERCLA requires Trustees to follow a four phase assessment procedure. The phases include preassessment, an assessment plan (which should be consistent with a reasonable cost criterion), damage assessment, and post-assessment. The damage assessment also has three phases: injury determination, quantification, and damage determination (Department of the Interior, 1991).

In the preassessment phase the Trustee is required to determine if an emergency exists with regards to potential injury of the natural resource[2]. If an emergency exists, and no liable party has responded to the emergency, then the Trustee is authorized to take limited action to abate the emergency situation.

Once an emergency action is completed, the Trustee performs a preliminary screen of available data to determine whether the damage caused by a release justifies the completion of a damage assessment. The Trustee can make this decision based on information from the site or from information that is readily available from standard research sources. If a damage assessment meets certain criteria the Trustee must completely document the decision to continue the assessment (Hall et al, 1987).

The purpose of the assessment plan is to ensure that the assessment is performed in a planned and systematic manner and at a reasonable cost (Hall et al, 1987). If the type B assessment is chosen then a damage assessment requires a detailed three-step approach[3].

The first step is the injury determination phase which is to establish that an injury has occurred to a natural resource and to link the injury to the release from a waste site. For purposes of damage assessment, natural resources are divided into five categories, including, surface water, ground water, air, geologic, or biological resources. Once an injury determination is complete, the Trustee must decide which economic methods will be chosen to estimate damages to the natural resource.

The second step in the damage assessment phase is to quantify the effects. That is, the Trustee converts the natural resource injury to a dollar amount by measuring the changes in the services provided by an injured resource as a result of the release.

The third step in the damage assessment phase requires the Trustee to estimate the amount of money to be sought as compensation for the natural resource injury. The measure of damages is the estimated cost for restoration, rehabilitation, replacement, and/or acquisition of equivalent resources, plus compensable value of the services that will be lost to the public through the period of recovery to the baseline conditions existing before the discharge or release. Compensable value encompasses all of the public economic values associated with an injured resource, including use values and nonuse values such as option, existence, and bequest values (Department of Interior, 1991).

Required in the third step is a Restoration and Compensation Determination Plan which should describe the restoration alternatives considered, the loss of services associated with each, and the estimated period of recovery associated with each alternative. Cost and valuation methodologies should also be described (Department of Interior, 1991).

With respect to valuation methodologies, all standard methods are admissible. Use values may be estimated using revealed preference methods: market price, travel cost, and hedonic price methods. According to the Department of the Interior, the contingent valuation method is the only nonmarket valuation methodology available that is capable of explicitly estimating non-use values (Department of Interior, 1991). However, Smith (1985) argues that the hedonic method can also be used to calculate nonuse values, specifically option price. In addition, there is a rebuttable presumption conferred upon natural resource assessments (Department of Interior, 1991).

Finally the post-assessment phase requires the Trustee to prepare a Report of Assessment which includes documentation and support for decisions made during the assessment (Hall et al, 1987).

Superfund provides no compensation for health effects (personal injury or death) caused by hazardous waste but it can be used to cover the costs of related health studies (Wolf, 1988). However, CERCLA has a provision that allows individuals who are suffering from latent illnesses caused by exposure to hazardous substances to sue liable parties without a time limit, since the damage caused by the exposure often occurs long before the symptoms become apparent (Wolf, 1988).

Recently, however, a number of States have enacted or attempted to enact Amendments or Acts that would provide funding for not only environmental damage but also for personal injury (NCPA, 1986). In 1985 Minnesota enacted an Amendment to the State Superfund Act that allows compensation for all damages for death, personal injury or disease including medical expenses, rehabilitation costs, burial expenses, loss of earning capacity, loss of past or future income, and damages for pain and suffering (NCPA, 1986).

On the other hand, the Michigan legislature passed in 1982 the Michigan Environmental Response Act (Public Act 307) which does not fund health related damages. However, the Act allows for recovery of response activities, fines, and exemplary damages, plus up to 50 million dollars in damages for injury to, destruction of, or loss of natural resources resulting from the release or threat of release, including the reasonable costs of assessing the injury, destruction, or loss resulting from the release or threat of release.

3. ECONOMIC ISSUES REGARDING EXISTING HAZARDS

Hazardous wastes impose economic damages on individuals and households (Kohlhase, 1991). Damages arise as the environment is contaminated by hazardous wastes. A degraded environment may require cleanup of polluted water and soils and repair to the natural environment. In addition, human health may be adversely affected by hazardous wastes consumed in contaminated water supplies or by ingestion of food contaminated by hazardous wastes.

Reducing or mitigating damages caused by hazardous waste benefits those individuals who were affected by the wastes. However, an important question is whether the costs of cleaning up a hazardous waste site and repairing the natural environment are outweighed by the benefits. This leads to three economic questions related to Superfund site assessment procedures discussed in section two.

First, in the assessment damage phase, the Trustee is required to quantify the interim damages from Superfund sites. This implies that readily available methods be available to estimate the interim damages. Thus tools for estimating the economic damages caused by Superfund sites need to be developed.

Second, as mentioned earlier, in the preassessment phase a Trustee must determine whether the damage caused by a release justifies the completion of a damage assessment. This implies there is a need for estimating if economic damages from Superfund waste sites are statistically significant, significant in size and if the estimates are reliable. Readily available economic damage estimates of Superfund waste sites can reduce the time and costs for assessing whether it is beneficial to complete a damage assessment.

Third, Superfund sites are given a HRS score. Priority for cleanup is based mainly on the HRS score. However, there is controversy over the relationship of the HRS and the economic damages caused by Superfund sites (Hird, 1990). It could be that a higher ranked Superfund site has smaller economic impacts than a lower ranked site or the cost of cleaning up a lower ranked site is much smaller, resulting in greater net benefits if the lower ranked site is cleaned up first. Thus to increase the benefits generated from the use of Superfund monies, economics should be considered in ranking sites for cleanup as well as appropriating money for restoring natural resources that were damaged.

4. RESEARCH OBJECTIVES: DEVELOPING A METHOD FOR ESTIMATING ECONOMIC DAMAGES

The first objective of this study is to develop a method for estimating the local area economic damages of Superfund sites. The economic damage estimates obtained from the method are one set of damages caused by Superfund sites - the local area economic damages. Nonuse values as well as use values of noncounty residents are not estimated using the method developed in this study. Estimates of local area economic damages can be one set of damages used in the preassessment phase to estimate the interim damages caused by a release of chemicals from a Superfund site.

The conceptual model used in this study for developing the method is a residential location model. The residential location model uses the change in individual wages and land rents across space to estimate the damages of Superfund sites.

It is expected people will prefer to locate in high rather than low amenity counties. In high amenity counties land rents are bid up and wages are bid down as households move to these counties. Adam Smith (1776) noted over 200 years ago that many factors affect the level of wages and rents paid. Wages are affected by the agreeableness or disagreeableness of the job, the easiness and cheapness, or the difficulty and expense of learning the job, the constancy or inconstancy of employment in the particular kind of job, the amount of responsibility required of the job, and the probability of success in the job. Rent is affected by things such as the fertility of the land. According to Adam Smith, amenities also affect the level of both wages and rents. For two counties that are identical except for the presence of a Superfund hazardous waste site, it is expected that lower land rents and/or higher wages would be necessary to induce households to remain in the area, once the waste is discovered. This implies that the benefits of protecting human health and natural resources can be estimated from this model by the compensating changes in wages and rents due to different numbers of Superfund sites across counties.

To estimate the changes in wages and rents across counties in response to the presence of Superfund sites, the hedonic pricing technique is applied. The data to empirically implement the residential location model is the 1980 U.S. Census Public Use Microdata A Sample combined with county level amenity data.

A second objective is to use the economic damage estimates to rank the priority of cleanup of Superfund sites. The ranking of Superfund sites using the damage estimates is compared to the EPA's ranking of Superfund sites using the HRS. Prioritization for cleanup, repair and compensation for injury to natural resources is based on the economic damages caused by Superfund sites.

CHAPTER TWO: LITERATURE REVIEW OF STUDIES ESTIMATING THE ECONOMIC DAMAGES OF SUPERFUND SITES USING THE HEDONIC PRICE METHOD

1. INTRODUCTION

The objective of this chapter is to review the hedonic price method as a technique for estimating the economic damages of Superfund waste sites. The review is divided into two sections.

Section one describes the hedonic price method and the welfare significance of price measures derived from the hedonic technique. The literature provides evidence that valid price measures of amenities can be derived from the hedonic price method.

Section two reviews research that has used the hedonic price method to estimate the economic damages of Superfund waste sites. The data, methods, and results of these studies are detailed.

By reviewing these studies characteristics common among the studies can be identified and if appropriate incorporated into an empirical model. In addition, the economic damages from Superfund sites estimated in the reviewed papers are compared to the economic damages estimated in the present study.

2. THE HEDONIC PRICE METHOD

There is a large literature on the use of the hedonic price method to estimate the value of amenities as well as other nonmarket goods[1]. The hedonic pricing method is simply a way to decompose the price of a good into the prices of the good's attributes. In this section, the analysis focuses on the decomposition of wages and rents into their component prices.

The output of the hedonic price method is a price function, or a rent or wage gradient which relates value to the quantity and/or quality of the amenity or disamenity (Freeman, 1979a). The following example demonstrates how a marginal implicit price for an amenity is derived.

Assume for example that the price of a home, r, is a linear function of n characteristics (z_i, $i=1,2,...,n$). Regressing r on the n characteristics results in equation 1:

$$(1)\quad r = a_o + a_1 z_1 + ... + a_n z_n + u,$$

where a_1 through a_n are the estimated coefficients of the n characteristics and u is an error term. The estimated coefficients are the marginal implicit prices of the house characteristics[2]. For example, the marginal implicit price of z_1, $\partial r/\partial z_1$, is a_1. The marginal price paid is the actual payment for the increased quantity of the characteristic.

Three assumptions are required to accurately estimate the value of an amenity using hedonic analysis (Freeman, 1979a, 1979b and Bartik and Smith, 1987). First, the amenity must be exclusive to the market transactions under examination. For example, the value of the amenity must be captured only by changes in rents if the hedonic property price model is used. Other markets, such as the labor market must not capture any amenity value with changes in the amenity across space, otherwise the hedonic property price model will provide biased results. The same is true if the labor market is being used to capture the value of an amenity. The main point is that the value of an amenity cannot be captured by looking at a single market (housing or labor) if more than one price (wages and rents) is involved in compensation.

Second, the impact of the amenity must be observable by some portion of the households in a locality. If all households are unaware of the existence of the amenity in their community then price differentials will not occur in the housing or labor market. In addition, some portion of households should be aware of the amenity in other communities they would consider relocating to for price differentials to occur in the labor and housing markets.

Third, some portion of the households must have the opportunity to choose among various quality or quantity levels of the amenity. If no household can choose among the amenity levels then price differentials are not expected to occur in the markets.

3. A REVIEW OF SUPERFUND WASTE STUDIES

A number of studies have estimated the economic effects that Superfund waste sites impose upon households using the hedonic price method. This section reviews these studies and compares data, methods, and results (Table 2.1).

Adler et al. (1982) used the hedonic property price method to estimate the economic damages caused by hazardous waste sites in two different communities. These

Table 2.1 - Hedonic Models used for Estimating the Damages of Superfund Waste Sites

Study	Objective and Data	Variables	Annual Benefit Estimate of removing a site per household (1990 dollars)
Adler et al., 1982. Examined one hazardous waste site in Pleasant Plains, NJ. The site contaminated the upper portion of two aquifers. Chemicals at the site include aromatic hydrocarbons, benzene and toluene among others. They also looked at a hazardous waste site in Andover,MN. Barrels of solvents, inks, paints, glues and grease were leaking. At Andover contamination onlyy occurred in wells located on the property where the site is located.	Determine whether if the social costs imposed by hazardous wastes are reflected in property values. Sales of 675 homes in Pleasant Plains from 1968 to 1981 and Sales of homes in Andover from 1978 to 1981.	Dependent variable: natural log of the selling price of the home. Independent variables: -structural characterisitcs -neighborhood characteristics -date of sale -distance variables were used to proxy the effect of the hazardous waste sites. Distance variables expected to capture both health and environmental risks. -Zone of contamination variables were used separately from the distance variables to capture both health and environmental effects of the sites in Pleasant Plains only.	In Pleasant Plains, $1,992 if 1.75 miles away to $7,269 if less than half a mile. The value of a residence 1.5 to 1.75 miles from a site sold on average 6 percent more than a residence within one-half mile. The damage estimates for Andover were not statistically significant from zero.
Harrison and Stock, 1984. The authors included in their analysis eleven sites located in the Boston, MA area. Sites contained toxic organic compounds or their equivalents. The size of the sites ranged from one acre up to 400 acres.	Estimate the benefits of removing the hazardous chemicals from a site. Sales of 2,182 individual homes in the Boston Metro area for years 1977-1981.	Dependent variable: natural log of the selling price of the home. Independent variables: -employment access -structural -the inverse square of the distance of a home to each site and the inverse square of the distance of a home to each site weighted by the area of the site proxies health effects. -environmental effects were proxied by the the number of nonhazardous and hazardous sites at one-half mile increments around a home. -neighborhood	The damage estimates were based on coefficient estimates that were not statistically significantly different from zero. $15 to $70 depending on the site. For a $100,000 residence willingness to pay for cleanup of a site 1.5 miles away is $1,600 versus $13,500 if one-half mile away.

Table 2.1: Hedonic Models used for Estimating the Damages of Superfund Waste Sites, Continued

Study	Objective and Data	Variables	Annual Benefit Estimate of removing a site per household (1990 dollars)
Mendelsohn, 1987. Waste site is the Boston harbor where PCB's were found in the sediment. Portions of the harbor were closed to certain activities.	Estimate the economic damages of PCB pollution in New Bedford harbor, Massachussetts. Sale of single family homes from 1964 to 1984 within 2 miles of the habor for three cities.	Dependent variable: sale price of the home Independent variables: -structural -neighborhood -access -waste pollution zones expected to proxy both environmental and health effects.	Not applicable since author found no significantly different effect on housing price after the contamination as versus before the contamination incident using the hedonic property price model.
McClelland et al. 1990. Examined impact of a waste site that covered 190 acres and contained 30 million cubic yards of refuse.	Estimate the impact of a Superfund site using a health risk variable. The sale of 178 homes from August 1983 to November 1985 in the Los Angeles area.	Dependent variable: Sale price of the home Independent variables: -neighborhood -structural -an aggregated neighborhood health risk belief variable to capture health effects.	Results were statistically significant from zero. $11,897 before closure and $5,822 after closure of the site for a $135,000 dollar residence.
Michaels and Smith. 1990. Used same eleven sites as found in Harrison and Stock.	Estimate the benefit of cleaning up or removing a site. That is, the site would no longer exist. The annual sales of homes in the Boston area for years 1977-81.	Dependent variable: natural log of the sale price of the home. Independent variables: -neighborhood -structural -town effect dummies -time dummies -distance to nearest waste site proxies both health and environmental effects. -distance to nearest site interacted with time dummies to capture announcement effect.	$248 to $300 for the removal of a site. Results based a on full market analysis which were statistically significant. Estimates using the submarkets bracket the estimate from the sample. The coefficient estimates are generally not significant for the submarkets.

Table 2.1: Hedonic Models used for Estimating the Damages of Superfund Waste Sites, Continued

Study	Objective and Data	Variables	Annual Benefit Estimate of removing a site per household (1990 dollars)
Kohlhase, 1991. Looked at seven sites containing various types of chemical contaminants. Size of sites ranged from 1 acre up to 56 acres.	Estimate the impact of listing a site on the NPL. The sale of homes in the Houston, Texas area for years 1976, 1980, and 1985.	Dependent variable: natural log of the house price. Independent variables: -structural -time period dummies -neigborhood -distance to nearest toxic waste site proxies both health and environmental effects.	$377 for the removal of a site. Estimate was for 1985 time period data. Estimate is statistically significant from zero. The coefficient estimates of the distance variables were not significant in 1976 but were significant but of the"wrong" sign in 1980.
Hoehn et al., 1987 and Blomquist et al., 1988. Looked at Superfund sites.	Derive unbiased method for estimating amenity values and estimate the quality of life in selected U.S. counties. Data on 34,414 households and 46,004 workers form 1980 Census data.	Dependent variables: average hourly earnings and monthly housing expenditures. Independent variables: -structural -neighborhood -climatic -environmental -socio-economic -number of Superfund sites proxies health and environmental effects.	$168 to remove a site from the county. Superfund site variable was significant. However, licensed waste sites were not statistically different from zero.
Nieves et al., 1991. Included Superfund sites, and two currently operating commercial facilities for disposal of low-level radioactive waste.	Estimate the impacts on social welfare caused by noxious facilities. Data on 60,404 households and 25,279 workers from 1980 Census data.	Dependent variables: annual wages plus other income and the value of the home. Independent variables: -structural -socio-economic -climatic -disequilibrium -instrumental -density of the number of hazardous waste sites proxies health and environmental risks. Density is the number of these sites per 100 square miles.	Damage estimates were not statistically significant from zero for the hazardous waste site category.

sites were not Superfund sites since the NPL did not begin until 1982. However, this study is included since it is often quoted in the literature and later studies incorporated many of the same methods used by Adler et al.

After a thorough search for an appropriate location with which to estimate the damages of hazardous waste sites, Adler et al. chose two cities with hazardous waste sites; Andover, Minnesota, and Pleasant Plains, New Jersey. These two cities were chosen for several reasons. One reason is that their populations are relatively homogeneous with respect to income, race and education. The authors point out that in deriving welfare loss estimates it is assumed that tastes and income are identical for all households. A second reason is that both cities have large residential populations located close to the sites. They expect this would produce sufficient turnover of residential property so as to have useable data. Third, the cities have no other major source of disamenities, thus it is easier to isolate the effects of the hazardous waste sites. Finally, households have information or knowledge of the site.

Another reason why Pleasant Plains was chosen is that actual widespread contamination of private wells was discovered and announced in 1974. That is, contamination of groundwater in the upper portion of two aquifers occurred. The contamination occurred when an illegal dumping operation took place on a former chicken farm near Pleasant Plains during a 10-month period in 1971. The chemicals dumped at the site included aromatic hydrocarbons, benzene, toluene, styrene, xylene, ketones, alcohols and phenolic resins.

The authors chose the Andover site because it is an example of a site for which there was more of a threat of further contamination than actual contamination at the time of the study. The waste site, owned by an individual, had many barrels of waste solvents, paints, inks, glues, and grease that had deteriorated and had begun to leak before they were moved to another location.

Data from county assessment offices was obtained for Pleasant Plains for the years 1968 to 1981. There were 675 observations on the sale price of homes. For Andover, 250 observations were collected for the years 1978 to 1981.

Analysis of the two cities differed. For Pleasant Plains, cross-section regressions were estimated for before the contamination incident and after the contamination incident (1974). This was done to test the hypothesis that the hedonic rent gradient before the contamination was different from the hedonic rent gradient after the contamination incident. For Andover, a regression was estimated using data after the site was discovered by local authorities.

The dependent variable in the regressions is the sale price of the home. The independent variables include a vector of lot and housing characteristics, locational or neighborhood characteristics, date of sale and variables for distance from the site. The regressions were estimated in log-linear form.

Distance variables were used to proxy the effect of the hazardous waste sites. The distance variables were specified as 11 1/4 mile dummy variables. Each dummy represents the observations inside one of 11 concentric circles each 1/4 mile apart. The distance extended out two and a half miles from the site.

For Pleasant Plains, an alternative model was also specified where, rather than using just the above discrete distance measures, the waste variable was a designated contamination zone. Two zones were identified. Zone 1 was the area where households were asked to seal their wells after the contamination was detected. Zone 2 was the area where households were ordered to dig deeper wells.

