research on this subject is clearly necessary. It seems clear that the conventional assuredness of researchers that there exists some stable, fixed, true underlying valuation that is straightforwardly elicited by contingent valuation techniques deserves serious reconsideration.

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An Interregional Hedonic Analysis of Noxious Facility Impacts on Local Wages and Property Values[1,2]

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Since the early work of Rosen, Roback, and more recently Blomquist, Berger, and Hoehn, economists have recognized that local environmental amenities influence wage rates and property values jointly. Moreover, local differentials in these prices can be used to implicitly value local amenities. Unfortunately, much of the empirical work on noxious facilities has focused on a narrow range of facility types, often within a single city. Generally, distance from the facility is used to proxy exposure to the disamenity, although it is possible that the mere existence of a noxious facility in a region has an impact on local residents. We employ an intercity hedonic model to measure the joint property value and wage effects of a broad range of noxious facilities. Using Public Use Microdata from the 1980 United States Census, we show that property values and/or wages are significantly influenced by the existence of noxious facilities. Calculated implicit prices reveal that local residents are most averse to the presence of petrochemical refineries and nuclear power plants.

1. INTRODUCTION

Claims of property value loss are commonly raised by homeowners when noxious facilities[3] are sited or when new information about the hazards of existing facilities is made public. While the capitalization of externalities into land values is consistent with economic theory, empirical measurement of impacts for each type of facility individually has not generated consistent results. This is true both for hedonic measurements and for other types of econometric analyses. Although it is well established that job and site risks impact regional labor markets, there are no

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[3]The term noxious is used to designate facilities that have been classified as locally undesirable land uses LULU's by Popper [4] and Smith and Desvousges [5].

studies relating the presence of a broad range of noxious facilities to local wage premiums.

In contrast, this study employs an interregional framework in an hedonic analysis of both wage and property markets to evaluate impacts of eight different categories of facilities. The approach offers several advantages. First, since multiple facility types are controlled, we can be more confident of the marginal impact of a particular type of facility. Second, the technique provides insights into the relative impact on property and labor markets of noxious facilities as a form of disamenity. It also permits calculation of an implicit price for each type of noxious facility that is composed of wage and property value impacts. The development of equitable compensation measures and the identification of social cost-minimizing siting criteria for noxious facilities are both dependent on the accurate estimation of impacts.

The remainder of this paper is divided into four sections. In Section 2, we contrast the intercity and intracity hedonic methods, both of which have been used to derive implicit prices for environmental amenities and disamenities. The third section gives a brief description of the intercity hedonic model. The unique data base and the structure of the estimated model are described in Section 4, and the final section contains a discussion of the findings and of directions for further research.

2. OVERVIEW OF HEDONIC MODEL

The hedonic model has its origins in the work of Lancaster [6] and Rosen [7] and has been applied to value amenities such as air quality (Ridker and Henning [8], Nelson [9], Harrison and Rubinfeld [10]), airport noise (Nelson [11]), and public safety (Thaler [12]). It has also been used to consider the impact of various types of noxious facilities such as nuclear plants (Gamble and Downing [13, 14], Nelson [15]), coal-fired power plants (Blomquist [16]), hazardous waste facilities (Harrison and Stock [17], Smith and Desvousges [5], Michaels and Smith [18], McClelland *et al.* [19]), chemical manufacturing (Baker [20]), and radioactive materials production [21]. Often, proximity to the site is used to measure impacts. The usefulness of this approach depends on several things. First, it requires an impact gradient for the facility which is relatively steep. Second, if distance is to provide an adequate measure, it must be the case that other amenities and disamenities, as well as employment opportunities, which are correlated with distance from the site, are controlled.[4]

Rosen [1] was the first to consider amenities in an intercity as opposed to intracity framework, and Cropper and Arriaga-Salinas [24] suggest that the intercity approach may be preferable in some applications. For example, site characteristics which have broad regional economic impacts may have local impact gradients which are very flat, but for which intercity differentials are substantial. Cropper and Arriaga-Salinas [24] also argue that the intracity model does not value site characteristics at the place of work. We further note that benefit estimates obtained from a single market may not be generalizable to other markets. However, when multiple market data are employed, the marginal prices are readily generalized to encompass all regions represented in the data, permitting national benefit estimates to be derived.[5]

Since the early work of Rosen [1], the intercity model has been refined. Whereas the Rosen model avoids the issue of joint capitalization of amenities into intercity wages and land values by assuming home production theoretically and examining real wages empirically, Roback [2] develops a general equilibrium model of intercity household and firm location. In Roback's model, wages and land rents are simultaneously determined by the actions of utility-maximizing households and cost-minimizing firms. This model is further refined by Blomquist *et al.* [3], who make city size endogenous. The models of Roback and Blomquist *et al.* derive implicit prices as a weighted sum of the capitalized influence in land and labor markets.