Thus, only one hedonic regression was estimated for Andover, which has a distance variable proxying the hazardous waste site after it was discovered by local authorities. On the other hand, four regressions were estimated for Pleasant Plains, a pre- and post-contamination event for the two specified models, the distance model and contamination zone model.

The results for Andover show that the coefficients on the dummy distance variables were not statistically significant at the 95% level and not of the expected sign. That is, the negative sign on the dummy distance variables imply that distance from the site is negatively correlated with property prices. Apparently the existence of contamination had triggered no local differences in property values. According to the authors this was probably due to the fact that Andover draws on a different aquifer than the aquifer at risk and the contamination that did occur was not substantial and was limited to wells located on the same property as the waste site. In addition, the existence of a municpal landfill one-half mile north of the site reduced the ability of the model to capture the disamenity effect of the hazardous waste site. Other variables in the regression were generally significant. The adjusted R^2 was 0.656. As noted earlier, Andover was included in the analysis to test if the "threat" of contamination to water supplies causes property price differentials to arise in the housing market.

The results for Pleasant Plains with respect to the zone of contamination formulation was not significant with an adjusted R^2 of .911. The authors speculate that this may be due to the boundaries of zones overlapping areas that are more highly valued. That is, the zones are capturing effects other than that caused by the waste site.

With respect to the distance formulation for Pleasant Plains, the pre-contamination results on the distance variables were not significant as expected, while the post-contamination distance variables were significant. The adjusted R^2 for the pre- and post-contamination regressions were .788 and .892 respectively. In fact, the authors speculate that the post-contamination estimates might have been even larger if not for three events. One event was that the local government responded quickly to cleaning up the contamination soon after the contamination was discovered. Second, public water supply hookup for private well owners occurred one month after the date of discovery. Third, no demonstration of contamination had occurred since 1976. In addition, the existence of a landfill nearby may be reducing the size and significance of the hazardous waste variable.

Using the post-contamination distance model results for Pleasant Plains, economic damages in 1990 dollars were estimated to range from $7,269 per household if the household is located close to the site (less than half a mile), down to $1,992 per household if the household is located 1.75 miles from the site. In addition, a residence 1.5 to 1.75 miles from the site sold on average for six percent more than a residence within one-half mile of the site.

Harrison and Stock [HS] (1984) applied the hedonic property value model to estimate the benefits of cleaning up hazardous waste sites in the Boston area. Their model attempts to measure health and aesthetic damages associated with hazardous and nonhazardous waste sites. Health effects, caused by hazardous waste sites, result from drinking contaminated water, breathing contaminated air, coming in contact with contaminated soil, or experiencing the results of an explosion or fire at the site. Aesthetic effects from hazardous and nonhazardous sites include unsightly visual impacts, noise, traffic or odor. The aesthetic effects would not be eliminated in their model even if the hazardous wastes at the site is removed because even though the hazardous wastes are removed the nonhazardous characteristics of the site remains, such as noise and visual effects of the site. The benefits of cleaning up hazardous sites in their model are therefore characterized by the elimination of adverse health effects. That is, the hazardous site becomes nonhazardous.

Eleven sites in the Boston area were identified as containing hazardous material. Most of these sites were on-site lagoons used to store process wastes. One of the sites was identified as hazardous because it contained a variety of halogenated and aromatic organic compounds which are listed as toxic under the Resource Conservation and Recovery Act. The authors chose the other ten additional sites because they were judged to be equivalent in toxicity to the first site based on the rating scheme used for the Superfund. The size of the sites in acres were 1, 4, 5, 10, 10, 25, 30, 180, 200, 300, and 400.

HS empirical results were based on housing transactions for single family detached residences in the Boston Metropolitan area. Data for 2,182 individual housing tracts for November 1977 to March 1981 were collected. In their analysis the dependent variable was the actual selling price of the home in 1980 dollars. OLS was applied to a log-linear hedonic price equation with the natural logarithm of the selling price of the home as the dependent variable.

The independent variables included four employment accessibility variables, fourteen structural attribute variables such as square feet of living space and lot size, three neighborhood variables such as the full property tax rate, two amenity variables, a number of health and aesthetic risk variables and fixed effect and time variables.

Two variables were constructed to represent the risk of health effects from hazardous waste sites. One variable was the inverse square of the distance of an individual's home to each site (RISK1). The second variable was the inverse square of distance of the individual's home to the site weighted by the area of the site (RISK2). According to the authors these variables were intended to proxy the decrease in chemical mass from the site to distances further from the site and are expected to capture the risk of human contact with the toxic chemicals found at a hazardous waste site.

To control for the aesthetic disamenity effects of waste disposal sites (noise, traffic, odors) the authors included as independent variables the number of sites (non hazardous sites, industrial sites and landfills) at one-half mile increments from 0.0 to 2.5 miles around the house. The sites include 41 non-hazardous industrial sites that stored wastes on-site and 49 commercial and municipal landfills in the Boston area. The industrial sites are similar to the hazardous sites except in the composition of the wastes and thus represent a good approximation to a hazardous site after cleanup. That is, the industrial character of a site would remain but no hazardous material would be present. Thus the authors expect the disamenity effects of hazardous sites can be captured by the distance to nonhazardous sites. That is, authors assumed that aesthetic effects from waste sites occur whether they are hazardous or not. Therefore, what they estimated were the aesthetic impacts of non-hazardous waste sites on households.

One problem the authors failed to recognize is that their health risk variables may also capture disamenity affects of hazardous waste sites. That is, as distance from the site increases, it is expected that noise, dust etc. would decrease. Thus, their health variables may capture some of the environmental damages of hazardous waste sites. This may affect the size and sign of the estimated health effects.

Due to a lack of data on neighborhood characteristic variables, the authors included town dummies in the equation to account for omitted neighborhood characteristics. In addition, to control for the fact that their observations occurred over a five-year period during which interest rates and other common influences on housing prices varied widely, they included dummies for the quarter in which the sale of the home occurred. In other words, they controlled for time effects.

Finally, to account for the fact that the presence of a hazardous waste site might interact nonlinearly with the house price itself, they included interaction terms in which the two hazardous waste health variables, RISK1 and RISK2, were multiplied by a predicted price obtained from an initial regression.

Using OLS, the adjusted R-squared statistic for the estimated equation was 0.80. The results for the estimated coefficients displayed the expected sign for structural variables and neighborhood variables. The estimates were statistically significant. Coefficients for the accessibility variables had the expected signs but were not statistically significant. The estimate of the coefficient for the town dummy variable was significant whereas the estimate of the fixed effect (time) dummy was not significant.

The estimates for aesthetic coefficients were positive rather than negative, except for waste sites 2.5 to 3.0 miles from the place of residence, however, the estimated coefficients were not statistically significant (t-statistics ranged from -0.74 to 1.72). HS explanation for this result was that proximity to waste sites proxies local accessibility advantages that are not accounted for by their area-wide accessibility measures. They concluded that advantages of proximity to industrial centers outweigh the aesthetic disadvantages.

The health damage coefficients were positive and insignificant (t-statistics for RISK1 and RISK2 were 0.46 and 0.36, respectively). The interaction terms were negative as expected since the interaction terms reflected an increasing marginal value of waste cleanup as predicted house price rises. However, these interaction terms were insignificant with t-statistics of 0.46 and 0.38.

HS estimated the total benefit of cleaning up a single hazardous waste site in the Boston area ranged from $3.6 to $17.4 million dollars (1980 dollars), depending on which site was cleaned up. In 1990 dollars the benefit ranges from $5.7 to $27.6 million dollars. The benefit was $15 to $70 (1990 dollars) per year per household depending on which site would be cleaned up. The authors noted that for a $160,000 house, the willingness to pay for cleanup of a site 1.5 miles away in 1990 dollars is $2,540; if the site is only one-half mile away the estimated willingness to pay increases to $21,415. Note that these willingness to pay estimates were calculated from their basic equation even though the coefficients were not significant. This implies that their benefit estimates probably should be ignored.

HS point out that their benefit estimates are imprecisely measured because of the 2,182 observations in the data set only 515 of the observations have a hazardous waste site within four miles of the house. In addition, the benefit estimates vary due to differences in the size of the site and the location of the site. Some locations have a relatively dense population with expensive homes while other locations are less densly populated with lower housing prices.

HS developed an alternative econometric approach to the health risk variables since the specification of these variables implies a specific functional form for the distance from the site and the willingness to pay to remove its toxic materials. Instead, similar to the aesthetic variables, they estimated a less restrictive series of equations adding variables based on the number of hazardous waste sites falling in half-mile rings. To obtain a nonparametric estimate of the effect of distance on the willingness to pay, they varied the distances at which the half-mile rings began. That is, they did not assume a restrictive set of distributions concerning the health data, instead they allowed the distance of waste sites from a home to vary. Four regressions were run, with the second ring respectively beginning at 0.125, 0.250, 0.375 and 0.5 miles. The coefficients on these new variables provide a semiparametric estimate of the benefits of cleaning up a site at a given distance. For example, the benefit of cleaning up a site 1.5 miles away is given by the coefficient on the waste variable representing the ring from 1.25 to 1.75 miles.

The results of the semiparametric estimation procedure confirmed the implication of HS basic equation that the value of cleaning up a hazardous waste site is substantial for houses near the site (no statistical results were provided). However, this value declines sharply with distance and becomes negative for distances greater than one mile. The authors suggested that this negative value occurs because the variables are picking up the effect of omitted beneficial aspects of proximity to the sites. Therefore, the authors concluded that the benefits estimated using the semiparametric technique may underestimate the true value that households place on removing toxic material. HS did not provide regression estimates for the semiparametric specification thus it is difficult to make judgements about their results. The basic equation is the preferred estimating technique.

The objective of Mendelsohn (1988) was to estimate the economic damages of PCB pollution in New Bedford harbor (Massachusetts) on nearby households. PCB's were discovered in the harbor in 1976, and in 1979 the harbor was closed to numerous uses. The author assumes that the "pollution" event date was January 1, 1981, since most residents would have knowledge of the event by that date[4].

Mendelsohn used three different techniques for estimating the effect of hazardous waste on housing values. The approaches were the hedonic approach, the repeat sale approach and the fixed effect approach. The repeat sale approach uses previous sales as a point of comparison. That is, the repeat sale approach uses pairs of sales for the same house to control for house to house variation. The premise of repeat sale is that housing characteristics which do not change will continue to have the same price.

The fixed effect approach uses the mean of the full set of sales for each house to control for unwanted variation. Both the fixed effect and repeat sale approach take advantage of their panel data structure and control for differences by examining changes in prices for the same house. All three approaches assume: 1) Differences in sales values between homes can be explained by the difference in the qualities of the home and 2) homeowners will pay more for homes which are closer to a valued amenity and this price differential reflects the marginal value of the amenity. However, only the regression estimates for the hedonic results from Mendelsohn's paper will be discussed.

The data used to implement the hedonic model are sales of single family homes from 1964 to 1984 within 2 miles of the harbor for the towns of Fairhaven, Dartmouth, and New Bedford. Hedonic regressions were estimated for before and after the pollution event (1981).

The dependent variable in the regressions is the sale price of the home. The independent variables include structural variables, neighborhood variables, access variables and the waste pollution variables which are zones of pollution.

Three zones of pollution were identified. PCBZONE1 is the most polluted zone and is the inner harbor where no swimming, fishing, or lobstering is permitted. The next most polluted zone is the proximate outer harbor PCBZONE2, where there are some restrictions on fishing and lobstering. PCBZONE3 represents the outermost zone which is considered unpolluted. In every case, the author tied houses to the quality of water nearest them. Thus, as the author points out, the pollution variable does not reflect pollution on each property but rather the proximity of the house to water sediments which may contain PCB's.

Mendelsohn's hedonic model was estimated using OLS for both the linear and semilog functional form. In addition, hedonic regressions were estimated for before and after the pollution event.

The R^2 on the linear and semi-log pre-pollution event (before 1981) regressions were .51 and .48 respectively. In addition, the coefficients on PCBZONE1 and PCBZONE2 were significant. The t-statistics were 1.93 and 5.45 for the linear form and 1.23 and 6.48 for the semi-log specification. These results imply that the loss for a household (1987 dollars) located near PCBZONE1 is $6,194. The loss for being near PCBZONE2 is $9,882.

The R^2 on the linear and semi-log post-pollution event were .53 and .62 respectively. The t-statistics on PCBZONE1 and PCBZONE2 for the linear form were 0.09 and 1.10 respectively and for the semi-log specification were 0.59 and 5.87

respectively. The regression results imply that the value of a home located near PCBZONE1 is $600. The loss for being located near PCBZONE2 is $3,720.

These results imply that damages actually decreased after the post-pollution event. The author speculates that the pre-pollution event variables may have been capturing the influence of omitted variables or possibly another disamenity. Another potential reason for this result is his specification of the pollution date. It may be that the majority of households were aware of the site before 1981 and over time may have adjusted to the contamination incident.

McClelland et al. (1990) estimated the impact of a Superfund site on households using the hedonic property price model. The uniqueness of his study is that a neighborhood risk variable was used to capture the effect of the site. This is in contrast to most studies which attempt to use some type of distance variable as a proxy for the site.

Data was obtained on the sale price of homes in the Los Angeles metropolitan area located near the site. The sale price of 178 homes from August 1983 to November 1985 were collected. The landfill site was closed in late 1984. At the time of its closing, it was proposed for inclusion on the NPL. The site covers 190 acres and contains approximately 30 million cubic yards of refuse. Nearby residents felt problems associated with the site included possible health problems associated with the site, leachate disposition, migrating gas, landfill use after closure, and property devaluation. However, California department of health experts found no indication of serious health effects caused by the site. In addition, they do not expect major health problems in the future.

In the hedonic regression, the dependent variable is the sale price of the home. Independent variables included proximity to a major freeway, square footage of the home, sale date of the home, if the home had a pool, and a health risk variable to capture the effects of a waste site on the sale price of the home.

The health risk variable is an aggregate estimate of the collective neighborhood risk judgment of the site. The health risk estimate was obtained from a survey of 768 households in which each household was asked to assess the risks of living near a waste site. The risk was the number of deaths per million individuals. A risk ladder was used to help the individual identify comparable risks. A response of 500 deaths per million individuals at risk from the site placed the respondent in the high risk group.

Based on the survey, the area surrounding the site was divided into neighborhoods. Approximately 10 to 15 respondents from the survey were included in each neighborhood. For each neighborhood, the proportion of responses from the survey that fell into the high risk group were calculated. This calculated percentage for each neighborhood was used as the proxy for estimating the damages of waste sites. The mean neighborhood risk proportion in the high risk group before the site closure was 47 percent and after closure was 23 percent.

Using OLS for the semi-log specification of the hedonic equation, the R^2 was .81 and the t-statistic on the neighborhood risk estimate was -2.73. This implies that for each increase of 10 percent in the proportion of neighborhood respondents in the high risk group, house prices in the neighborhood decreased on average by about $2,084 (1985 dollars). Closing the landfill increased the average house value ($135,000) by approximately $5,001. Even after closing the site, house prices are approximately $4,793 lower than they would be if there were no health risk beliefs.

The authors speculate that the health risk beliefs on sale price may have been even greater if not for measurement error and if buyers were more aware of the landfill and its problems.

Michaels and Smith [MS] (1990) used the hedonic property value approach to estimate the benefits of removing hazardous waste sites from the greater Boston area. A key point in their paper is the assumption of separate housing submarkets in the Boston area rather than the assumption of a single market as had been done in previous studies. In addition, MS contended that distance between a home and a landfill with hazardous waste can serve as a proxy for two effects - the disamenity associated with landfills in general and the heightened perception of risk when hazardous wastes are present.

The authors used the same eleven hazardous waste sites as described in Harrison and Stock (1984). As of 1984, four of the sites had been included on the NPL. In addition, they used the same data on house sales as Harrison and Stock - sales prices for 2,182 single-family homes between November 1977 and March 1981. The main focus of their study is not to repeat the Harrison and Stock study but to attempt to show that segmentation occurs in the housing market which affects valuation of hazardous waste sites.

In their estimated equation, Michaels and Smith included the natural logarithm of the deflated sale price (1977 dollars) of the house as the dependent variable. Independent variables included linearly into the equation were structural characteristics, distance to landfill, and neighborhood characteristics. Three variables were used to specify the effect of hazardous waste sites on households. One of these waste variables was the distance to the nearest waste site (MINDHW). The other two waste variables were interaction variables.

One interaction variable is the multiplication of MINDHW by TIME1, a dummy variable, where TIME1 attempts to capture the short-term response to announcements of hazardous waste sites. This short-term response was specified as six months after the discovery of the waste site. The second interaction variable is the multiplication of MINDHW by TIME2, where TIME2 is a dummy variable for sales after the end of the six month discovery period.

The authors estimated one full sample hedonic price function, which included all 2,182 observations. They also estimated four separate hedonic price functions for housing submarkets identified by housing realtors in the Boston area. The submarkets were classified as premier, above average, average or below average.

Using ordinary least squares, the results showed that the full sample hedonic price function performed best overall. It had an adjusted R-square of 0.626. The signs on the coefficients were as expected and were generally statistically significant. The t-ratios for MINDHW, TIME1*MINDHW, and TIME2*MINDHW were 1.288, 4.213, and 6.901 respectively. The hedonic price function for the premier, above average, average, and below average submarkets had adjusted R-squared statistics of 0.72, 0.67, 0.56, and 0.56 respectively. However, estimated coefficients tended to be not significant and not always of the expected sign in the submarket hedonic functions. T-ratios for the four submarkets for the variables MINDHW, TIME1*MINDHW and TIME2*MINDHW ranged from -3.348 to 0.369, -0.877 to 2.26, and -1.195 to 7.229, respectively.

However, a Brown-Durbin-Evans test (cusum of squares statistic), an independent statistical test for estimating the stability of the hedonic function, implied that a single hedonic price function was not adequate for describing the determinants of the real sales prices in suburban Boston. That is, the Brown-Durbin-Evans test implied that they misspecified their equation by assuming a single housing market.

In addition, a Tiao-Goldberger test is used to determine if there are distinguishable differences in the hedonic price functions across markets. The results of the test suggested that most of the independent variables have significantly different effects on real prices in the different submarkets. In addition, all of their distance measures had significantly different effects across markets.

Finally, Michaels and Smith estimated the marginal willingness to pay to remove a hazardous waste site in 1977 dollars for the full sample and for three of the submarkets with plausible estimates. The estimates ranged from $38 to $1799 dollars per year per household depending on the housing submarket. In this case, the removal of a site is the equivalent of an increase in the distance to the nearest source of hazardous waste exposure. They pointed out that a simple average of the benefit estimates across submarkets is $139 versus $115 for the full sample estimate in 1977 dollars ($300 versus $248 in 1990 dollars).

Based on their submarket estimation, Michaels and Smith concluded that any distance/timing measure is a poor proxy for a household's perceptions of the disamenity and risk associated with hazardous waste sites. The distance measures may be capturing other amenities or disamenities present in the towns that are difficult to measure. In addition, if households expect the town to respond quickly and effectively to contamination events there is less likelihood that the market will exhibit premia for homes with increased distances from landfills with hazardous wastes. Also they contended that identification of distinct submarkets can help characterize the influence that specific housing or site attributes have on equilibrium prices.

One problem specifically analyzed in the Michaels and Smith article is the assumption that there is one hedonic price function for an urban area, a contention made by Freeman (1979b). If an urban area actually consists of several different submarkets then one should be estimating hedonic price functions for each submarket rather than one hedonic price function for an entire market. However, according to Freeman at least two conditions must be met for different hedonic price functions to exist in an urban area. First, there must be some barrier to the mobility of buyers in each submarket so that buyers in one submarket cannot participate in another submarket.

Second, either the structure of demand, the structure of supply, or both should be different across submarkets. Even if buyer immobility exists, if the demand and supply structures are similar among submarkets then the hedonic price functions will be similar.

Michaels and Smith found different hedonic price functions among their identified submarkets in the Boston area. However, other studies have not found significant differences in the hedonic price function among submarkets (Nelson, 1978). Linneman (1980) provided evidence of a national housing market hedonic price function. For three geographic regions in the United States (represented by Chicago, Los Angeles, and a national sample of the largest 34 cities) Linneman could not find a significant difference between the subsectors in Chicago and Los Angeles and the national sample. The hypothesis that the functional forms of the hedonic price functions for the regions are the same as the nation was not rejected.

On the other hand, Michaels and Smith may be picking up different functional forms, not different equilibriums. That is, the submarkets they estimated may be located on different sections of the same non-linear hedonic price function or they are estimating the equation using the incorrect functional form.

Kohlhase (1991) used the hedonic property price model to estimate the impact of EPA announcements and policy actions on housing markets. Data on individual housing sales in the Houston, Texas area were collected for the years 1976 (n=1,969), 1980 (n=1,083) and 1985 (n=1,881). Three time periods were chosen so as to examine the stages of environmental awareness in Houston concerning local area toxic waste sites.

Ten toxic waste sites, which are on the NPL were identified in the Houston area (Harris county). Most of the toxic sites were used as waste disposal dumps by manufacturing plants located on the site. Three of the sites were solely operated as waste disposal pits. All sites caused significant contamination of groundwater, surface water, soil and in some cases air. In addition, drinking water wells are within 2,500 feet of each site.

The final data set was based on home sales within a 7 mile radius of seven of the sites. A more detailed description of the seven sites is shown in Table 2.2 and was adapted from Table 2 in the Kohlhase paper.

The year 1976 was chosen because at this time there was no NPL or Superfund list. 1980 was the period concurrent with the creation of the NPL. Finally, by 1985, all seven sites were announced to be on the NPL. The author then estimates, using OLS, three regression equations pertaining to the three years of interest.

The dependent variable in the regressions is the natural log of the selling price of the home. Independent variables include a vector of housing characteristics, a vector of neighborhood and location characteristics, a vector of quarterly time period dummies

Table 2.2 - Characteristics of Toxic Waste Sites in Kohlhase (1991)

Site Name	Date Announced on NPL	Characteristics of Waste Site[a]
Brio	10-84	56-acre site; pollutants include copper, vinyl chloride, flourene, styrene, ethyl benzene; water well 2500 ft.
Crystal	7-82	5-acre site; arsenic contamination; emergency capping of site with clay late 1982; water well 300 ft.
Geneva	9-83	13-acre site; pollutants include PCB, vinyl chloride, asbestos insulation; emergency capping of site with clay late 1982; water well 900 ft.
Harris-Farley	7-82	2-acre site; pollutants include styrene tars and its degradation products; Dow Chemical began clean-up in 1984; water well on site.
North Calvacade	10-84	23-acre site; main pollutant creosote; water well 200 feet.
South Calvacade	10-84	46-acre site; pollutants include polynucleor aromatic compounds associated with creosote, benzopyrene, chrysene, flouranthene, anthracene; water well 1500 ft.
Sol-Lynn	10-84	1-acre site; pollutants include trichloroethylene (TCE) and polychlorinated biphenyls (PCBs); water well on site.

[a] Water well is distance of the site to sources of public water supply.

and the distance in miles to the nearest toxic waste site (TOXIC). She also included the square of TOXIC in the equation because the quadratic formulation allows a nonlinear price-distance relation and the computation of a range for the perceived effect of TOXIC on house values.

For the 1976 regression the R^2 was .89. The coefficients on TOXIC and TOXIC squared were statistically not significantly different from zero.

For 1980 regression the R^2 was .88. The coefficients on TOXIC and TOXIC squared were significant but of the "wrong" sign, negative rather than positive. She attributes this to other unmeasured economic trends. For example, between 1976 and 1980 an employment subcenter grew in the areas of the toxic sites. Thus distance to the site could be proxying for distance to local employment.

Finally, for the 1985 regression, the R^2 was .83. The coefficients on TOXIC and TOXIC squared were significant (t-statistics are 2.1 and 3.4 respectively) and of the hypothesized sign (positive).

Using the estimates from the 1985 equation, the marginal price of TOXIC evaluated at the means is $2,364. She finds the marginal willingness to pay to be on average 1.08 miles farther from a hazardous waste site is $377 (1990 dollars). This represents the benefit to the average household for removing a site. This compares to approximately $250 for the Michaels and Smith study.

In addition, she finds for the 1985 sample that TOXIC is significant for all distances up to 6.2 miles from the site. In 1985, she finds that the price of a home would likely be higher if it were further from the site, by as much as $3,310 per mile evaluated at the means.

She concludes that the announcement effect of the EPA, that is, the listing of the site to the NPL, is the primary cause of the depression in housing values observed. This is based on the fact that in 1976 six of the seven sites were still operating and that in 1980 the Superfund was created and five of the seven sites were still operating yet the regression results were not significant or of the "wrong sign". However, by 1985 all seven sites were announced to be on the Superfund list and the results were statistically significant and of the expected sign.

Based on her results, she suggests that households have the ability to determine whether or not a site will continue to be toxic, but households seem to be unable to accurately distinguish between degrees of toxicity. That is, the ranking of the site on the NPL doesn't seem to affect the size of damages, rather the listing of the site on the NPL affects household damage estimates.

Finally she shows points out that the one site that was cleaned up during 1984-1986, no depressive effect on housing is observed in the 1985 sample. She claims that this provides evidence that consumers act on the information that is available to them, and that government and private efforts to clean-up toxic wastes can enhance housing values.

It is interesting to note that the announcement effect had an effect in the Kohlhase study but not the Mendelsohn study. This can be due to the fact that the announcement effect in Kohlhase had to do with the listing of the site on the NPL. Mendelsohn's announcement effect was based on the potential that household's had heard about the pollution problem in the harbor. Listing of a site to the NPL may cause more concern than just hearing about the pollution problem. In addition, the type of risks involved differ. NPL sites in Kohlhase have the potential of contaminating drinking water supplies, while the harbor site in Mendelsohn is not used for drinking water purposes.

Hoehn et al. [HBB] (1987) and Blomquist et al. [BBH] (1988) papers focus on providing empirical evidence that the value of amenities are captured simultaneously by both the labor and housing markets. Both papers argued that hedonic studies that focus on a single market such as labor or housing estimate amenity prices that are only partial prices and thus are unreliable measures of amenity values in an interregional context. To correct this problem, the price of amenities in an interregional context may be posed as the sum of the partial implicit prices estimated from the labor market and the housing market.

These studies estimated a set of amenities using data on housing prices for 34,414 households and wages for 46,004 workers in 253 counties. The studies estimated two equations, a wage equation and a rent equation. Both estimated equations included the same amenity variables. Amenities included the number of Superfund sites per county and the number of licensed waste sites in the county among others.

The dependent variable in the wage equation was the hourly wage for the worker. In addition, other independent variables included in the wage equation were a number of worker characteristic variables and climatic, environmental and neighborhood amenity variables.

The dependent variable in the rent equation was the monthly housing expenditures. Other variables included in the equation were a number of structural characteristic variables and climatic, environmental and neighborhood amenity variables.

HBB and BBH performed a Box-Cox search over the functional forms of the equations. Both equations were linear in the independent variables. However, the dependent variable was transformed in both cases (See either paper for a discussion of the Box-Cox transformation). The equations were estimated using standard OLS techniques. The R^2 for the wage and rent equations were .3138 and .6624 respectively in both the HBB and BBH papers.

The Superfund site variable was significant in both equations (t-statistics were 19.37 and 6.29 respectively for the rent and wage equation). The full implicit price on the number of Superfund sites per county was -$168.24 (1990 dollars). This implies that a household needs compensation of 168 dollars annually for each additional Superfund site. The t-statistic on the full implicit price was -2.43.

Particularly interesting is the finding that the number of licensed waste sites in the county was not significant. This implies that if households have some degree of confidence that a site is well managed they do not feel threatened by the site. Superfund sites on the other hand are mainly nonlicensed sites and thus household concerns are expected to be higher than for licensed sites.

Finally, Nieves et al. (1991), using an interregional wage-rent model similar to Blomquist et al's, estimated the economic damages associated with noxious facilities, including Superfund sites. A wage equation and a rent equation were estimated for owners and renters of housing.

Eight different types of noxious facilities were included in the analysis including: nuclear-powered electric generating plants, coal-fired generating plants, gas- and oil-fired generating plants, military chemical weapons storage sites slated for decommissioning, hazardous waste sites, petrochemical refineries, radioactively contaminated sites managed by the U.S. Department of Energy under the Formerly Utilized Sites Remedial Action Program, and liquefied natural gas storage facilities.

The hazardous waste category includes both chemical waste sites, all of which existed in 1980 and are listed on the Environmental Protection Agency's NPL. Also included in the hazardous waste category are two currently (at the time of this study) operating commercial facilities for disposal of low-level radioactive waste. These sites are not listed on the NPL.

Data on these noxious facilities were combined with 1980 Public Use Microdata Sample B from the United States Census of Bureau. This data set contains information on workers and households. There were 25,279 observations for workers. They confined the sample to workers who earned calculated wages of more than $2 per hour. Because of truncation in the PUMS data set, the income category of "$75,000" and up was omitted from the data set.

There were 60,404 observations on housing included in the Nieves et al. data set. Observations omitted from the data set were rent data in the category "$999 and up", as well as estimated market values in the category "$175,000 and up".

Other data combined with the noxious facility data included human capital and industry control variables in the wage equation, structural variables in the rent equation, and local price variables, disequilibrium control variables, and county and city level control amenity variables in both equations. In addition, instrumental variables were included in both equations.

Three different specifications of the noxious facilities were tested. This included the density of all noxious facilities in the area, the density of each type of facility in the area, and a dummy variable signifying if the facility is located in the area. Density is in number of facilities per 100 square miles.

The dependent variable in the wage equation is annual wages plus other income. The dependent variable in the rent equation is the owner's estimate of the market value of the residence. The rent and wage equation were estimated separately for owners and renters since they estimated that there were significant differences between owner and renter characteristics.

The equations were estimated using two-stage least squares and the functional forms of the equations were double-log. Nieves et al. based the estimation procedure on the basis of Henderson's (1982) finding that the amenity can be fully captured in estimates for just one of the markets if effects on the other market are simultaneously controlled. Their results imply that hazardous waste sites are an amenity rather than a disamenity, however, the estimated coefficients were not significant at the 0.01 level. The authors assume the unexpected results for hazardous waste sites may reflect either lack of public information about these sites in 1980 or that Superfund sites are associated with productive activities.

4. IMPLICATIONS OF THESE STUDIES

These studies attempted to estimate the damages that Superfund waste sites inflict on households, although for the HBB and BBH studies this was not their main objective. However, the results are not satisfactory for a number of reasons.

First, distance measures appear to be a poor proxy for exposure to hazardous waste sites. As pointed out by Harrison and Stock and Michaels and Smith, distance proxies tend to capture other effects such as distance to the central city and other unaccounted for amenities and disamenities.

The papers by HS, Mendelsohn, Adler et al., and Michaels and Smith (MS) did not find hazardous waste sites as significantly affecting housing prices. In the case of HS, Mendelsohn, and MS this is very likely due to their distance variables capturing the value of other variables not accounted for in the Boston area. There are a large number of other amenities and disamenities located in the Boston area. In the case of Adler, other landfills may have affected the result for Andover.

Kohlhase on the other hand, had somewhat more success than other researchers with respect to using distance as a proxy for hazardous waste sites. One reason for this may be the level and number of other externalities affecting the distance variable across the Houston and Boston areas. In any case, her 1980 results highlights some of the problems associated with distance proxies.

In addition to the distance and other externality problems, the site themselves may not be significant enough to find significant effects. For example, McClelland et al. found significant effects on households from a waste site. This site however was extremely large and noticeable by the public. Many of the sites in the other studies were relatively small, many 1-10 acres.

The HBB and BBH papers point out the importance of simultaneously including the labor and housing market in amenity valuation. Their results imply that the poor results found in many of the other papers may be related to not only the distance and externality problem but also to not including both the labor and housing markets in measuring the value of hazardous waste sites. In addition, HBB and BBH provides evidence that amenity values are captured by differences in amenities within and across cities. Thus, they showed that to obtain unbiased amenity prices, the price differentials which arise in the housing and labor markets should be included in the analysis. This is an improvement over the other studies. The other studies did not take the amenity valuation across cities into account.

There is one point that needs to be addressed when estimating the value of amenities. The question concerns the degree of aggregation in housing and wage markets. The HBB, BBH and Nieves et al. studies need to be concerned about the size of the sample to be included in the analysis. More specifically, the number of households and workers in each county used can affect benefit estimates. That is, they need to be confident that the sample size is large enough in each county so that it is representative of all the households in the county.

Significantly, in the paper by Kohlhase (1991) where the distance proxies seemed to perform well, she specified the distance proxy in quadratic form. The other papers either assumed a linear distance or used concentric rings at various distances from a home. The quadratic form takes into account the possibility of nonlinearities between distance from a site and economic damages. The effects of nonlinearity was not taken into account in the HBB or BBH papers.

A final point is the difference in the results for the valuation of Superfund sites between the BBH and Nieves et al. studies. One possibility is that Nieves et al. included two currently operating commercial facilities for disposal of low-level radioactive waste along with Superfund sites. Households may view radioactive sites differently from Superfund sites. That is, the radioactive sites are licensed while Superfund sites are not. Household perceptions of risks may be greater for unlicensed sites versus licensed sites. As shown in HBB licensed sites do not have significant effects. Another possibility is that the sample size for Nieves et al. was much smaller than in BBH, 84 cities/counties versus 253 counties. Ninety-six Superfund sites and two radioactive sites were distributed across the 84 cities. There were 195 other type of sites distributed across the 84 cities. It could be that Nieves et al. did not capture the variation in Superfund sites across areas due to a small sample size.

CHAPTER THREE: A CONCEPTUAL MODEL FOR ESTIMATING THE LOCAL AREA ECONOMIC DAMAGES OF SUPERFUND WASTE SITES

1. INTRODUCTION

This chapter constructs a conceptual model that can be used to estimate the local area economic damages of Superfund sites. The conceptual framework derived in this chapter is a household-firm location decision model. In this study, households and firms must decide which county to reside in. Households and firms are expected to make their location decisions with respect to local wages, rents, and amenities.

2. INTERREGIONAL WAGE-RENT MODEL

Household and firm location decisions are best viewed as the choice of composite bundles of wages, rents and amenities (Rosen, 1979). Households maximize utility and firms minimize cost by choosing the optimal bundle of wages, rents and amenities.

Local climatic, environmental and social conditions impact the economic activity within the local area. Past studies have suggested that characteristics of a local area (negative or positive) affect local area activities such as migration rates, business investment, new business formation, and recreation activity (Graves and Waldman, 1991, Greenwood et al., 1991 and Nieves et al., 1991). Changes in these activities can lead to changes in local property values, local wage rates and thus cause changes in local economic development.

Henderson (1982) and Graves and Knapp (1985) showed conceptually that the value of regional amenities are captured simultaneously in both labor and property markets. Roback (1982), Hoehn et al. (1987), Blomquist et al. (1988), and Nieves et al. (1991) provide empirical evidence that labor and property markets simultaneously capture the value of amenities.

The conceptual model which is used to estimate the economic damages of Superfund sites is a household-firm location decision model. Economic damages are measured by the compensating changes in housing (land rents) and labor markets (wages) for households and firms located in a county which has Superfund hazardous waste site(s). The model developed in this section is based on Roback's (1982) and Blomquist et al's (1988) models. Similar to the Blomquist et al. paper, the model assumes a fixed number of urban areas in which households and firms may locate and that before location decisions are made, households and firms are freely mobile. In addition, an urban area is assumed to be composed of two counties. Each county is assumed to have a fixed amount of land and a different package of amenities available to households and firms. It is assumed there is no cross-county commuting and work hours are exogenous.

In the Roback (1982) and Blomquist et al. (1988) articles, the firm is included in the analysis. The same applies here even though this paper concentrates on the household. The importance of including the firm is that the wages firms pay must match the wages that the workers receive. In addition, firms compete with households for land, thus the price of land depends on firm and household demand.

2.1 The Household

Households are assumed to be identical in tastes and skills[1]. Households maximize utility with respect to a budget constraint. For the case of households making a location decision choice, households gain utility through the use of a traded composite good x, local residential land l, and amenities a. The representative utility function is:

$$(1) \qquad u(x,l;a)$$

where u(·) is homogeneous of degree zero in prices and income, strictly quasi-concave, strictly increasing and positive by nonsatiation.

A budget constraint requires that the cost of the composite good and land consumption do not exceed wages w. There is assumed to be no nonlabor income in this model. The budget constraint requires:

$$(2) \qquad w=x+(r*l)$$

where r is the local rental cost of land.

Maximizing equation 1 subject to equation 2 and substituting in the resulting demand functions yields the indirect utility function:

$$(3) \qquad v=v(w,r;a)$$

where the unit price of the composite good is suppressed since it always equals one.

The indirect utility function for a household located in county k is:

(4) $$v_k = v_k(w_k, r_k; a_k)$$

A worker residing in county k demands residential land

$l_k = -\dfrac{v_r^k}{v_w^k}$ (i.e. v_r^k *is* $\dfrac{\partial v^k}{\partial r^k}$ and v_w^k *is* $\dfrac{\partial v^k}{\partial w^k}$). The amount of land in county k is fixed and equal to L. The number of households in county k is thus $N_k = L_k/l_k$ if all land is used for residences. It is assumed there is one composite worker per household and that demand for residential land is the same for all households.

2.2 The Firm

Firms combine local labor and capital to produce the traded composite good x. The prices of x and capital are fixed by international markets (i.e. assume an open economy where labor and capital shift internationally). The price of capital and wages are normalized on the price of x, and the price of x is set equal to unity. In addition, production technology is assumed to exhibit constant returns to scale in both labor and capital. The constant returns to scale assumption allows the use of the unit production cost function. The unit production costs for a firm located in county k are:

(5) $$c_k = c_k(w_k, r_k; a_k)$$

where c_k is the firm's unit production cost function, and the firm uses the labor provided by each household. All other variables are as previously defined. The price of capital is left implicit since capital is perfectly mobile and is uninfluenced by amenities, its rate of return will be equal in all places. Hence, capital input can be assumed to be optimized out of the problem (Roback, 1982). It is expected that unit costs increase with an increase in w and r, but the change in costs with respect to a depends on whether a is an amenity or disamenity in the production process.

2.3 Equilibrium

For a spatial equilibrium to occur, households and firms cannot improve their utility and firms cannot reduce their unit costs by relocating. That is, wages and rents have adjusted so that a move cannot improve one's present situation. More specifically, an intercounty equilibrium occurs when all firm's production costs are equal to the unit product price and households across all counties have a common level of utility. There has been some controversy over the assumption of equilibrium (i.e. Evans, 1990). However, Graves et al. (1991) and Greenwood et al. (1991) have provided empirical evidence that the assumption of equilibrium has no significant effects on the quantitative or qualitative amenity valuation estimates.

For a given county, the set of wages and land rents that maintains an intercounty equilibrium satisfies the following set of equations:

$$1 = c_k(w_k, r_k; a_k) \tag{6}$$

$$v_o = v_k(w_k, r_k; a_k) \tag{7}$$

where v_o represents constant utility for all households across urban areas (counties) and the unit cost function for all firms equals the product price, which is assumed to be unity.