Whereas most hedonic analyses of noxious facilities concentrate attention on the influence within cities, at least one study investigates the intercity impact. Blomquist *et al.* [3] consider the presence of Superfund sites; waste treatment, storage, and disposal sites; and the volume of landfill waste on land values and wage rates in their derivation of an urban quality-of-life-index. They find that all three facility types have a significant positive influence on housing expenditures as well as on hourly wage rates. The combined effect, which is reflected in the full implicit price, is negative as expected, and Superfund sites are found to have the strongest marginal impact.

3. THEORETICAL INTERCITY HEDONIC MODEL

The model used in this paper is fully developed in Roback [2] and Blomquist *et al.* [3] (hereafter R-BBH), and thus we do not repeat the derivation here. In addition, a more general model, which incorporates the effect of compensation for damages, similar to that developed by Hageman [22] in an intracity model, is not considered in this paper. The reason is that this model is applied to 1979 data. While the possibility of compensation for damages existed in 1979, the probability was actually quite low. It should be noted, however, that there are indications that such an assumption is less valid when looking toward the future.[6]

The R-BBH model assumes that both households (which maximize utility across space) and firms (which minimize costs across space) are in equilibrium. Hence,

[4] Hageman [22] notes that certain environmental goods (or bads) may have both positive and negative impacts on property values, depending on their influence on employment. For example, proximity to a nuclear power plant may reduce property values because of the increased risk in the event of an accident, while at the same time property values may increase if the plant is an important source of employment. Bender and Hwang [23] show that both primary and secondary employment centers must be controlled for when deriving the intraurban land rent function. In an attempt to avoid this problem in their study of a hazardous waste site, McClelland *et al.* [19] use a measure of perceived risk constructed from survey responses in a hedonic model. Their findings suggest that neighborhood risk perception does reduce local property value.

[5] It is important to recognize that the intercity model is not a substitute for the intracity model. Rather, they should be viewed as complementary tools in valuing amenities, with the intercity model more appropriate in some circumstances, and the intracity model preferred in others. In applications where both can be applied, they offer an opportunity to test for consistency.

[6] For example, Nieves *et al.* [25] examine negotiated settlements between Wisconsin communities and waste disposal facilities. These settlements exist as a result of a 1981 Wisconsin law which establishes a process of negotiating compensation for waste disposal facility siting.

the implicit price for an amenity is derived as the weighted sum of the capitalized value of the amenity in local wages and land rents. The implicit price is defined by Eq. (1).

$$P^* = W * k_1 * d \ln R/dA - W * d \ln W/dA. \tag{1}$$

W is the annual wage and R is the annual land rent. The fraction of income spent on land is represented by k, so the expenditure on land ($W * k_1$) provides the weight on the rent component of the implicit price.[7] Thus, P^* is the annual implicit price paid (in higher land rents and sacrificed wages) for a marginal improvement in the amenity. The following section derives reduced-form wage and land rent functions and then uses those functions to derive implicit price estimates for a wide range of location-specific attributes.

4. AN EMPIRICAL MODEL OF NOXIOUS FACILITY IMPACTS

A data base is developed that combines individual data on housing value and wages with a broad range of noxious facilities, amenities and disamenities, fiscal measures, and other control variables. To implicitly value noxious facilities, a unique data set is constructed for eight different facility types. After a discussion of the selection of study sites, we turn to the development of the empirical model and description of the noxious facility data.

4.1. Study Site Selection

The selection of study sites was a multistage process that started with the choice of a range of facility types that present different employment opportunities and physical hazard risks to the surrounding population. The eight categories of facilities are

NUP	nuclear power electric generating plants
COP	coal-fired electric generating plants
GOP	gas- and oil-fired electric generating plants
CHM	military chemical weapons storage sites slated for decommissioning
HWS	chemical or radioactive hazardous waste sites
PCR	petrochemical refineries
RAC	formerly utilized, radioactively contaminated sites managed by the Department of Energy
LNG	liquefied natural gas storage facilities[8]

[7]Henderson [26] shows that so long as the average rent levels are controlled, the intercity hedonic wage equation alone can be used to derive implicit prices. Clark and Cosgrove [27] further establish that the intercity hedonic land rent equation can yield full implicit prices with wages controlled. We only derive implicit prices from uncontrolled intercity wage and rent functions in this paper.

[8]The hazardous waste category is mainly composed of Superfund sites. In addition, this category includes two operating commercial low-level radioactive waste disposal facilities. The RAC sites have residual radioactive contamination from materials produced for the Manhattan Project or subsequent projects and are not associated with any ongoing operations. For the spatial units examined in this sample, we have complete coverage of the facilities in these categories.

TABLE 1
Number of Facilities by Facility Type and Census Region

Region (sites)	Type of Facility								
	NUP	COP	GOP	CHM	HWS	PCR	RAC	LNG	Total
New England (5)	2	0	6	0	4	0	0	1	13
Middle Atlantic (15)	5	10	8	0	43	5	4	3	78
South Atlantic (17)	5	7	9	1	9	1	0	3	35
East North Central (8)	1	11	4	1	8	2	0	0	27
East South Central (4)	1	2	0.	2	2	0	0	2	9
West North Central (8)	0	4	12	0	7	4	2	1	30
West South Central (6)	1	2	6	0	7	15	0	0	31
Mountain (4)	0	3	4	2	3	2	0	0	14
Pacific (9)	6	0	4	0	10	4	0	1	25
Total (76)	21	39	53	6	93	33	6	11	262

After defining the facility categories, specific sites were selected using the data units of the 1980 United States Census Public Use Microdata "B" Sample (hereafter PUMS). Because the PUMS covers the entire 48 contiguous states, one goal of the sample selection process was to obtain a representative sample encompassing the full range of variation in site characteristics, population density, and amenities. However, the PUMS county grouping may cover a wide geographic area,[9] so a second goal was to select sites that constitute a geographic area small enough so that average amenity levels within that area are representative for the resident population. In a few cases where a region and facility type could be represented by two alternative geographic areas of widely disparate sizes (in terms of square miles) within the same region, the smaller county grouping was chosen. Finally, when PUMS county groupings were composed of noncontiguous geographical areas, those areas were deleted from the sample, as were areas of greater than 10,000 square miles. Study areas in the final sample range from 22 to 7218 square miles, with a mean area of just over 1500 square miles.

There are a total of 76 PUMS study areas in the sample, of which 70 contain 262 noxious facility sites. Six study areas are included that did not contain any facilities of the types studied. Other types of facilities that provide waste disposal, transportation, or production services may also be located in any of the study sites. The density of many of these excluded types of facilities generally increases with population density. The distribution of the noxious facilities among the nine Census Divisions is shown in Table 1. The Middle Atlantic region contains the largest number of facilities (78) mainly due to the number of hazardous waste sites identified in these states. Also, most of the nuclear power plants are located in the east and west coastal states, while petrochemical refineries are concentrated in the West South Central region. In general, the distribution of most facility types for this sample reflects the distribution of the total population of facilities across regions.

[9]To protect individual confidentiality, the geographical areas defined have a population of at least 100,000. In sparsely populated areas, this creates very large multicounty data units. There are 28 multicounty areas in the sample, of which 2 have areas larger than 5000 square miles.

4.2. Regression Model

We specify two equations to measure the distinct influence of location factors on annual housing rent equivalent (ANNRENT) and annual market wages (ANNWAGE).

$$\text{ANNRENT} = R(\text{STRUCTURE, PRICE, DISEQ, LOCDUMMY, FISCAL, AMENITY, NOXIOUS}) \quad (2)$$

$$\text{ANNWAGE} = W(\text{HC \& IND, PRICE, DISEQ, LOCDUMMY, FISCAL, AMENITY, NOXIOUS}) \quad (3)$$

Independent variables for human capital and for industry controls (HC & IND) are included in the wage equation, while housing structural characteristics (STRUCTURE) are included in the housing rent equation. Additional independent variable categories include local prices (PRICE), disequilibrium controls (DISEQ), regional and local location dummy variables (LOCDUMMY), fiscal factors such as local taxes and spending levels (FISCAL), amenity controls (AMENITY), and noxious facilities (NOXIOUS).

Data from several sources were assembled to construct a data set that provides details of wage and housing values, as well as the locational features of those markets. All of the data are for 1976–1980. Data for wages, residential housing values, and HC & IND and STRUCTURE attributes are taken from the PUMS.