Marginal implicit amenity prices, p_a, are estimated by taking the total derivative of equation 7 and rearranging to find $p_a = va_k/vw_k$. Thus the price of the amenity a for a household is

$$(8) \qquad p_a = t_k(dr_k/da_k) - dw_k/da_k$$

where t_k is the equilibrium household demand for land, dr_k/da_k is the equilibrium rent differential and dw_k/da_k is the equilibrium wage differential. Thus, the marginal implicit price of the amenity is the sum of the land expenditure and the negative of the wage differential.

Aggregate marginal benefits of removing, say, a waste site, would require summing the marginal implicit prices across all households.

Equilibrium wage and rent gradients are obtained by taking the total differential of equations 6 and 7 and solving for dr_k/da_k and dw_k/da_k. Comparative static analysis can then be used to solve for the anticipated sign of the equilibrium wage and rent differentials given specific assumptions regarding a_k.

$$(9) \qquad dw_k/da_k = 1/B\{-va_k cr_k + ca_k vr_k\}$$

$$(10) \qquad dr_k/da_k = 1/B\{va_k cw_k - ca_k vw_k\}$$

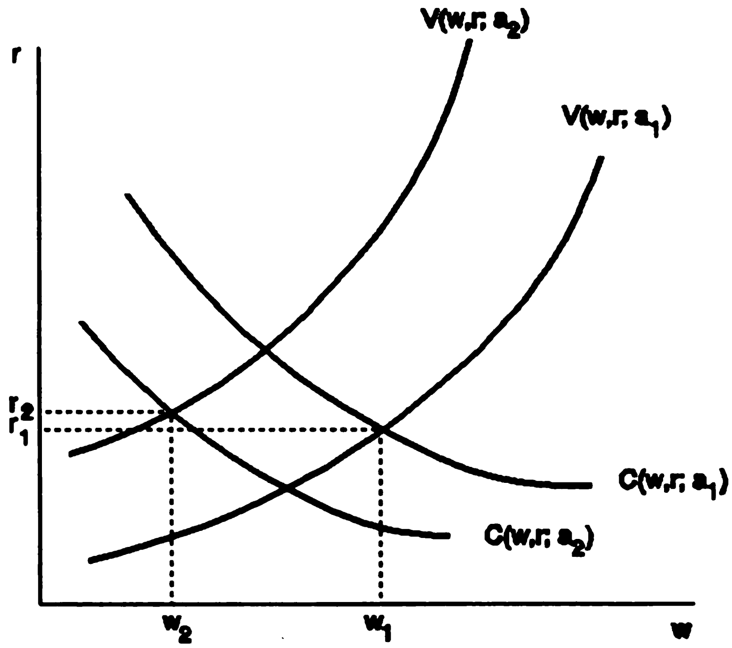
where B is $(vw_k cr_k - cw_k vr_k) > 0$. (See appendix A for derivation of the gradients). The signs on the wage and rent gradients depend on 1) the effect of amenities on the worker's utility, and 2) the impact of amenities on production costs. For example, if the amenity increases household utility and is a production disamenity then the sign on the rent gradient is ambiguous, since households are willing to pay a higher rent to take advantage of the amenity while firms would need compensation in the form of lower rents to reside in the county with the production disamenity. On the other hand, the sign on the wage gradient is unambiguously positive since households are willing to accept a lower wage to take advantage of the local amenity while firms pay lower wages to offset the cost of the disamenity.

Another way to understand how wages and rents are determined by the interaction of the equilibrium conditions of the housing and labor market is seen in Figure 3.1. In Figure 3.1 assume again that a is an unproductive amenity for firms and is a desirable amenity for households. In addition, assume that a_2, the quantity of the amenity in county two, is greater than a_1, the quantity of the amenity in county one. The downward-sloping iso-cost curves are combinations of wages and rents which equalize production unit costs at a given level of a. With a being unproductive, factor prices must be lower in county two to equalize costs in both counties.

The upward-sloping iso-utility curves represent combinations of wages and rents such that utility is equalized at given levels of a. In county two, households must pay higher rents at every wage to be indifferent between the two counties. The equilibrium level of wages and rents is found at the intersection of the iso-cost and iso-utility curves. In county one, the equilibrium wage and rent is w_1 and r_1 respectively. In county two, the high amenity county, the equilibrium wage and rent is w_2 and r_2 respectively.

As seen in Figure 3.1, in the more amenable county two, wages are lower while rents are only slightly higher. This is because with an unproductive amenity, firms prefer low amenity counties while households prefer high amenity counties. Thus,

Figure 3.1 - Wage and Rent Equilibrium



in county two firms will pay lower wages while households will be willing to accept lower wages to reside in county two. On the other hand, firms require lower rents to reside in county two while households are willing to pay higher rents to take advantage of the greater quantity of amenity a. The result is that wages in county one are higher than in county two, while the difference in rents is less clear[2].

The analysis in Figure 3.1 becomes less clear when aggregation economies are included in the model as was done in the HBB and BBH articles. Aggregation economies or effects is when the population of an area affects the production costs of local firms. Assuming an amenity is valued by households, a change in amenities in county j results in a change in county population that in turn affects the cost of firms within county j. The shift in costs induces a change in wages and rents. This implies that the signs on the wage and rent gradients can vary depending on the affect of city size on firm production costs.

Following Blomquist et al (1988) and Roback (1982) the last step is to replace the land rent, r, by the price of housing, g, since it is the price of housing that is normally observed, not land rents. This is important since housing prices are a function of the characteristics of the house and its environment. Thus equation 7 becomes:

$$v_o = v_k(w_k, g_k; a_k) \tag{11}$$

and the equilibrium conditions are found using equations 6 and 11. The price of an amenity a then becomes:

$$p_a = h_k(dg_k/da_k)-(dw_k/da_k) \tag{12}$$

where h_k is the quantity of housing purchased by a household in county k.

3. INCREMENTAL AND AGGREGATE DAMAGES OF SUPERFUND SITES

The price of an amenity as estimated in equation (12) can be used to estimate the incremental economic damages per household and the aggregate economic damages per household of Superfund sites. Incremental economic damages per household are the damages imposed on households from additional Superfund sites in a county and aggregate economic damages per household are the sum of the incremental economic damages per household. For a Superfund site, equation (12) can be interpreted as the marginal damage of a Superfund site located in the county. The incremental economic damages per household for Superfund sites are:

$$(13) \qquad D(s,z) = h_k(dg_k/ds_k + dg_k/dz_k) - (dw_k/ds_k + dw_k/dz_k)$$

where s is the number of Superfund sites, D(s,z) is the incremental damage of the s Superfund site and $z=s^2$. The first term in parentheses is the effect of Superfund sites on housing rents and the second term in parentheses is the effect of Superfund sites on wage rates. Aggregate economic damages per household from Superfund sites is the sum of the incremental economic damages per household:

$$(14) \qquad \sum_{s=1}^{n} D(s,z) = h_k(dg_k/ds_k + dg_k/dz_k) - (dw_k/ds_k + dw_k/dz_k)$$

where n is the number of Superfund sites located in the county. Aggregate economic damages per county is estimated by multiplying aggregate economic damages per household, equation (14), by the number of households in the county.

CHAPTER FOUR: ANALYTICAL METHODS FOR ESTIMATING THE LOCAL AREA ECONOMIC DAMAGES OF SUPERFUND WASTE SITES

1. INTRODUCTION

The purpose of this chapter is to develop methods to estimate the local area economic damages of Superfund waste sites. The chapter proceeds in two sections. The first section describes the wage and rent equations as well as the econometric procedures used in the empirical model. Section two describes the data used to empirically implement the model.

2. WAGE AND RENT EQUATIONS

2.1 Econometric Specification of the Model

Assume for an individual i in household h (h=1,...,H) located in county k (k=1,...,K), the wage (w_{ihk}) equation is:

$$w_{ihk} = \alpha_o + \alpha_1 z_{ihk} + \alpha_2 c_k + \alpha_3 g_k + \alpha_4 e_k + \nu_{ihk}, \tag{1}$$

and the rent (r_{hk}) equation is[1]:

$$r_{hk} = \beta_o + \beta_1 s_{hk} + \beta_2 c_k + \beta_3 g_k + \beta_4 e_k + \mu_{hk}. \tag{2}$$

In addition:

z_{ihk} is a vector of the individual attributes for worker ihk.

c_k is a vector of climatic conditions in county k.

g_k is a vector of social conditions in county k.

e_k is a vector of environmental conditions in county k.

s_{hk} is a vector of structural characteristics of the house for hk.

ν_{ihk} and μ_{hk} are random error terms. $(\nu_{ihk} | z_{ihk}, c_k, g_k, e_k, s_{hk})$ are i.i.d. with mean 0 and variance σ^2_ν and $(\mu_{hk} | z_{ihk}, c_k, g_k, e_k, s_{hk})$ are i.i.d. with mean 0 and variance σ^2_μ.

α_o, α_1, α_2, α_3, α_4, β_o, β_1, β_2, β_3 and β_4 are vectors of coefficients to be estimated.

2.1.1 Correction for Hetereoskedasticity

In previous work (HBB, BBH and Nieves et al.) the possibility of contemporaneous correlation between the error terms in the rent and wage equations was not taken into account. However, it is possible that the errors in the wage and rent equations are correlated, that is, for example, some amenity may significantly influence county level wages and rents but was not included in either equation. If this occurs then the equations may be related through nonzero covariances associated with the error terms across different equations. Thus, any connection between the equations lies solely in the error terms (Judge et al. 1988). This implies that if ordinary least squares is applied separately to the wage and rent equations, a loss of efficiency occurs because OLS equation by equation does not take into account the nonzero covariances. Estimated parameters however, remain unbiased and consistent. Thus the standard errors on the estimated coefficients are larger and hypothesis testing is less powerful.

To test for the effect of cross-correlated wage and rent errors, equation (1) is reformulated by aggregating within the household. That is, instead of using equation (1), the wage equation based on the individual level, the average household wage and the mean worker characteristics of the household are used in the wage equation[2]. Equation (1) can then be rewritten as

(3)
$$w_{hk} = \alpha_o + \alpha_1 z_{hk} + \alpha_2 c_k + \alpha_3 g_k + \alpha_4 e_k + \zeta_{hk},$$

where w_{hk} is the average wage in household hk and z_{hk} is a vector of average characteristics of the workers in the household. $(\zeta_{hk} | z_{hk}, c_k, g_k, e_k, s_{hk})$ is distributed independently (but not identically) with mean 0 and variance $\frac{\sigma_\nu^2}{N_{hk}}$ and N_{hk} is the number of workers in household h in county k.

However, a problem which arises from equation (3) is hetereoskedasticity, as seen in the conditional distribution of ζ_{hk} from the average wage equation (eq. (3)). Hetereoskedasticity occurs by aggregating within the household. Since the number of workers varies by household, averaging causes the variance of the error term to differ across households. As a general result, parameter estimates under heteroskedasticity are consistent and unbiased but inefficient and the covariance matrix estimates are inconsistent and biased.

To correct for this problem, the wage equation is multiplied through by the square root of N_{hk}.

The wage equation then becomes:

(4)
$$\sqrt{N_{hk}}\, w_{hk} = \alpha_o \sqrt{N_{hk}} + \alpha_1 \sqrt{N_{hk}}\, z_{hk} + \alpha_2 \sqrt{N_{hk}}\, c_k + \alpha_3 \sqrt{N_{hk}}\, g_k + \alpha_4 \sqrt{N_{hk}}\, e_k + \epsilon_{hk},$$

where $\epsilon_{hk} = \sqrt{N_h}\,\varsigma_{hk}$ and $(\epsilon_{hk} | z_{hk}, c_k, g_k, e_k, s_{hk})$ are i.i.d. with mean 0 and variance σ^2_ν. This weighting procedure causes the error term to again become constant (homoskedastic) across households (i.i.d). Equations (2) and (4) represent the rent and wage equations to be empirically estimated.

Following the assumption made before $(\nu_{ihk} | z_{ihk}, c_k, g_k, e_k, s_{hk})$ are i.i.d. with mean 0 and variance σ^2_ν and $(\mu_{hk} | z_{ihk}, c_k, g_k, e_k, s_{hk})$ are i.i.d with mean 0 and variance σ^2_μ. Further assume that $Cov(\nu_{ihk}\mu_{hk} | z_{ihk}, c_k, g_k, e_k, s_{hk}) = \rho\sigma_\nu\sigma_\mu$. It can then be assumed that:

$$(5) \qquad Cov(\epsilon_{hk}\mu_{hk} | z_{hk}, c_k, g_k, e_k, s_{hk}) = \rho\sigma_\nu\sigma_\mu$$

where ρ is the correlation coefficient between the disturbances. If there is no contemporaneous correlation between the disturbances then ρ is equal to zero and OLS equation by equation is the BLUE. A ρ not equal to zero implies that use of OLS equation by equation leads to less efficient parameter estimates and inconsistent covariance matrix estimates (Judge et al, 1988).

The implication for this model is that more efficient parameter estimates and consistent covariance matrix estimates of the local area economic damages of Superfund sites are obtained if inter-equation correlation is taken into account. If OLS is used to derive the economic damages of Superfund sites, the efficiency of the model is lower, thus standard errors of the estimates are higher, thereby affecting statistical testing[3]. Variables which are significant at the margin can affect a decision regarding whether the variable is important in influencing some other variable. Thus, providing more efficient estimates can be important for empirical and policy analysis.

To take account of the possibility that there may be correlation between the wage and rent equations, the seemingly unrelated regressions (SUR) model is applied. In a

SUR model, equations (2) and (4) are estimated jointly using feasible generalized least squares (FGLS) (Fomby et al, 1984). The estimated covariance matrix used in estimating the parameters takes into account the correlation between the error terms of the wage and rent equations. This would be seen in the off-diagonals of the covariance matrix. However, to apply FGLS, stronger assumptions are needed than are required for OLS. That is, $(\mu_{hk} | z_{ihk}, c_k, g_k, e_k, s_{hk})$ and $(\nu_{ihk} | z_{ihk}, c_k, g_k, e_k, s_{hk})$ are conditional on "all" independent variables. For OLS, μ_{hk} is not conditional on z_{ihk} and ν_{ihk} is not conditional on s_{hk}. For FGLS to be consistent, the error terms cannot be related to any of the independent variables. The efficiency gains from using SUR is greater as the correlation between the error terms increase or as the correlation between the independent variables decrease across the wage and rent equations (Judge et al, 1988).

To test for the appropriateness of the SUR model, a langrangean multiplier test can be performed to test for H_o: $\rho = 0$ (the covariance between the error terms equals zero)(Judge et al, 1988). The test statistic is given by:

(6) $$\lambda = T(r_{12}^2)$$

where T is the number of observations and r^2_{12} is the squared correlation:

(7) $$r_{12}^2 = \frac{\hat{\sigma}_{12}^2}{\hat{\sigma}_{11}\hat{\sigma}_{22}}$$

where $\hat{\sigma}_{12}^2$ is the square of the estimated covariance between the wage and rent equation and $\hat{\sigma}_{11}$ and $\hat{\sigma}_{22}$ are the estimated variances for the wage and rent equation respectively. Obviously, $r_{12}^2 = \rho^2$. Under the null hypotheses, λ has an asymptotic χ^2-distribution with 2 degrees of freedom. The null hypothesis is rejected if λ is greater than the critical value, implying that the covariances are significantly different from zero and that the SUR model leads to consistent and efficient estimates.

To summarize the econometric model, the averaged data in the wage equation is first weighted to correct for aggregation bias. The SUR model is then applied to estimate the weighted average wage equation and the rent equation jointly as a system to assess potential efficiency gains and to acquire a consistent covariance matrix.

3. DATA TO IMPLEMENT THE EMPIRICAL MODEL.

The data used to implement the empirical model in section 2 was obtained from an earlier study by Blomquist et al. (1988). The data from their study was micro data on workers and household obtained from the 1980 Census 1 in 1000 A Public-Use Sample. The authors merged the microdata with county noncensus amenity variables by county. The merged aggregate data consist of observations on 34,414 households and 46,004 workers who reside in the households. 253 counties are represented in the sample where each county has a population exceeding 100,000 individuals.

The 46,004 workers were then matched to the household data. After determining which workers matched with which household, the average hourly earnings and average characteristics of the workers within each household were calculated. The matching of workers with households resulted in 23,937 observations. This is less than the number of households because for a number of the households there were no matches with workers.

3.1 Rent data

The Blomquist et al. housing sample includes all housing units on ten or fewer acres for which value of the unit or contract rent is reported. For renters, monthly housing expenditure is defined as gross rent including utilities. For owners, reported house value is converted to monthly imputed rent using a 7.85 percent discount rate. Monthly expenditures for utilities plus monthly payments for real estate taxes and insurance are added to obtain gross imputed rent for owners. Monthly housing expenditure is the dependent variable in the rent equation.

The rent equation as described above also includes a vector of structural housing conditions. The vector of housing conditions, their description and mean value in the data set is reported in table 4.1.

3.2 Wage data

The wage sample in the Blomquist paper includes all individuals aged 16 and over who reported their earnings, hours and weeks, had nonzero wage and salary earnings, and had positive total earnings. This includes part-time workers. The dependent variable in the wage equation for the present study is average hourly earnings for a household. Average hourly earnings for a single worker are calculated by dividing annual earnings by the product of average hours worked per week and number of weeks worked per year. The average hourly earnings for a household are the sum of average hourly earnings for the household divided by the number of workers in the household.

The wage equation also includes worker attributes. The vector of worker attributes, their description and mean value are also reported in table 4.1.