The housing sample includes owner-occupied units and excludes units lacking individual access and residences used for commercial purposes. Owners with reported property values in the category "$175,000 and up" are excluded.[10] The resulting sample consists of 45,899 units. The sample of workers used to estimate the wage equation is composed of those 18 years and older who report wage and salary income or nonfarm self-employment income.[11] The sample is confined to workers who earn calculated wages in excess of $2.00 per hour,[12] who both live and work in one of the study sites, and for whom occupation is identified. Because the PUMS income data distribution is truncated, the income category of $75,000 and up" is omitted from the analysis. The final sample size is 23,735 persons.

The remaining data are taken from numerous sources, which are outlined in Table II, and are typically defined for a city or county in the region. In all cases,

[10]If the absence of noxious facilities is a normal good, omitting the highest category from either equation will bias implicit price estimates downward. Using a data subset, we investigated whether the truncation of the sample biased coefficients in either equation. Less than 1% of the observations in the wage sample and less than 2% in the housing sample are dropped. When those observations were included, and a Tobit technique was used to correct for potential trunctation bias, we found nearly identical results. Indeed, no regression coefficients changed sign or significance level. Since the appropriate value to assign to the omitted categories is uncertain, we believe that their exclusion is necessary. In addition, the consequences of the decision to truncate the sample appear to be minimal.

[11]Farm income is omitted because it may incorporate returns to farmland and buildings.

[12]Those who report hourly earnings of less than $2.00 per hour are dropped due to the likelihood of underreported income.

TABLE II

Variables and Data Sources[a]

Variable	Variable definition
	Housing model variables
ACREGT1	1 if acres greater than 1; 0 otherwise
ANNRENT	Annualized rental expenditure on owner-occupied housing
BATHROOM	Number of bathrooms
BEDROOM	Number of bedrooms
BLDNGAGE	Median of building age interval in years
CENTAIR	1 if central air conditioning; 0 otherwise
CONDO	1 if condominium unit; 0 otherwise
DETACHED	1 if detached single-family house; 0 otherwise
HEATING	1 if central system; 0 otherwise
OTHRROOM	Total number of rooms minus bedrooms
SEWAGE	1 if public sewage; 0 otherwise
WATER	1 if public system or private company; 0 otherwise
YRMOVED	Years since move to unit (median of interval)
	Wage model variables
ANNHOURS	Average hours worked per week times weeks worked
ANNWAGE	Wage and salary plus nonfarm self-employment income
DISABLE	1 if work disability; 0 otherwise
EDUC	Highest year of school attended
EXPER	Age minus education minus 6
EXPERSQ	Experience squared
FULLTIME	1 if average hours of work greater than 39 hours per week; 0 otherwise
MARITAL	1 if now married; 0 otherwise
SEX	1 if female; 0 if male
SEXMAR	SEX * MARITAL, 1 if married female; 0 otherwise
VETERAN	1 if veteran of the Armed Forces; 0 otherwise
WHITE	1 if white; 0 otherwise
Industry dummy variables	Separate industry dummies include agriculture, forestry, and fisheries: construction; entertainment and recreation services; business and repair services; mining; public administration; professional and related services; wholesale and retail trade; transportation, communications, and other public utilities; finance, insurance, and real estate; and manufacturing (the omitted category)
Occupation dummy variables	Separate occupation dummies are included for farming and fishing (the omitted category); managerial and professional specialties; operators, fabricators, and laborers; precision production craft and repair; service; and technical, sales, and administrative support
	Price, disequilibrium, and location dummy variables
COLINDEX	Cost-of-living index excluding housing [33]
UNEMPLOY	Percentage of total labor force in the region unemployed [34]
PCTUNION	Percentage of the labor force unionized in 1980 [35]
VACANCY	Percent of the year-round housing units vacant [34]
CNTRLCTY	1 if central city of SMSA; 0 otherwise
RURAL	1 if outside SMSA; 0 otherwise
COAST	1 if ocean coast location; 0 otherwise[b]
Census Division	8 dummy variables for census Division. The East North Central Division is the left-out category

TABLE II (*Continued*)