Table 4.1 - Description and Mean of Variables in Wage and Rent Data Set

Variable	Description	Mean
WAGE	Average hourly earnings for the household (1980 dollars)	8.75
RENT	Monthly rent for housing (1980 dollars)	492.97
SITE	Number of NPL sites in the county	3.54
SITESQ	Quadratic number of sites in the county ($SITE^2$)	31.24
HDD	Number of heating degree days	4271.80
CDD	Number of cooling degree days	1162.89
PRECIP	Average Annual precipitation (inches)	31.81
HUMID	Average humidity	68.27
WIND	Average wind speed (miles/hour)	8.87
SUN	Percent of possible sunshine	61.28
CC	Dummy variable for central city status (=1 if household is located in central city, 0 otherwise)	0.30
PUPTEACH	Pupil-teacher ratio	13.02
CRIME	Violent crime rate (per 100,000 individuals)	656.30
COAST	If county touches an Ocean or Great Lake (=1 if touches either)	0.34
NPDES	The number of national pollution discharge elimination systems effluent dischargers	1.56
QTOX	Total licensed waste for landfills (in metric tons)	472.02
TSP	Total suspended particulates	73.51
VIS	Visibility (miles)	15.85
WATER	Square miles of surface water in the county	19.72
UNIT	Units at address (The number of housing units with a particular house)	2.45
AGE	Age of the house in year	22.53
STORIES	Number of stories in the house	2.30
ROOMS	Number of rooms in the house	5.64
BEDS	Number of bedrooms in the house	3.65
BATHS	Number of bathrooms in the house	1.55
CONDO	Dummy variable for condominium status (=1 if condo.)	0.03
AIRCON	Dummy variable for central air conditioning (=1 if air)	0.33
SEWER	Dummy variable for public sewer hookup (=1 if public)	0.88
PUBWATER	Dummy variable for public water supply (=1 if public)	0.94
YARD	Dummy variable for if lot size exceeds 1 acre (=1 if 1 to 9 acres, 0 otherwise)	0.07
RENTER	Dummy variable for renter status (=1 if renter)	0.38
RUNIT	Interaction term between RENTER and UNIT	1.77
RAGE	Interaction term between RENTER and AGE	8.81
RSTORIES	Interaction term between RENTER and STORIES	1.02
RROOMS	Interaction term between RENTER and ROOMS	1.55

Table 4.1 - Description and Mean of Variables in Wage and Rent Data Set, Continued

Variable	Description	Mean
RBEDS	Interaction term between RENTER and BEDS	1.06
RBATHS	Interaction term between RENTER and BATHS	0.45
RCONDO	Interaction term between RENTER and CONDO	0.01
RAIRCON	Interaction term between RENTER and AIRCON	0.10
RSEWER	Interaction term between RENTER and SEWER	0.36
RYARD	Interaction term between RENTER and YARD	0.01
EXPER	Years of all work experience	18.40
RACE	Dummy variable for race (=0 if white, 1 otherwise)	0.15
SEX	Dummy variable for gender (=1 if female)	0.44
MARRIED	Dummy variable for marriage (=1 if married)	0.58
SCHOOL	Years of schooling	12.92
DISABLED	Dummy variable for disabled (=1 if disabled)	0.05
ENROLL	Dummy variable for school enrollment status (=1 if enrolled in school)	0.12
TECH	Occupational dummy variable (=1 if technician)	0.34
PROF	Occupational dummy variable (=1 if professional)	0.25
CRAFT	Occupational dummy variable (=1 if craftsment)	0.12
OPER	Occupational dummy variable (=1 if operator)	0.17
UNION	Percent of industry of covered by unions	23.92
EXPER2	Quadratic of years of experience ($EXPER^2$)	549.81
SEXPER	Interaction variable of EXPER and SEX	7.81
SEXPER2	Interaction variable of EXPER2 and SEX	233.86
SRACE	Interaction variable of RACE and SEX	0.08
SMARRIED	Interaction variable of MARRIED and SEX	0.21
SKIDS	Interaction variable of KIDS, number of children under 18, with SEX	1.07

3.3 Amenity Data

A number of county level amenity variables were included in the wage and rent equation. These amenity variables can be classified into three groups; climatic, social and environmental variables.

3.3.1 Climatic Data

A number of county level climatic variables were included in both the wage and rent equation. Climatic variables include heating and cooling degree days, annual precipitation, average humidity, average wind speed, and percentage of possible sunny days.

3.3.2 Social Data

A number of county level social variables were included in both the wage and rent equations. Social variables include central city status, the pupil-teacher ratio in the county, and the violent crime rate.

3.3.3 Environmental Data

Several county level environmental variables were included in both the wage and rent equations. Environmental variables include a dummy variable which signifies if the county touches a Great Lake or ocean, a number of pollution variables including the number of pollution dischargers in the county, the quantity of toxic waste in the county, the total suspended particulates that occurs on average in the county and the visibility in miles within the county. A final variable is the area of surface water in the county.

3.3.4 Superfund Data

The number of Superfund sites in a county is included in both the wage and rent equations. The existence of a Superfund site in a county is expected to capture the risk to the environment and natural resources from the site. As the number of Superfund sites in a county increases, it is expected that the risks to the environment and natural resources increase. As shown in Kohlhase (1991), households value the presence of a Superfund site but do not distinguish between toxicity levels of Superfund sites. This implies that households view each Superfund site as being similar in risk as all other Superfund sites. Therefore it is expected that the number of Superfund sites per county should capture the economic damages imposed on local area households.

The data on Superfund sites was obtained from the EPA and includes all sites on the NPL as of December 1990. The Superfund data set was merged to the data on wages and rents.

CHAPTER FIVE: RESULTS AND DISCUSSION OF THE LOCAL AREA ECONOMIC DAMAGES OF SUPERFUND WASTE SITES

1. ESTIMATION OF THE LOCAL AREA ECONOMIC DAMAGES OF SUPERFUND SITES

The wage and rent equations are both estimated in log-linear form. The dependent variables in the wage and rent equations, average hourly earnings and monthly expenditures on housing respectively, were transformed using the natural log, while the independent variables in both equations were included linearly. As pointed out in chapter two, the log-linear functional form is typically used to specify rent equations. In addition, the log-linear functional form is typically used to specify wage equations (Dickie and Gerking, 1987; Gyourko and Tracy, 1989 and Roback, 1988).

The number of Superfund sites per county was included in both the rent and wage equations quadratically. It is expected that the economic damages from Superfund sites increase at a decreasing rate. The quadratic form allows one to statistically test the hypothesis that Superfund sites affect wages and rents nonlinearly. This would be of importance to policymakers making decisions on the use of monies to clean up Superfund sites. If SITE is included in the model linearly, this implies that Superfund sites impose constant marginal economic damages on households. On the other hand, nonlinear specification of SITE implies nonconstant marginal damages.

The quadratic form can be thought of as using the second order Taylor's expansion to approach the "true" function and it is generally an appropriate method for including variables in a model to allow for a more flexible functional form (Driscoll and Boisvert, 1991). The other independent variables were included in the equation linearly as a first order approximation, since the study is not specifically interested in the other variables. Following Blomquist et al. some of the worker attribute and structural characteristic variables were included nonlinearly.

Table 5.1 reports parameter estimates for the model. Column one lists the variable names of both the wage and rent equations. Column two lists the OLS parameter estimates for the rent equation, and column three lists the WLS (weighted least squares) for the wage equation. Columns four and five list the SUR parameter estimates for the rent and weighted average wage equations respectively. The standard error of the estimates are in parentheses below the parameter estimates.

As seen in table 5.1, the adjusted R^2's for the rent and wage equations using OLS and weighted least squares are 0.673 and 0.407 respectively. There were 23,937 observations in each equation. The adjusted R^2 for the SUR model is 0.566.

The estimated coefficients for the structural and worker attribute characteristics were generally significant different from zero at a significance level of 0.01 using a two-tailed test in both the independent and SUR models. In addition, the estimated coefficients for the amenity variables were statistically significant at a significance level of 0.01 in most cases.

Looking specifically at Superfund sites with SUR estimation, the coefficient on SITE in the rent equation is 0.0129 with a standard error of 0.00134. The SITE coefficient in the wage equation using SUR is 0.0106 with a standard error of 0.00204.

Table 5.1 - Parameter Estimates and Standard Errors for OLS and SUR[a]

Variable	Independent Model ln(RENT) (OLS)	Independent Model ln(WAGE) (WLS)	SUR Model ln(RENT)	SUR Model ln(WAGE) (weighted average data)
INTERCEPT	5.834 (0.08255)***	0.180 (0.02111)***	5.815 (0.08209)***	0.198 (0.02101)***
SITE	0.128×10^{-1} (0.00134)***	0.102×10^{-1} (0.00204)***	0.129×10^{-1} (0.00134)***	0.106×10^{-1} (0.00204)***
SITESQ	-0.127×10^{-3} (0.00008)	-0.381×10^{-3} (0.00013)***	-0.133×10^{-3} (0.00008)	-0.397×10^{-3} (0.00013)***
HDD	-0.208×10^{-4} (0.000002)***	0.370×10^{-5} (0.000004)	-0.205×10^{-4} (0.000002)***	0.390×10^{-5} (0.000004)
CDD	-0.131×10^{-3} (0.000005)***	-0.164×10^{-4} (0.000008)**	-0.130×10^{-3} (0.000005)***	-0.170×10^{-4} (0.000008)**
PRECIP	-0.275×10^{-2} (0.00036)***	-0.113×10^{-2} (0.00051)**	-0.270×10^{-2} (0.00036)***	-0.108×10^{-2} (0.00051)**
HUMID	-0.612×10^{-2} (0.00059)***	0.196×10^{-2} (0.00060)***	-0.592×10^{-2} (0.00058)***	0.215×10^{-2} (0.00060)***
WIND	0.174×10^{-1} (0.00211)***	0.105×10^{-1} (0.00314)***	0.174×10^{-1} (0.00211)***	0.111×10^{-1} (0.00313)***
SUN	0.243×10^{-2} (0.00057)***	-0.606×10^{-3} (0.00061)	0.260×10^{-2} (0.00057)***	-0.386×10^{-3} (0.00061)
CC	-0.887×10^{-1} (0.00611)***	-0.662×10^{-1} (0.00947)***	-0.907×10^{-1} (0.00610)***	-0.702×10^{-1} (0.00947)***
PUPTEACH	-0.861×10^{-2} (0.00119)***	0.752×10^{-2} (0.00180)***	-0.841×10^{-2} (0.00119)***	0.748×10^{-2} (0.00180)***
CRIME	0.895×10^{-4} (0.000007)***	0.837×10^{-4} (0.00001)***	0.897×10^{-4} (0.000007)***	0.822×10^{-4} (0.00001)***
COAST	0.850×10^{-1} (0.00589)***	-0.757×10^{-2} (0.00914)	0.841×10^{-1} (0.00589)***	-0.851×10^{-2} (0.00913)
NPDES	-0.157×10^{-1} (0.00110)***	-0.150×10^{-2} (0.00174)	-0.157×10^{-1} (0.00110)***	-0.180×10^{-2} (0.00174)
QTOX	0.284×10^{-4} (0.000002)***	0.130×10^{-4} (0.000003)***	0.284×10^{-4} (0.000002)***	0.131×10^{-4} (0.000003)***
TSP	-0.105×10^{-2} (0.00014)***	-0.284×10^{-3} (0.00020)	-0.103×10^{-2} (0.00014)***	-0.284×10^{-3} (0.00020)
VIS	-0.239×10^{-2} (0.00026)***	-0.367×10^{-3} (0.00038)	-0.234×10^{-2} (0.00026)***	-0.285×10^{-3} (0.00038)
WATER	0.307×10^{-3} (0.00007)***	0.631×10^{-4} (0.00011)	0.300×10^{-3} (0.00007)***	0.591×10^{-4} (0.00011)
UNIT	0.433×10^{-2} (0.00417)	-	0.386×10^{-2} (0.00414)	-
AGE	-0.507×10^{-2} (0.00023)***	-	-0.496×10^{-2} (0.00023)***	-

Table 5.1 - Parameter Estimates and Standard Errors for OLS and SUR, Continued

	Independent Model		SUR Model	
Variable	ln(RENT) (OLS)	ln(WAGE) (WLS)	ln(RENT)	ln(WAGE) (weighted average data)
STORIES	0.401×10^{-1} $(0.00443)^{***}$	-	0.394×10^{-1} $(0.00441)^{***}$	-
ROOMS	0.781×10^{-1} $(0.00210)^{***}$	-	0.772×10^{-1} $(0.00208)^{***}$	-
BEDS	0.184×10^{-1} $(0.00348)^{***}$	-	0.185×10^{-1} $(0.00346)^{***}$	-
BATHS	0.226 $(0.00504)^{***}$	-	0.223 $(0.00501)^{***}$	-
CONDO	-0.199 $(0.01930)^{***}$	-	-0.202 $(0.01919)^{***}$	-
AIRCON	0.116 $(0.00669)^{***}$	-	0.113 $(0.00665)^{***}$	-
SEWER	0.383×10^{-1} $(0.00926)^{***}$	-	0.352×10^{-1} $(0.00921)^{***}$	-
PUBWATER	-0.230×10^{-2} (0.01150)	-	-0.236×10^{-2} (0.01144)	-
YARD	0.160 $(0.01132)^{***}$	-	0.159 $(0.01126)^{***}$	-
RENTER	-0.170 $(0.03032)^{***}$	-	-0.170 $(0.03015)^{***}$	-
RUNIT	-0.733×10^{-2} $(0.00429)^{*}$	-	-0.685×10^{-2} (0.00427)	-
RAGE	0.251×10^{-3} (0.00035)	-	0.284×10^{-3} (0.00035)	-
RSTORIES	-0.238×10^{-1} $(0.00468)^{***}$	-	-0.238×10^{-1} $(0.00465)^{***}$	-
RROOMS	-0.118×10^{-1} $(0.00468)^{***}$	-	-0.116×10^{-1} $(0.00465)^{**}$	-
RBEDS	0.116×10^{-1} (0.00746)	-	0.123×10^{-1} $(0.00741)^{*}$	-
RBATHS	-0.552×10^{-1} $(0.00953)^{***}$	-	-0.542×10^{-1} $(0.00947)^{***}$	-
RCONDO	0.271 $(0.03053)^{***}$	-	0.271 $(0.03035)^{***}$	-
RAIRCON	0.902×10^{-1} $(0.01105)^{***}$	-	0.894×10^{-1} $(0.01099)^{***}$	-
RSEWER	-0.784×10^{-1} $(0.02070)^{***}$	-	-0.809×10^{-1} $(0.02058)^{***}$	-
RYARD	-0.217 $(0.02223)^{***}$	-	-0.217 $(0.02210)^{***}$	-

Table 5.1 - Parameter Estimates and Standard Errors for OLS and SUR, Continued

Variable	Independent Model ln(RENT) (OLS)	Independent Model ln(WAGE) (WLS)	SUR Model ln(RENT)	SUR Model ln(WAGE) (weighted average data)
EXPER	-	0.370×10^{-1} (0.00149)***	-	0.363×10^{-1} (0.00148)***
RACE	-	-0.864×10^{-1} (0.01678)***	-	-0.667×10^{-1} (0.01669)***
SEX	-	-0.430×10^{-1} (0.02114)**	-	-0.449×10^{-1} (0.02101)**
MARRIED	-	0.219 (0.01423)***	-	0.215 (0.01415)***
SCHOOL	-	0.578×10^{-1} (0.00171)***	-	0.545×10^{-1} (0.00170)***
DISABLED	-	-0.131 (0.01937)***	-	-0.118 (0.01926)***
ENROLL	-	-0.584×10^{-1} (0.01363)***	-	-0.568×10^{-1} (0.01355)***
TECH	-	0.202 (0.01410)***	-	0.194 (0.01402)***
PROF	-	0.349 (0.01613)***	-	0.337 (0.01604)***
CRAFT	-	0.220 (0.01798)***	-	0.215 (0.01788)***
OPER	-	0.121 (0.01639)***	-	0.119 (0.01630)***
UNION	-	0.482×10^{-2} (0.00025)***	-	0.500×10^{-2} (0.00024)***
EXPER2	-	-0.559×10^{-3} (0.00003)***	-	-0.549×10^{-3} (0.00003)***
SEXPER	-	-0.151×10^{-1} (0.00233)***	-	-0.153×10^{-1} (0.00232)***
SEXPER2	-	0.271×10^{-3} (0.00004)***	-	0.278×10^{-3} (0.00004)***
SRACE	-	0.605×10^{-1} (0.02726)**	-	0.613×10^{-1} (0.02710)**
SMARRIED	-	-0.247 (0.02384)***	-	-0.244 (0.02371)***
SKIDS	-	-0.310×10^{-1} (0.00474)***	-	-0.274×10^{-1} (0.00471)***
Adjusted R^2	0.673	0.407	0.566[b]	

[a] Standard errors are in parentheses. Hypothesis is that estimates are significantly different from zero. Levels of significance are denoted by asterisks. *** means the estimate is significant at the α=0.01 level. ** means the estimate is significant at the α=0.05 level. * means the estimate is significant at the α=0.10 level. Based on two-tailed test.

[b] System R^2 for the wage and rent SUR system.

With respect to SITESQ, using SUR, the coefficients in the rent and wage equations are -0.000133 (s.e.=0.00008) and -0.000397 (se=0.00013) respectively.

The annualized implicit price of a Superfund site is found by multiplying the rent parameter estimates by the number of months per year (12) and multiplying the estimated wage coefficients by 2725, the product of the sample means of workers per household (1.61), mean hours per week worked (38.53) and the mean weeks worked per year (43.92). Based on equation 2.13 and using the estimates from table 5.1, the price of a Superfund site is estimated as follows[1]:

$$(5.1)\quad \begin{aligned} P_{SITE} &= [(\beta_{r,SITE} + 2*\beta_{r,SITESQ}*SITE)12*e^{(\beta_o+\beta_1 x_1+\ldots+\beta_m x_m)}] \\ &\quad - [(\beta_{w,SITE} + 2*\beta_{w,SITESQ}*SITE)2725*e^{(\beta_o+\beta_1 x1+\ldots+\beta_n x_n)}], \end{aligned}$$

where the β's are the SUR parameter estimates from table 5.1, r and w represent the β coefficients for the rent and wage equations respectively, m is the number of variables in the rent equation, n is the number of variables in the wage equation, and e is the exponential. Consistent with Hoehn's et al. and Blomquist's et al. results, the annualized implicit price of the Superfund variable is $-107 in 1980 dollars.

To test if the SUR model increased the efficiency of the parameter estimates the langrangean multiplier test described in Chapter four was done. With a chi-square distribution with two degrees of freedom it was found that the estimated langrange statistic, λ, was 279, which exceeds the critical value at a significance level of 0.01. This implies that the covariances between the wage and rent equation are not equal to zero and that the SUR model uses the information in the covariance matrix to generate more efficient estimates than using the independent model.

To compare the effects of taking into account aggregation by households, table 5.2 includes nonweighted wage coefficient estimates for workers in column three and weighted wage coefficient estimates for workers in columns two and four. Columns two and four are reproduced from table 5.1. Column two is included as a comparison of weighted OLS. The wage coefficients were estimated using the SUR model in columns three and four.

As reported in table 5.2, the system weighted R^2 for the nonweighted and weighted SUR estimates are 0.541 and 0.556 respectively. The standard errors of the estimated coefficients are generally lower for weighted SUR than for unweighted SUR. This is because the covariance matrix and thus the standard error of the unweighted SUR coefficient estimates are biased by the hetereoskedasticity. Because the estimated variances of the coefficient estimates are biased, calculated confidence intervals and test of significance are invalid. On the other hand, the estimated coefficients for the unweighted SUR are unbiased and consistent but not efficient. Thus weighting increases the efficiency of the coefficient estimates (Kmenta, 1986). For example, the coefficient estimate for SITESQ in the weighted SUR is almost one-third larger than for SITESQ in unweighted SUR.

With respect to the weighted OLS and weighted SUR, the standard errors are generally similiar for the county level amenities, however, the standard errors on the worker attributes are generally lower for SUR. In this case weighted OLS has a biased covariance matrix and thus standard errors as well as inefficient but unbiased and consistent coefficient estimates. The reason the covariance matrix for weighted OLS is

Table 5.2 - Parameter Estimates and Standard Errors for Unweighted SUR and Weighted OLS and SUR[a]

Variable	OLS ln(WAGE) (weighted average data)	SUR ln(WAGE) (nonweighted average data)	 ln(WAGE) (weighted average data)
INTERCEPT	0.180 (0.02111)***	0.522 (0.14226)***	0.198 (0.02101)***
SITE	$0.102\text{x}10^{-1}$ (0.00204)***	$0.925\text{x}10^{-2}$ (0.00230)***	$0.106\text{x}10^{-1}$ (0.00204)***
SITESQ	$-0.381\text{x}10^{-3}$ (0.00013)***	$-0.266\text{x}10^{-3}$ (0.00014)*	$-0.397\text{x}10^{-3}$ (0.00013)***
HDD	$0.370\text{x}10^{-5}$ (0.000004)	$0.138\text{x}10^{-5}$ (0.000004)	$0.390\text{x}10^{-5}$ (0.000004)
CDD	$-0.164\text{x}10^{-4}$ (0.000008)**	$-0.150\text{x}10^{-4}$ (0.000009)**	$-0.170\text{x}10^{-4}$ (0.000008)**
PRECIP	$-0.113\text{x}10^{-2}$ (0.00051)**	$-0.179\text{x}10^{-2}$ (0.000618)***	$-0.108\text{x}10^{-2}$ (0.00051)**
HUMID	$0.196\text{x}10^{-2}$ (0.00060)***	$-0.649\text{x}10^{-4}$ (0.00101)	$0.215\text{x}10^{-2}$ (0.00060)***
WIND	$0.105\text{x}10^{-1}$ (0.00314)***	$0.103\text{x}10^{-1}$ (0.00359)***	$0.111\text{x}10^{-1}$ (0.00313)***
SUN	$-0.606\text{x}10^{-3}$ (0.00061)	$-0.221\text{x}10^{-2}$ (0.00098)**	$-0.386\text{x}10^{-3}$ (0.00061)
CC	$-0.662\text{x}10^{-1}$ (0.00947)***	$-0.723\text{x}10^{-1}$ (0.01049)***	$-0.702\text{x}10^{-1}$ (0.00947)***
PUPTEACH	$0.752\text{x}10^{-2}$ (0.00180)***	$0.556\text{x}10^{-2}$ (0.00206)***	$0.748\text{x}10^{-2}$ (0.00180)***
CRIME	$0.837\text{x}10^{-4}$ (0.00001)***	$0.816\text{x}10^{-4}$ (0.00001)***	$0.822\text{x}10^{-4}$ (0.00001)***
COAST	$-0.757\text{x}10^{-2}$ (0.00914)	$-0.263\text{x}10^{-2}$ (0.01015)	$-0.851\text{x}10^{-2}$ (0.00913)
NPDES	$-0.150\text{x}10^{-2}$ (0.00174)	$-0.292\text{x}10^{-3}$ (0.00192)	$-0.180\text{x}10^{-2}$ (0.00174)
QTOX	$0.130\text{x}10^{-4}$ (0.000003)***	$0.142\text{x}10^{-4}$ (0.000003)***	$0.131\text{x}10^{-4}$ (0.000003)***
TSP	$-0.284\text{x}10^{-3}$ (0.00020)	$-0.532\text{x}10^{-3}$ (0.00024)**	$-0.284\text{x}10^{-3}$ (0.00020)
VIS	$-0.367\text{x}10^{-3}$ (0.00038)	$-0.630\text{x}10^{-3}$ (0.00045)	$-0.285\text{x}10^{-3}$ (0.00038)
WATER	$0.631\text{x}10^{-4}$ (0.00011)	$0.788\text{x}10^{-4}$ (0.00012)	$0.591\text{x}10^{-4}$ (0.00011)
EXPER	$0.370\text{x}10^{-1}$ (0.00149)***	$0.372\text{x}10^{-1}$ (0.00144)***	$0.363\text{x}10^{-1}$ (0.00148)***

Table 5.2 - Parameter Estimates and Standard Errors for Unweighted SUR and Weighted OLS and SUR, Continued

Variable	OLS ln(WAGE) (weighted average data)	SUR ln(WAGE) (nonweighted average data)	SUR ln(WAGE) (weighted average data)
RACE	-0.864×10^{-1} (0.01678)***	-0.706×10^{-1} (0.01664)***	-0.667×10^{-1} (0.01669)***
SEX	-0.430×10^{-1} (0.02114)**	-0.626×10^{-1} (0.02187)***	-0.449×10^{-1} (0.02101)**
MARRIED	0.219 (0.01423)***	0.211 (0.01321)***	0.215 (0.01415)***
SCHOOL	0.578×10^{-1} (0.00171)***	0.537×10^{-1} (0.00175)***	0.545×10^{-1} (0.00170)***
DISABLED	-0.131 (0.01937)***	-0.114 (0.01927)***	-0.118 (0.01926)***
ENROLL	-0.584×10^{-1} (0.01363)***	-0.787×10^{-1} (0.01441)***	-0.568×10^{-1} (0.01355)***
TECH	0.202 (0.01410)***	0.203 (0.01451)***	0.194 (0.01402)***
PROF	0.349 (0.01613)***	0.361 (0.01638)***	0.337 (0.01604)***
CRAFT	0.220 (0.01798)***	0.21680 (0.01819)***	0.215 (0.01788)***
OPER	0.121 (0.01639)***	0.127 (0.01679)***	0.119 (0.01630)***
UNION	0.482×10^{-2} (0.00025)***	0.497×10^{-2} (0.00025)***	0.500×10^{-2} (0.00024)***
EXPER2	-0.559×10^{-3} (0.00003)***	-0.567×10^{-3} (0.00003)***	-0.549×10^{-3} (0.00003)***
SEXPER	-0.151×10^{-1} (0.00233)***	-0.145×10^{-1} (0.00224)***	-0.153×10^{-1} (0.00232)***
SEXPER2	0.271×10^{-3} (0.00004)***	0.277×10^{-3} (0.00004)***	0.278×10^{-3} (0.00004)***
SRACE	0.605×10^{-1} (0.02726)**	0.810×10^{-1} (0.02573)***	0.613×10^{-1} (0.02710)**
SMARRIED	-0.247 (0.02384)***	-0.281 (0.02130)***	-0.244 (0.02371)***
SKIDS	-0.310×10^{-1} (0.00474)***	-0.290×10^{-1} (0.00471)***	-0.274×10^{-1} (0.00471)***
Adjusted R^2	0.407	0.541[b]	0.566[b]

[a] Standard errors are in parentheses. Hypothesis is that estimates are significantly different from zero using a two-tailed test. Levels of significance are denoted by asterisks. *** means the estimate is significant at the α=0.01 level. ** means the estimate is significant at the α=0.05 level. * means the estimate is significant at the α=0.10 level.

[b] System R^2 for the wage and rent SUR system.

still biased is that it doesn't take into account the correlation between the wage and rent error terms. Thus the weighted SUR provides more efficient parameter estimates than weighted OLS or unweighted SUR as well as an unbiased covariance matrix.

2. INCREMENTAL AND AGGREGATE DAMAGES OF SUPERFUND WASTE SITES

The parameter estimates from table 5.1 can be used to estimate the incremental and aggregate economic damages of Superfund waste sites per household. Table 5.3 reports the estimated incremental and aggregate damages per household of Superfund sites using the coefficient estimates from table 5.1. Incremental and aggregate damages per household are estimated for up to 11 sites in a county. Damages are annual damages for a household and are in 1980 dollars. The standard errors for the damage estimates are in parentheses.

The incremental damage per household for an additional site in a county decreases from approximately 107 dollars per household for the first site to approximately 7 dollars for a ninth site in the county. For additional Superfund sites beyond nine, incremental damages become negative. This occurs as households don't place additional damages on large numbers of Superfund sites in a county.

Using a Wald test (Kmenta, 1986) it is found that incremental damages are significantly different from zero at a significance level of 0.05 only for the first seven sites. This implies that aggregate damages become constant for seven or more sites, which is intuitively more appealing than decreasing aggregate damages for 10 or more sites in a county.

Table 5.3 - Aggregate and Incremental Damage Estimates[a]

Number of sites	Aggregate damages[b]	Incremental damages[b]
1	106.73 (30.1)	106.73 (30.1)
2	201.03 (60.3)	94.30 (26.6)
3	282.84 (85.0)	81.87 (23.3)
4	352.33 (106.4)	69.44 (20.4)
5	409.34 (124.6)	57.01 (18.0)
6	453.92 (139.9)	44.58 (16.3)
7	486.07 (152.6)	32.15 (15.6)
8	505.79 (163.0)	19.72 (16.0)
9	513.07 (171.8)	7.30 (17.5)
10	507.93 (179.6)	-5.14 (19.8)
11	490.36 (187.1)	-17.57 (22.6)

[a] Standard errors are in parentheses.
[b] Annual damages per household in 1980 dollars.

3. A RESTRICTED MODEL FOR ETIMATING DAMAGES

To take account of the fact that aggregate household economic damages level off for seven or more Superfund sites in a county, the empirical model with respect to the Superfund variables is reformulated. This was accomplished by imposing a number of restrictions on the model.

First, a dummy variable was generated where the dummy equals one if there are more than seven Superfund sites in the county and equals zero if there are less than eight Superfund sites in the county. The next step was to interact the dummy term with both SITE and SITESQ in the wage and rent equations. That is, the rent and wage equations are reformulated as:

$$(5.2.1) \qquad rent = \beta_o + \beta_1 SITE + \beta_2 SITESQ + \beta_3 DSITE + \beta_4 DSITESQ + \beta_5 DUMMY + \ldots + \beta_m x_m$$

$$(5.2.2) \qquad wage = \alpha_o + \alpha_1 SITE + \alpha_2 SITESQ + \alpha_3 DSITE + \alpha_4 DSITESQ + \alpha_5 DUMMY + \ldots + \alpha_n x_n \,,$$

where DSITES is the interaction variable between DUMMY and SITE and DSITESQ is the interaction variable between DUMMY and SITESQ and m and n are the number of parameters in the rent and wage equations respectively. The last step is to place the following set of restrictions on the reformulated empirical model described by equations 5.2.1 and 5.2.2:

$$12*\beta_{5,r}*e^{(\beta_o+\ldots+\beta_m X_m)} - 2725*\beta_{5,w}*e^{(\beta_o+\ldots+\beta_n X_n)} =$$

$$(12*\beta_{1,r}*e^{(\beta_o+\ldots+\beta_m X_m)}*7 - 2725*\beta_{1,w}*e^{(\beta_o+\ldots+\beta_n X_n)}*7) \tag{5.3.1}$$

$$+ (12*\beta_{2,r}*e^{(\beta_o+\ldots+\beta_m X_m)}*7^2 - 2725*\beta_{2,w}*e^{(\beta_o+\ldots+\beta_n X_n)}*7^2),$$

$$[12*\beta_{1,r}*e^{(\beta_o+\ldots+\beta_m X_m)} - 2725*\beta_{1,w}*e^{(\beta_o+\ldots+\beta_n X_n)}] \tag{5.3.2}$$

$$+ [12*\beta_{3,r}*e^{(\beta_o+\ldots+\beta_m X_m)} - 2725*\beta_{3,w}*e^{(\beta_o+\ldots+\beta_n X_n)}] = 0,$$

$$[2*12*\beta_{2,r}*e^{(\beta_o+\ldots+\beta_m X_m)} - 2*2725*\beta_{2,w}*e^{(\beta_o+\ldots+\beta_n X_n)}] \tag{5.3.3}$$

$$+ [2*12*\beta_{4,r}*e^{(\beta_o+\ldots+\beta_m X_m)} - 2*2725*\beta_{4,w}*e^{(\beta_o+\ldots+\beta_n X_n)}] = 0.$$

The first restriction limits aggregate economic damages per household for a county with eight or more sites to equal the aggregate economic damages per household of a county with seven sites. This was done since it was found that aggregate economic damages per household level off for seven or more Superfund sites in a county. The last two restrictions restrict incremental economic damages per household for eight or more sites to equal zero. This was done since it was shown previously using the Wald test that incremental economic damages per household were insignificant for eight or more Superfund sites.

The SUR model was reestimated with the above restrictions and the estimates are shown in table 5.4. The full implicit prices for SITE and DSITE offset each other for more than seven sites in a county, and the full implicit prices for SITESQ and DSITESQ offset each other for more than seven sites in a county. Thus, DUMMY

Table 5.4 - Parameter Estimates and Standard Errors for Restricted SUR[a]

Variable	SUR Model ln(RENT)	SUR Model ln(WAGE) (wt. average data)
INTERCEPT	6.038 (0.08557)***	0.200 (0.02101)***
SITE	0.220×10^{-2} (0.00383)	0.735×10^{-2} (0.00555)
SITESQ	0.210×10^{-2} (0.00060)***	0.270×10^{-3} (0.00077)
DSITE	-0.132 (0.01080)***	-0.464×10^{-1} (0.00634)***
DSITESQ	0.245×10^{-2} (0.00068)***	0.109×10^{-2} (0.00077)
DUMMY	0.938 (0.06848)***	0.312 (0.02285)***
HDD	-0.260×10^{-4} (0.000003)***	0.396×10^{-5} (0.000003)
CDD	-0.149×10^{-3} (0.000005)***	-0.214×10^{-4} (0.000007)***
PRECIP	-0.257×10^{-2} (0.00036)***	-0.833×10^{-3} (0.00051)
HUMID	-0.862×10^{-2} (0.00064)***	0.157×10^{-2} (0.00060)***
WIND	0.180×10^{-1} (0.00212)***	0.115×10^{-1} (0.00312)***
SUN	0.299×10^{-2} (0.00058)***	0.770×10^{-4} (0.00061)
CC	-0.980×10^{-1} (0.00611)***	-0.744×10^{-1} (0.00943)***
PUPTEACH	-0.972×10^{-2} (0.00119)***	0.716×10^{-2} (0.00179)***
CRIME	0.920×10^{-4} (0.000007)***	0.866×10^{-4} (0.00001)***

Table 5.4 - Parameter Estimates and Standard Errors for Restricted SUR, Continued

Variable	SUR Model ln(RENT)	 ln(WAGE) (wt. average data)
COAST	0.991×10^{-1} (0.00611)***	-0.917×10^{-3} (0.00906)
NPDES	-0.140×10^{-1} (0.00112)***	-0.120×10^{-2} (0.00175)
QTOX	0.271×10^{-4} (0.000002)***	0.124×10^{-4} (0.000003)***
TSP	-0.115×10^{-2} (0.00014)***	-0.226×10^{-3} (0.00020)
VIS	-0.311×10^{-2} (0.00026)***	-0.438×10^{-3} (0.00038)
WATER	0.970×10^{-4} (0.00007)	-0.113×10^{-4} (0.00011)
UNIT	0.404×10^{-2} (0.00413)	-
AGE	-0.481×10^{-2} (0.00023)***	-
STORIES	0.398×10^{-1} (0.00439)***	-
ROOMS	0.771×10^{-1} (0.00208)***	-
BEDS	0.180×10^{-1} (0.00345)***	-
BATHS	0.221 (0.00499)***	-
CONDO	-0.207 (0.01912)***	-
AIRCON	0.117 (0.00663)***	-
SEWER	0.423×10^{-1} (0.00919)***	-
PUBWATER	0.320×10^{-2} (0.01140)	-

Table 5.4 - Parameter Estimates and Standard Errors for Restricted SUR, Continued

Variable	SUR Model ln(RENT)	ln(WAGE) (wt. average data)
YARD	0.159 (0.01122)***	-
RENTER	-0.164 (0.03004)***	-
RUNIT	$-0.724\text{x}10^{-2}$ (0.00425)*	-
RAGE	$0.171\text{x}10^{-3}$ (0.00035)	-
RSTORIES	$-0.252\text{x}10^{-1}$ (0.00463)***	-
RROOMS	$-0.119\text{x}10^{-1}$ (0.00463)**	-
RBEDS	$0.120\text{x}10^{-1}$ (0.00739)	-
RBATHS	$-0.530\text{x}10^{-1}$ (0.00944)***	-
RCONDO	0.271 (0.03023)***	-
RAIRCON	$0.863\text{x}10^{-1}$ (0.01095)***	-
RSEWER	$-0.808\text{x}10^{-1}$ (0.02050)***	-
RYARD	-0.221 (0.02201)***	-
EXPER	-	$0.364\text{x}10^{-1}$ (0.00148)***
RACE	-	$-0.667\text{x}10^{-1}$ (0.01668)***
SEX	-	$-0.441\text{x}10^{-1}$ (0.02101)**
MARRIED	-	0.215 (0.01415)***

Table 5.4 - Parameter Estimates and Standard Errors for Restricted SUR, Continued

Variable	SUR Model ln(RENT)	SUR Model ln(WAGE) (wt. average data)
SCHOOL	-	0.546×10^{-1} (0.00170)***
DISABLED	-	-0.118 (0.01926)***
ENROLL	-	-0.558×10^{-1} (0.01355)***
TECH	-	0.194 (0.01401)***
PROF	-	0.337 (0.01603)***
CRAFT	-	0.216 (0.01787)***
OPER	-	0.120 (0.01629)***
UNION	-	0.499×10^{-2} (0.00024)***
EXPER2	-	-0.550×10^{-3} (0.00003)***
SEXPER	-	-0.154×10^{-1} (0.00231)***
SEXPER2	-	0.279×10^{-3} (0.00004)***
SRACE	-	0.608×10^{-1} (0.02710)**
SMARRIED	-	-0.244 (0.02370)***
SKIDS	-	-0.271×10^{-1} (0.00471)***
Adjusted R^2	0.568[b]	

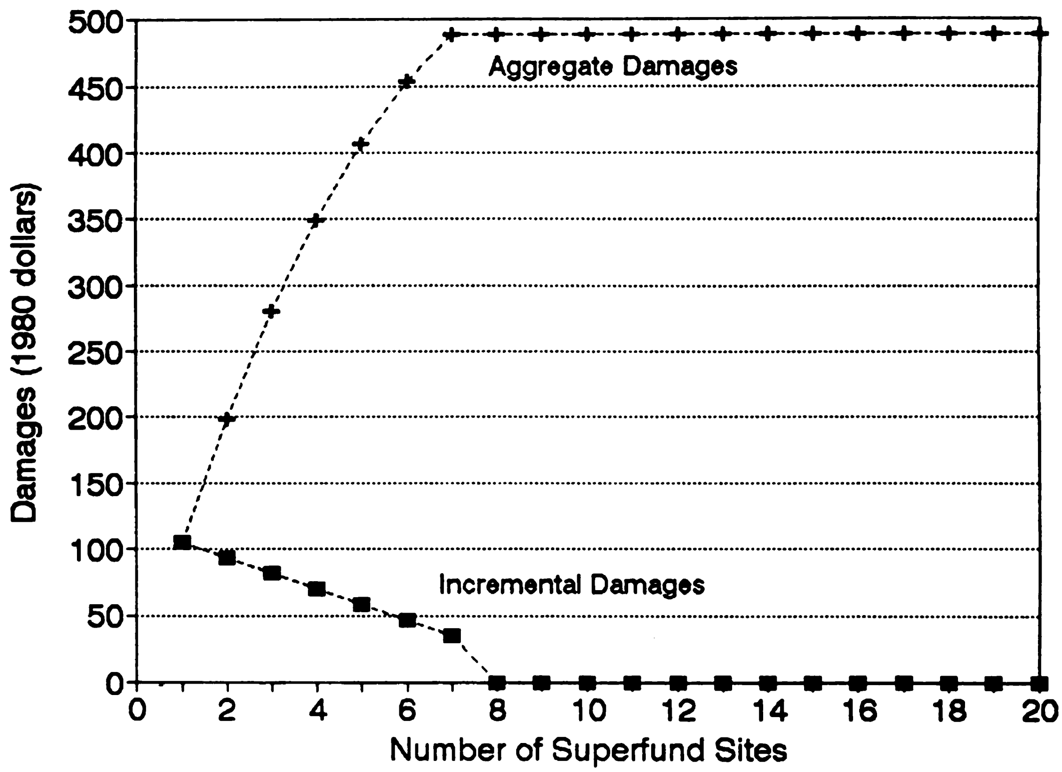
[a] Standard errors are in parentheses. Hypothesis is that estimates are different from zero using a two-tailed test. Levels of significance are denoted by asterisks. *** means the estimate is significant at the $\alpha = 0.01$ level. ** means the estimate is significant at the $\alpha = 0.05$ level. * means the estimate is significant at the $\alpha = 0.10$ level.

[b] System R^2 for the wage and rent SUR system.

captures the aggregate damages for more than seven sites in a county, which equals the aggregate damages of seven sites in a county. An F-test was done to test if there is a statistical difference between this model and the unrestricted model. One cannot reject the null hypothesis at the .05 significance level that the models are the same. Thus, the more appealing restricted model is used to estimate the incremental and aggregate economic damages of Superfund sites.

As with the unrestricted model, the incremental and aggregate economic damages of Superfund sites can be estimated using the restricted SUR estimates from table 5.4. Figure 5.1 shows in 1980 dollars the incremental and aggregate damages of Superfund sites per household using the restricted SUR model estimates. Note the leveling off of aggregate damages at approximately 480 dollars per household for seven or more sites in a county.

Figure 5.1 - Incremental and Aggregate Damages of Superfund Sites (per household)



CHAPTER SIX: RANKING SUPERFUND SITES USING THE LOCAL AREA ECONOMIC DAMAGE ESTIMATES

1. INTRODUCTION

The EPA's HRS ranking scheme may be undesirable from an economic standpoint (Hird, 1990). The EPA ranks hazardous waste sites based on the total score derived from the hazard ranking system. The basis for ranking is the threat to human health and welfare and to natural resources and the environment (Wolf, 1988). Thus, the total score derived is not based on markets in the economy but rather on scientific assessment of risks. This implies that the basis for cleaning up sites is not the actual damages imposed on households but rather the assessment of risks obtained from the hazard ranking system (HRS).

The objective of this chapter is to provide a method for using the local area economic damage estimates to rank the cleanup of Superfund sites. This market based ranking can then be compared to the ranking of sites based on the HRS.

2. HOUSEHOLD AND COUNTY LEVEL ECONOMIC DAMAGES OF SUPERFUND SITES

Table 6.1 shows in 1980 dollars the household and county annual aggregate economic damages from Superfund sites. It should be emphasized that the damage

Table 6.1 - Annual Economic Damages of Superfund Sites
(1980 dollars)

RANK	COUNTY	STATE	NUMBER OF NPL SITES	NUMBER OF HOUSING UNITS IN THOUSANDS	HOUSEHOLD ANNUAL AGGREGATE ECONOMIC DAMAGES FROM SUPERFUND SITES[a]	STANDARD ERROR OF HOUSEHOLD DAMAGES	COUNTY ANNUAL AGGREGATE DAMAGES FROM SUPERFUND SITES (THOUSANDS)
-	Sample Total	-	499	32,186			14,472,000
1	Los Angeles	CA	12	2,854	804	184	2,295,000
2	Harris	TX	8	984	804	184	791,000
3	Maricopa	AZ	7	600	804	183	482,000
4	Santa Clara	CA	22	474	804	184	381,000
5	King	WA	6	525	725	154	381,000
6	Nassau	NY	12	432	804	185	347,000
7	Broward	FL	6	477	725	155	346,000
8	Suffolk	NY	8	406	804	185	326,000
9	Hennepin	MN	7	379	804	185	305,000
10	Cook	IL	1	1,993	150	89	300,000
11	Bergen	NJ	9	307	804	183	247,000
12	St. Louis	MO	5	358	634	134	227,000
13	Hillsborough	FL	7	261	804	184	210,000
14	Orange	CA	2	720	289	110	208,000
15	Sacramento	CA	5	324	634	136	205,000
16	Essex	NJ	5	317	634	136	201,000
17	Philadelphia	PA	2	685	289	109	198,000
18	Oakland	MI	4	372	530	124	197,000
19	San Bernadino	CA	4	366	530	123	194,000
20	Montgomery	PA	15	232	804	185	187,000
21	Alameda	CA	3	444	416	117	185,000
22	Duval	FL	7	227	804	185	182,000
23	Allegheny	PA	2	571	289	109	165,000
24	Middlesex	NJ	11	203	804	182	164,000
25	Milwaukee	WI	3	378	416	119	157,000
26	Salt Lake	UT	6	214	725	154	155,000
27	Fresno	CA	7	192	804	182	154,000
28	DuPage	IL	5	235	634	136	149,000
29	Pierce	WA	7	185	804	184	149,000
30	Monmouth	NJ	8	181	804	182	145,000

Table 6.1 - Annual Economic Damages of Superfund Sites, Continued
(1980 dollars)

RANK	COUNTY	STATE	NUMBER OF NPL SITES	NUMBER OF HOUSING UNITS IN THOUSANDS	HOUSEHOLD ANNUAL AGGREGATE ECONOMIC DAMAGES FROM SUPERFUND SITES[a]	STANDARD ERROR OF HOUSEHOLD DAMAGES	COUNTY ANNUAL AGGREGATE DAMAGES FROM SUPERFUND SITES (THOUSANDS)
31	Wayne	MI	1	875	150	89	131,000
32	Kent	MI	10	163	804	184	131,000
33	Marion	IN	3	309	416	120	129,000
34	Montgomery	OH	4	227	530	123	121,000
35	Bucks	PA	6	165	725	152	120,000
36	Shelby	TN	3	286	416	119	119,000
37	Erie	NY	2	387	289	108	112,000
38	Spokane	WA	9	137	804	182	111,000
39	San Diego	CA	1	718	150	89	108,000
40	Lake	IL	6	148	725	155	108,000
41	Hamilton	OH	2	343	289	111	99,000
42	Macomb	MI	3	236	416	118	98,000
43	Tarrant	TX	2	338	289	110	97,000
44	Burlington	NJ	13	121	804	182	97,000
45	Denver	CO	3	228	416	119	95,000
46	Dallas	TX	1	625	150	90	94,000
47	Chester	PA	9	110	804	182	89,000
48	Berks	PA	6	120	725	151	87,000
49	Ramsey	MN	3	177	416	119	73,000
50	Contra Costa	CA	2	252	289	111	73,000
51	Camden	NJ	3	174	416	115	72,000
52	Atlantic	NJ	8	88	804	183	70,000
53	Hudson	NJ	2	221	289	108	64,000
54	Niagra	NY	6	85	725	154	61,000
55	Sedgwick	KS	3	146	416	117	60,000
56	Winnebago	IL	5	93	634	140	59,000
57	Delaware	PA	2	201	289	109	58,000
58	Greenville	SC	4	108	530	121	57,000
59	Mobile	AL	3	131	416	114	55,000
60	Orange	FL	2	183	289	109	53,000
61	Dane	WI	3	126	416	119	52,000

Table 6.1 - Annual Economic Damages of Superfund Sites, Continued
(1980 dollars)

RANK	COUNTY	STATE	NUMBER OF NPL SITES	NUMBER OF HOUSING UNITS IN THOUSANDS	HOUSEHOLD ANNUAL AGGREGATE ECONOMIC DAMAGES FROM SUPERFUND SITES[a]	STANDARD ERROR OF HOUSEHOLD DAMAGES	COUNTY ANNUAL AGGREGATE DAMAGES FROM SUPERFUND SITES (THOUSANDS)
62	Kalamazoo	MI	5	79	634	139	50,000
63	Waukesha	WI	4	91	530	120	48,000
64	San Francisco	CA	1	316	150	89	48,000
65	Westchester	NY	1	316	150	89	47,000
66	Genesee	MI	2	163	289	111	47,000
67	Passaic	NJ	2	158	289	108	46,000
68	Will	IL	3	109	416	119	45,000
69	Kern	CA	2	154	289	110	45,000
70	Palm Beach	FL	1	287	150	87	43,000
71	Broome	NY	4	81	530	123	43,000
72	Monterey	CA	3	103	416	116	43,000
73	Stanislaus	CA	3	102	416	117	43,000
74	Ingham	MI	3	99	416	121	41,000
75	Stark	OH	2	143	289	112	41,000
76	Galveston	TX	4	77	530	129	41,000
77	Jefferson	KY	1	266	150	87	40,000
78	San Joaquin	CA	2	136	289	111	39,000
79	Jefferson	AL	1	259	150	89	39,000
80	Richland	SC	3	92	416	120	38,000
81	St. Joseph	IN	3	91	416	121	38,000
82	Lancaster	PA	2	129	289	108	37,000
83	Adams	CO	3	89	416	123	37,000
84	Anne Arundel	MD	2	127	289	110	37,000
85	Lackawanna	PA	3	88	416	114	37,000
86	Dakota	MN	4	67	530	120	35,000
87	Wake	NC	2	113	289	106	33,000
88	Pima	AZ	1	216	150	88	33,000
89	Clark	WA	3	73	416	124	30,000
90	Erie	PA	2	102	289	107	30,000
91	Ventura	CA	1	183	150	88	27,000
92	Union	NJ	1	183	150	88	27,000

Table 6.1 - Annual Economic Damages of Superfund Sites, Continued
(1980 dollars)

RANK	COUNTY	STATE	NUMBER OF NPL SITES	NUMBER OF HOUSING UNITS IN THOUSANDS	HOUSEHOLD ANNUAL AGGREGATE ECONOMIC DAMAGES FROM SUPERFUND SITES[a]	STANDARD ERROR OF HOUSEHOLD DAMAGES	COUNTY ANNUAL AGGREGATE DAMAGES FROM SUPERFUND SITES (THOUSANDS)
93	Yakima	WA	3	65	416	122	27,000
94	Oneida	NY	2	94	289	107	27,000
95	Benton	WA	5	43	634	141	27,000
96	Butler	OH	2	92	289	108	27,000
97	Cumberland	NJ	4	47	530	129	25,000
98	Cumberland	NC	2	81	289	111	23,000
99	Rockland	NY	2	80	289	112	23,000
100	Calhoun	MI	3	54	416	111	22,000
101	Elkhart	IN	3	52	416	116	22,000
102	Rock	WI	3	51	416	117	21,000
103	Lexington	SC	3	51	416	117	21,000
104	Jefferson	CO	1	137	150	87	21,000
105	St. Charles	MO	3	50	416	121	21,000
106	Harford	MD	3	49	416	122	21,000
107	Luzerne	PA	1	134	150	90	20,000
108	East Baton Rouge	LA	1	134	150	90	20,000
109	Snohomish	WA	1	129	150	85	19,000
110	Polk	FL	1	127	150	87	19,000
111	Polk	IA	1	122	150	90	18,000
112	Volusia	FL	1	122	150	91	18,000
113	Albany	NY	1	115	150	87	17,000
114	Brevard	FL	1	113	150	88	17,000
115	Arapahoe	CO	1	113	150	88	17,000
116	Allen	IN	1	111	150	90	17,000
117	Hamilton	TN	1	110	150	91	17,000
118	Johnson	KS	1	103	150	88	15,000
119	Charleston	SC	1	99	150	91	15,000
120	Weber	UT	2	50	289	119	15,000
121	Lorain	OH	1	96	150	94	14,000
122	Dauphin	PA	1	95	150	84	14,000
123	Chesterfield	VA	2	49	289	102	14,000

Table 6.1 - Annual Economic Damages of Superfund Sites, Continued
(1980 dollars)

RANK	COUNTY	STATE	NUMBER OF NPL SITES	NUMBER OF HOUSING UNITS IN THOUSANDS	HOUSEHOLD ANNUAL AGGREGATE ECONOMIC DAMAGES FROM SUPERFUND SITES[a]	STANDARD ERROR OF HOUSEHOLD DAMAGES	COUNTY ANNUAL AGGREGATE DAMAGES FROM SUPERFUND SITES (THOUSANDS)
124	Richmond City	VA	1	91	150	87	14,000
125	St. Louis	MN	1	87	150	92	13,000
126	Ector	TX	2	43	289	117	12,000
127	Santa Cruz	CA	1	80	150	88	12,000
128	Lancaster	NB	1	76	150	92	11,000
129	Boulder	CO	1	73	150	95	11,000
130	Washington	MN	2	37	289	109	11,000
131	Linn	IA	1	65	150	93	10,000
132	Richmond	GA	1	65	150	62	10,000
133	Stearns	MN	2	34	289	178	10,000
134	Brown	WI	1	62	150	97	9,000
135	Racine	WI	1	62	150	81	9,000
136	Gaston	NC	1	59	150	84	9,000
137	Alachua	FL	1	59	150	85	9,000
138	Berkshire	MA	1	56	150	90	8,000
139	Blair	PA	1	52	150	96	8,000
140	Jefferson	MO	1	50	150	80	8,000
141	Lycoming	PA	1	45	150	88	7,000
142	Monroe	MI	1	45	150	89	7,000
143	Vigo	IN	1	43	150	93	6,000
144	Minnehaha	SD	1	43	150	94	6,000
145	Yellowstone	MT	1	43	150	94	6,000
146	Roanoke City	VA	1	43	150	94	6,000
147	Calhoun	AL	1	42	150	94	6,000
148	New Hanover	NC	1	41	150	97	6,000
149	Aiken	SC	1	40	150	101	6,000
150	Woodbury	IA	1	39	150	77	6,000
151	Kankakee	IL	1	37	150	81	6,000

[a] Household damages were estimated using the sample average wage and sample average rent rather than $e^{(\cdot)}$ from equation 5.1.

estimates do not include existence, option, and other values of noncounty residents which may be important.

There are 151 counties included in the sample. Of the 253 counties in the original data set, only 151 had one or more Superfund sites as of December 1990. In addition, there are other counties with Superfund sites not included in this sample. Those counties were not one of the 253 counties in the original data set. Column one is the rank number. Rank is by county annual aggregate economic damages from Superfund sites. Columns two and three report the county and state name respectively. Column four is the number of Superfund sites located in the county. The number of Superfund sites located in a county ranged from one site up to 22 Superfund sites in Santa Clara county in California. Column five is the number of yearly housing units in the county in 1980[1]. This is used as a proxy for the number of households residing in the county. Column six is the household annual aggregate economic damages from Superfund sites in 1980 dollars[2]. Column seven is the standard error for the household damage estimate. Finally, column eight is the county annual aggregate economic damages from Superfund sites in thousands of 1980 dollars. County annual aggregate economic damages was estimated by multiplying column five by column six.

As seen in table 6.1 Los Angeles county had the greatest county annual aggregate economic damages, over two billion annually. Harris county in Texas was second with 791 million dollars of damages annually from Superfund sites. Kankakee county in Illinois had the smallest county annual aggregate economic damages from Superfund sites, only six million annually.

There are two factors driving the county annual aggregate economic damage estimates. One factor is the number of Superfund sites located in the county. The second factor is the population within the county. The effect of population is significant. For example, Montgomery county, Pennsylvania has 15 Superfund sites yet is ranked 20 on the list, while other counties, such as Cook county, Illinois, are ranked higher even though they have less Superfund sites. The reason for this result is that Cook county has a significantly greater population which is affected by Superfund sites than Montgomery county, 2 million housing units versus 232 thousand housing units. The county annual aggregate economic damages for all 151 counties is approximately 14.5 billion dollars.

Another method for ranking counties is to estimate the household and county annual incremental economic damage of the nth site. This is shown in table B.1 in appendix B. For example, Los Angeles county would have a household annual incremental economic damage of zero for the 12th site, while Cook county has a household annual incremental economic damage of 150.3 dollars. The county annual economic damage from the incremental site is estimated by multiplying the household incremental economic damage by the number of households in the county. This procedure can be done for all counties and the rank reestimated. It can be seen in the first row that the county annual aggregate economic damages for all 151 counties from the incremental site is approximately 3.3 billion dollars.

3. COMPARING THE RANKING OF COUNTIES USING AGGREGATE COUNTY DAMAGES AND THE HAZARD RANKING SYSTEM

In this section, the ranking of sites for cleanup based on the hazard ranking system (HRS) is compared to the ranking of sites based on county annual aggregate economic damages. The 151 counties with Superfund sites are ranked using the scores obtained from the HRS and from the aggregate county damage as seen in table 6.1. It is assumed that greater damages implies greater benefits if all the sites are cleaned up in the county.

3.1 Implementation and Results of the Rank Comparisons

The first step is to rank the 151 counties from the sum of the highest HRS scores to the lowest HRS scores. In the case of ties between counties, the counties were given the same ranking.

Second, the 151 counties were ranked from highest county annual aggregate economic damages to lowest county annual aggregate economic damages. As for the HRS ranking, ties were given the same ranking.

The next step was to match the HRS and county annual aggregate economic damage rankings for each county and to run a Spearman correlation test of rankings. The results from the test show that the value of the Spearman correlation was 0.689, implying that there is strong correlation between the HRS and the ranking system based on the economic impacts of Superfund sites.

To test if population was the driving force in the HRS rank being similar to the damage estimate rank, the HRS rank was reestimated with the population factors removed from the HRS scores and the new HRS rank is compared to the damage estimate rank.

As mentioned before, the HRS score is based on four pathways which chemicals from a Superfund site can potentially affect human health, welfare and the environment. These pathways include a groundwater route, surface water route, air route, and a direct contact route.

Within each route are a number of factors including; toxicity rating of the site, quantity of hazardous waste at the site, distance of the Superfund site to the nearest public well and population among others. Many of these factors are included in each pathway. Most of the factors are expected to capture the risk to human health. One specific factor that is expected to capture environmental effects is distance to a sensitive environment. Distance to a sensitive environment is found in the air migration route, direct contact route and surface water route. Population factors are found in all four routes.

To do a comparison of the HRS scores without the population factor, a smaller subset of 104 counties were used in the analysis due to missing data and other incompatibilities. First, for comparison, the full HRS rank was compared to the damage estimate rank. The Spearman correlation was 0.644, slightly smaller than for all 151 counties. The Spearman correlation for the population factors taken out of the HRS score resulted in a Spearman correlation of 0.632. Finally, with the population factors only included in the HRS resulted in a Spearman correlation of 0.640. These results imply that the population factors have a slight affect on the correlation between the HRS rank and the damage estimate rank.

CHAPTER SEVEN: CONCLUSIONS, IMPLICATIONS AND FUTURE RESEARCH

1. INTRODUCTION

The objective of this study was to develop analytical methods for estimating the local area economic damages of Superfund waste sites. The conceptual framework was a residential location model, where damages of Superfund sites are estimated by the adjustment of wages and rents to Superfund sites across counties in the sample. The damage estimates were subsequently used to measure county level aggregate damages caused by Superfund sites. Additionally, the county damage estimates were used to rank the cleanup of Superfund sites and this rank was compared to the EPA's Hazard Ranking System.

2. IMPLICATIONS

Superfund sites are not prioritized on the basis of benefit-cost analysis. There is concern, though, that Superfund sites impose significant damages on households. This implies that methods are needed for estimating the economic damages associated with Superfund sites.

Previous studies that attempted to estimate the damages of Superfund sites met with mixed results. In most cases the method used to estimate damages was a hedonic rent model where distance from a home to the Superfund site was used to proxy the damages associated with the site. However, it was found that in most cases distance variables performed poorly. In addition, these studies did not take into account the possibility that economic damages may be captured in other markets.

An improvement in the methods was explored by Blomquist et al, 1988. They provided evidence that the economic damages associated with Superfund sites were captured simultaneously in both the housing and labor market. In addition, rents are affected intraregionally as well as interregionally.

The method developed in this study was based on the Blomquist et al, 1988 model. In contrast to their study, the number of Superfund sites in a county was allowed to affect rents and wages nonlinearly. In addition, the average household wage and characteristics were used in the analysis. Finally, seemingly unrelated regressions rather than simple OLS was used to estimate the wage and rent gradients.

Using the model developed in this study, it was estimated that Superfund sites are associated with statistically significant damages. The economic damage estimates were used to rank the cleanup of Superfund sites. The present method used by the EPA for ranking the cleanup of Superfund sites is the Hazard Ranking System (HRS). It was hypothesized that ranking sites using the county damage estimates would differ from the HRS ranking. However, the HRS rank was found to be similar to the rank using the county damage estimates.

The implication of the method used in this study to estimate economic damages is that it detects statistically significant and large damages from Superfund sites. The method appears to be useful in estimating the interim damages caused by Superfund sites on local residents.

An important result that can effect the rank of cleaning up sites was the finding that damages imposed on county residents are significant and non-zero up to seven Superfund sites. The implication is that it may not be beneficial to cleanup the first few Superfund sites in a county which have a large number of Superfund sites. Rather, the benefits of cleanup will tend to be higher in counties with very few Superfund sites and/or large populations. However, it is noted that factors other than economics may come into play for ranking the cleanup of sites.

3. FUTURE RESEARCH

It was estimated that the number of Superfund sites in a county captures the local area economic damages of Superfund sites. However, it may be useful to examine whether there are other factors or variables that could be used to estimate the economic damages of Superfund sites.

One alternative is to use the HRS score of a Superfund site as a proxy for the local area health and natural resource damages caused by the site. It was shown that ranking sites using aggregate damages was similar to the ranking using the HRS. This implies that damage estimates using the HRS may be comparable. In addition, one could compare the economic damage associated with licensed waste sites versus nonlicensed waste sites (Superfund sites).

A second research question is to estimate if there exists a single national housing hedonic gradient. Since property is immobile this would seem to be more of concern than that of a single wage hedonic. Trade-offs among housing characteristics that differ substantially across locations may indicate the existence of separate regional submarkets

(Nieves et al., 1991). If submarkets exist, this may imply that amenity value estimates from a single national housing hedonic are unreliable.

Nelson (1978), Butler (1980), and Linneman (1980) provided evidence that the assumption of a national housing hedonic has only a slight effect on the explanatory power of the hedonic and only a slight effect on the accuracy of the coefficients. However, more recently Michaels and Smith (1990) provided evidence that submarkets exist in the housing market and amenity valuations derived from the different submarkets are significantly different. These results imply that more work needs to be done to determine if amenity valuation can be done assuming a single housing hedonic gradient.

Another research question is to estimate if workers have different wage hedonic gradients. That is, test if workers in different occupations view the risks from Superfund sites differently. The assumption in this study is that one wage hedonic can be estimated. That is, it is assumed that the labor market is sufficiently homogenous to estimate one model for the nation. However, workers tradeoff wages with the level of risk in their occupation. This implies that adverseness to risk may vary across occupations. If so, then workers in one occupation may perceive the risks from Superfund sites to be smaller than workers in different occupations. This could result in different housing hedonics as well. In addition, it may seem reasonable that there may be barriers to arbitrage across age groups in both the housing and labor markets.

Finally, the importance of the present study is that an analytical model was constructed which can be used to estimate the local area economic damages of Superfund waste sites. The ranking of sites based on the damage estimates are only preliminary estimates. To make the results more up to data and applicable to policymakers, the wage and rent data should be updated using either the 1990 Census data or more recent wage-rent data. Damage estimates obtained from the analytical model using 1990 Census data could then be used to rank the cleanup of sites.

ENDNOTES

ENDNOTES

CHAPTER ONE

1. For a discussion of the hazard ranking system see Haness and Warwick (1991).

2. An emergency is defined as any situation related to a discharge or release requiring immediate action to avoid an irreversible loss of natural resources or to prevent or reduce any continuing danger to natural resources, or a situation in which there is a similar need for emergency action (Hall et al, 1987).

3. A type A regulation does not require the detailed three-step approach.

CHAPTER TWO

1. Ridker and Henning (1967) were the first to apply the hedonic property value approach to estimate the value of air pollution. Since that time the hedonic price method has been used to estimate the value of public safety (Clark and Cosgrove, 1990), cultural amenities (Clark and Kahn, 1988), nuclear power plants (Gamble and Downing, 1982; Nelson, 1981), and public parks (Schroeder, 1982) among other things.

2. It is not necessary to assume linearity in the variables to derive marginal implicit prices, though the prices will be derived in a manner different from above if nonlinearity is assumed.

3. The pollution event terminology used by Mendelsohn is more accurately an information event.

CHAPTER THREE

1. Roback (1988) extended her 1982 model by extending the assumption of identical workers into two types of workers with different preferences. Her results point out that the wages of on type of worker prove to be dependent on the preferences of the other type.

2. By assuming identical workers Roback (1982) shows that the estimated wage difference will be an underestimate of the true equalizing wage difference for those with strong tastes for amenities and an overestimate for those with weak preferences. However, she points out that estimates assuming identical workers are kind of an average of the true gradients for the various type workers. Thus the expected affect on wages and rents are more diluted if nonhomogeneous work force is built into the model. In addition, Hoehn et al. (1987) has shown that by including aggregation economies into the model further dilutes the expected effect on wages and rents from amenities.

CHAPTER FOUR

1. Within a household there is no need to distinguish i.

2. Instead of the average worker in a household the primary worker could have been chosen, however, there are problems associated with using the primary worker. In many cases, the household location decision is decided by the sum of a couple's income. To a much lesser extent, identifying the primary worker can be a problem.

3. Due to inconsistent covariance matrix estimates, if a cross-equation restriction is tested, it may lead to false results.

CHAPTER FIVE

1. Since the rent and wage equations are log-linear, the equations are linearized as follows: $\ln w = c + \beta x$ implies that $w = e^{[c+\beta x]}$ thus $\frac{\partial w}{\partial x_i} = e^{[c+\beta x]} \frac{\partial \beta x}{\partial x_i}$

CHAPTER SIX

1. Yearly housing units was obtained from the 1980 Census of Housing.

2. Aggregate damages of Superfund sites are the sum of the incremental damages. Incremental damages are estimated as:

$$ID = [12*492.97(\beta_{1,r}+2\beta_{2,r}SITE)]-[8.75*2725(\beta_{1,w}+2\beta_{2,w}SITE)]$$

where $\beta_{1,r}$ and $\beta_{2,r}$ are the rent coefficients and $\beta_{1,w}$ and $\beta_{2,w}$ are the wage coefficients for SITE and SITESQ respectively. To annualize the damage estimates the rent coefficients are multiplied by 12 (months per year) and the wage coefficients are multiplied by 2725, the product of the sample means of workers per household (1.61), mean hours per week worked (38.53), and the mean weeks worked per year (43.92). Since the rent and wage equations were estimated in log-linear form, the rent equation is multiplied by the average rent paid per household (492.97) and the wage equation is multiplied by the average wage received per household (8.75).

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APPENDIX A

DERIVATION OF WAGE AND RENT GRADIENTS

APPENDIX A

This appendix includes the derivation of the wage and rent gradients, equations (9) and (10) in chapter three. The k subscript is left out in the derivations.

The first step is to totally differentiate equations (6) and (7) from chapter three and include on the right hand side the change in utility or costs with respect to amenities. This results in the following:

(1) $V_w dw/da + V_r dr/da = -V_a$

(2) $C_w dw/da + C_r dr/da = -C_a$

Equations 1 thru 2 are then put in matrix form below:

$$\begin{bmatrix} V_w & V_r \\ C_w & C_r \end{bmatrix} * \begin{bmatrix} \dfrac{dw}{da} \\ \dfrac{dr}{da} \end{bmatrix} = \begin{bmatrix} -V_a \\ -C_a \end{bmatrix}$$

Set the first matrix equal to A, the second matrix equal to d and the third matrix equal to b, where $A*d=b$. To solve for the wage and rent gradients, shown in matrix d, the inverse of A is multiplied by b. That is $A^{-1}*b=d$.

The first step is to find the cofactor matrix of matrix A seen below:

$$\begin{bmatrix} C_r & -C_w \\ -V_r & V_w \end{bmatrix}$$

The adjoint of the cofactor matrix is:

$$\begin{bmatrix} C_r & -V_r \\ -C_w & V_w \end{bmatrix}$$

The determinant of the matrix A, Det. A is:

$$Det.A = C_r V_w - C_w V_r > 0$$

Multiplying the adjoint of the cofactor matrix by 1/detA results in the inverse of A, A^{-1}. So now the wage and rent gradients can be estimated by multiplying A^{-1} by matrix d. These result in the wage and rent gradients derived in chapter three.

APPENDIX B

ANNUAL INCREMENTAL COUNTY DAMAGES

Appendix B

Table B.1 - Annual Economic Damages of the Incremental Site
(1980 dollars)

Rank	County	State	NUMBER OF NPL SITES	NUMBER OF HOUSING UNITS IN THOUSANDS	HOUSEHOLD ANNUAL DAMAGES FROM INCREMENTAL SITE	STANDARD ERROR FOR HOUSEHOLD DAMAGES	COUNTY ANNUAL DAMAGES FROM THE INCREMENTAL SITE (THOUSANDS)
-	Sample Total	-	499	32,186	-	-	3,325,000
1	Cook	IL	1	1,993	150.32	88.88	300,000
2	Wayne	MI	1	875	150.32	88.88	131,000
3	San Diego	CA	1	718	150.32	88.88	108,000
4	Orange	CA	2	720	138.52	63.86	100,000
5	Philadelphia	PA	2	685	138.52	63.86	95,000
6	Dallas	TX	1	625	150.32	88.88	94,000
7	Allegheny	PA	2	571	138.52	63.86	79,000
8	Alameda	CA	3	444	126.71	44.03	56,000
9	Erie	NY	2	387	138.52	63.86	54,000
10	Milwaukee	WI	3	378	126.71	44.03	48,000
11	San Francisco	CA	1	316	150.32	88.88	48,000
12	Westchester	NY	1	316	150.32	88.88	47,000
13	Hamilton	OH	2	343	138.52	63.86	48,000
14	King	WA	6	525	91.30	74.90	48,000
15	Maricopa	AZ	7	600	79.49	100.99	48,000
16	Tarrant	TX	2	338	138.52	63.86	47,000
17	Broward	FL	6	477	91.30	74.90	44,000
18	Palm Beach	FL	1	287	150.32	88.88	43,000
19	Oakland	MI	4	372	114.91	38.48	43,000
20	San Bernadino	CA	4	366	114.91	38.48	42,000
21	Jefferson	KY	1	266	150.32	88.88	40,000
22	Marion	IN	3	309	126.71	44.03	39,000
23	Jefferson	AL	1	259	150.32	88.88	39,000
24	St. Louis	MO	5	358	103.10	52.01	37,000
25	Shelby	TN	3	286	126.71	44.03	36,000
26	Contra Costa	CA	2	252	138.52	63.86	35,000
27	Sacramento	CA	5	324	103.10	52.01	33,000

Table B.1 - Annual Economic Damages of the Incremental Site, Continued
(1980 dollars)

Rank	County	State	NUMBER OF NPL SITES	NUMBER OF HOUSING UNITS IN THOUSANDS	HOUSEHOLD ANNUAL DAMAGES FROM INCREMENTAL SITE	STANDARD ERROR FOR HOUSEHOLD DAMAGES	COUNTY ANNUAL DAMAGES FROM THE INCREMENTAL SITE (THOUSANDS)
28	Pima	AZ	1	216	150.32	88.88	33,000
29	Essex	NJ	5	317	103.10	52.01	33,000
30	Hudson	NJ	2	221	138.52	63.86	31,000
31	Macomb	MI	3	236	126.71	44.03	30,000
32	Hennepin	MN	7	379	79.49	100.99	30,000
33	Denver	CO	3	228	126.71	44.03	29,000
34	Delaware	PA	2	201	138.52	63.86	28,000
35	Union	NJ	1	183	150.32	88.88	27,000
36	Ventura	CA	1	183	150.32	88.88	27,000
37	Montgomery	OH	4	227	114.91	38.48	26,000
38	Orange	FL	2	183	138.52	63.86	25,000
39	DuPage	IL	5	235	103.10	52.01	24,000
40	Genesee	MI	2	163	138.52	63.86	23,000
41	Ramsey	MN	3	177	126.71	44.03	22,000
42	Camden	NJ	3	174	126.71	44.03	22,000
43	Passaic	NJ	2	158	138.52	63.86	22,000
44	Kern	CA	2	154	138.52	63.86	21,000
45	Jefferson	CO	1	137	150.32	88.88	21,000
46	Hillsborough	FL	7	261	79.49	100.99	21,000
47	Luzerne	PA	1	134	150.32	88.88	20,000
48	East Baton Rouge	LA	1	134	150.32	88.88	20,000
49	Stark	OH	2	143	138.52	63.86	20,000
50	Salt Lake	UT	6	214	91.30	74.90	20,000
51	Snohomish	WA	1	129	150.32	88.88	19,000
52	Polk	FL	1	127	150.32	88.88	19,000
53	San Joaquin	CA	2	136	138.52	63.86	19,000
54	Sedgwick	KS	3	146	126.71	44.03	18,000
55	Polk	IA	1	122	150.32	88.88	18,000
56	Volusia	FL	1	122	150.32	88.88	18,000
57	Lancaster	PA	2	129	138.52	63.86	18,000
58	Duval	FL	7	227	79.49	100.99	18,000

Table B.1 - Annual Economic Damages of the Incremental Site, Continued
(1980 dollars)

Rank	County	State	NUMBER OF NPL SITES	NUMBER OF HOUSING UNITS IN THOUSANDS	HOUSEHOLD ANNUAL DAMAGES FROM INCREMENTAL SITE	STANDARD ERROR FOR HOUSEHOLD DAMAGES	COUNTY ANNUAL DAMAGES FROM THE INCREMENTAL SITE (THOUSANDS)
59	Anne Arundel	MD	2	127	138.52	63.86	18,000
60	Albany	NY	1	115	150.32	88.88	17,000
61	Arapahoe	CO	1	113	150.32	88.88	17,000
62	Brevard	FL	1	113	150.32	88.88	17,000
63	Allen	IN	1	111	150.32	88.88	17,000
64	Mobile	AL	3	131	126.71	44.03	17,000
65	Hamilton	TN	1	110	150.32	88.88	17,000
66	Dane	WI	3	126	126.71	44.03	16,000
67	Wake	NC	2	113	138.52	63.86	16,000
68	Johnson	KS	1	103	150.32	88.88	15,000
69	Fresno	CA	7	192	79.49	100.99	15,000
70	Charleston	SC	1	99	150.32	88.88	15,000
71	Bucks	PA	6	165	91.30	74.90	15,000
72	Pierce	WA	7	185	79.49	100.99	15,000
73	Lorain	OH	1	96	150.32	88.88	14,000
74	Dauphin	PA	1	95	150.32	88.88	14,000
75	Erie	PA	2	102	138.52	63.86	14,000
76	Will	IL	3	109	126.71	44.03	14,000
77	Richmond City	VA	1	91	150.32	88.88	14,000
78	Lake	IL	6	148	91.30	74.90	14,000
79	Monterey	CA	3	103	126.71	44.03	13,000
80	St. Louis	MN	1	87	150.32	88.88	13,000
81	Oneida	NY	2	94	138.52	63.86	13,000
82	Stanislaus	CA	3	102	126.71	44.03	13,000
83	Butler	OH	2	92	138.52	63.86	13,000
84	Ingham	MI	3	99	126.71	44.03	13,000
85	Greenville	SC	4	108	114.91	38.48	12,000
86	Santa Cruz	CA	1	80	150.32	88.88	12,000
87	Richland	SC	3	92	126.71	44.03	12,000
88	St. Joseph	IN	3	91	126.71	44.03	12,000
89	Lancaster	NB	1	76	150.32	88.88	11,000

Table B.1 - Annual Economic Damages of the Incremental Site, Continued
(1980 dollars)

Rank	County	State	NUMBER OF NPL SITES	NUMBER OF HOUSING UNITS IN THOUSANDS	HOUSEHOLD ANNUAL DAMAGES FROM INCREMENTAL SITE	STANDARD ERROR FOR HOUSEHOLD DAMAGES	COUNTY ANNUAL DAMAGES FROM THE INCREMENTAL SITE (THOUSANDS)
90	Adams	CO	3	89	126.71	44.03	11,000
91	Cumberland	NC	2	81	138.52	63.86	11,000
92	Lackawanna	PA	3	88	126.71	44.03	11,000
93	Rockland	NY	2	80	138.52	63.86	11,000
94	Boulder	CO	1	73	150.32	88.88	11,000
95	Berks	PA	6	120	91.30	74.90	11,000
96	Waukesha	WI	4	91	114.91	38.48	11,000
97	Richmond	GA	1	65	150.32	88.88	10,000
98	Linn	IA	1	65	150.32	88.88	10,000
99	Winnebago	IL	5	93	103.10	52.01	10,000
100	Brown	WI	1	62	150.32	88.88	9,000
101	Broome	NY	4	81	114.91	38.48	9,000
102	Racine	WI	1	62	150.32	88.88	9,000
103	Clark	WA	3	73	126.71	44.03	9,000
104	Gaston	NC	1	59	150.32	88.88	9,000
105	Galveston	TX	4	77	114.91	38.48	9,000
106	Alachua	FL	1	59	150.32	88.88	9,000
107	Berkshire	MA	1	56	150.32	88.88	8,000
108	Yakima	WA	3	65	126.71	44.03	8,000
109	Kalamazoo	MI	5	79	103.10	52.01	8,000
110	Blair	PA	1	52	150.32	88.88	8,000
111	Niagra	NY	6	85	91.30	74.90	8,000
112	Dakota	MN	4	67	114.91	38.48	8,000
113	Jefferson	MO	1	50	150.32	88.88	8,000
114	Weber	UT	2	50	138.52	63.86	7,000
115	Calhoun	MI	3	54	126.71	44.03	7,000
116	Lycoming	PA	1	45	150.32	88.88	7,000
117	Monroe	MI	1	45	150.32	88.88	7,000
118	Chesterfield	VA	2	49	138.52	63.86	7,000
119	Elkhart	IN	3	52	126.71	44.03	7,000
120	Rock	WI	3	51	126.71	44.03	7,000

Table B.1 - Annual Economic Damages of the Incremental Site, Continued
(1980 dollars)

Rank	County	State	NUMBER OF NPL SITES	NUMBER OF HOUSING UNITS IN THOUSANDS	HOUSEHOLD ANNUAL DAMAGES FROM INCREMENTAL SITE	STANDARD ERROR FOR HOUSEHOLD DAMAGES	COUNTY ANNUAL DAMAGES FROM THE INCREMENTAL SITE (THOUSANDS)
121	Lexington	SC	3	51	126.71	44.03	7,000
122	Vigo	IN	1	43	150.32	88.88	6,000
123	Yellowstone	MT	1	43	150.32	88.88	6,000
124	Roanake City	VA	1	43	150.32	88.88	6,000
125	Minnehaha	SD	1	43	150.32	88.88	6,000
126	Calhoun	AL	1	42	150.32	88.88	6,000
127	St. Charles	MO	3	50	126.71	44.03	6,000
128	Harford	MD	3	49	126.71	44.03	6,000
129	New Hanover	NC	1	41	150.32	88.88	6,000
130	Aiken	SC	1	40	150.32	88.88	6,000
131	Ector	TX	2	43	138.52	63.86	6,000
132	Woodbury	IA	1	39	150.32	88.88	6,000
133	Kankakee	IL	1	37	150.32	88.88	6,000
134	Cumberland	NJ	4	47	114.91	38.48	5,000
135	Washington	MN	2	37	138.52	63.86	5,000
136	Stearns	MN	2	34	138.52	63.86	5,000
137	Benton	WA	5	43	103.10	52.01	4,000
138	Los Angeles	CA	12	2,854	0.00	0	0
139	Santa Clara	CA	22	474	0.00	0	0
140	Kent	MI	10	163	0.00	0	0
141	Spokane	WA	9	137	0.00	0	0
142	Nassau	NY	12	432	0.00	0	0
143	Monmouth	NJ	8	181	0.00	0	0
144	Suffolk	NY	8	406	0.00	0	0
145	Montgomery	PA	15	232	0.00	0	0
146	Chester	PA	9	110	0.00	0	0
147	Bergen	NJ	9	307	0.00	0	0
148	Atlantic	NJ	8	88	0.00	0	0
149	Burlington	NJ	13	121	0.00	0	0
150	Harris	TX	8	984	0.00	0	0
151	Middlesex	NJ	11	203	0.00	0	0