Variable	Variable definition
	Fiscal variables
LOCALTAX	Per capita local taxes in the county or counties of the PUMS County Group [34]
INCOMETX	Marginal statewide income tax, evaluated at $20,000 [36]
INTERGOV	Per capita spending from intergovernmental transfers from the state or federal government, in the county or counties of the PUMS County Group [34]
LOCALEXP	Per capita spending from county revenue sources [34]
	Amenity and disamenity variables
PRECIP	Annual inches of precipitation [37]
TEMPDIFF	Annual range (average July maximum minus average January minimum) of daily mean temperatures in degrees F [34]
HEATDAYS	Total heating-degree-days [34]
COOLDAYS	Total cooling-degree-days [34]
AVGWIND	Average wind speed [37]
PCTSUN	Realized percentage of the potential sunlight [37]
POPDENS	Population per square mile [34]
COMMUTE	Mean commuting time within the PUMS county group[b]
CRIME	Violent crimes per capita [34]
PCTMANUF	Percentage of total employment in manufacturing [34]
TSP	Annual average total suspended particulates [38]
	Noxious facility variables (density per 1000 square miles)
NFDNSNUP	Nuclear power plant either in operation or in final stages of construction by 1980[c]
NFDNSCOP	Coal-fired power plant either in operation or in the final stages of construction in 1980[c]
NFDNSGOP	Gas-fired or oil-fired power plant in operation in 1980; these are grouped together because in many cases, both fuels are used at a particular site[c]
NFDNSCHM	Chemical weapons storage site [39]
NFDNSHWS	Hazardous waste sites listed on the National Priorities List plus two commercial radioactive waste disposal sites [40]
NFDNSPCR	Petrochemical refineries [41]
NFDNSRAC	Radioactive contaminated sites having residual contamination from materials produced for the Manhattan Project or subsequent projects, not associated with any ongoing operations [42]
NFDNSLNG	Liquefied natural gas storage sites and terminal installations [43]

[a]Variables are from PUMS unless otherwise indicated.
[b]Calculated.
[c]Electric Utilities Data Base derived from DoE, Energy Information Administration monthly, quarterly, and annual reporting forms.

the county and city data that most closely correspond geographically to the PUMS data unit for each study site are selected.[13] The specifics of Eq. (2) and (3) are

[13]It should be noted that the matching is not perfect since some PUMS data units are composed of subcounty or multicounty areas. While this can reduce the precision of the empirical findings, we do not believe it presents a serious problem here. We reestimated the models using the subset of sites for which the geographic match of PUMS and other data units is exact and found no appreciable difference in the estimates.

detailed below.[14] We first describe the variables which are unique to each model, followed by those independent variables which are present in both models.

4.3. *Variables Unique to the Housing Rent or Wage Models*

The annual housing rent (ANNRENT) component of housing value is derived from the owner's estimate of the market value of the residence[15] It can be expected that those who have purchased most recently will provide the most accurate value estimates. Accordingly, the time period since moving into the house (YRMOVED) is included in the equation to account for variation in accuracy over time. Structural characteristics (STRUCTURE) of the housing unit are controlled using the measures listed and defined in Table II.

Annual wages, the summation of annual wages and self-employment income (ANNWAGE), is the dependent variable in the wage model. A vector of human capital and industry characteristics (HC & IND) which are listed and defined in Table II are employed to control for variation among individuals and their employment.

4.4. *Variables Common to Housing Rent and Wage Models*

Equations (2) and (3) share many of the same variables. The PRICE category contains a cost of living index (COLINDEX) computed without the cost of housing to account for the relative cost of produced goods. The DISEQ category is included to control for the possibility of temporary disequilibrium. We include the unemployment rate (UNEMPLOY) in both models. The wage model includes the percentage of the labor force that is unionized (PCTUNION), and the housing model includes the percentage of year-round housing units that are unoccupied (VACANCY). Percentage unionized is included in the disequilibrium category in recognition of the role of unions in maintaining higher returns to human capital than would otherwise be found under equilibrium conditions. The location dummy

[14]Although the basic structure of our model is the same as that for BBH, there are some important differences. First, spatial coverage of the models differs. BBH use the PUMS A Sample, whereas we use PUMS B which has more subcounty detail for some metropolitan areas. Second, our dataset includes PUMS county groups which are in nonmetropolitan as well as metropolitan areas, which is important in empirically modeling amenities, given the continued growth of population and employment in surburban and rural counties. Third, we include FISCAL factors in both regression models. Recent literature has suggested that such variables are capitalized into intercity wage differentials (Gyourko and Tracy [28]). Assuming the R-BBH framework, these factors should be capitalized into intercity housing rent differentials as well. Fourth, we control at least partially for disequilibrium influences in both equations. Henderson [26] has suggested that regional dummy variables can be used to account for regional disequilibrium, although we should note that more recent literature has modeled disequilibrium endogenously by simultaneously modeling the behavior of migrants (see, for example, Greenwood *et al.* [29], Bartik *et al.* [30], Mathur and Stein [31], and Herzog and Schlottman [32]). Finally, we include an expanded list of noxious facilities.

[15]The first term in Eq. (2) represents the annual land rent price. Since housing value is the asset price, we computed the annual housing rental price as the yearly payment on the mortgage principle plus interest assuming an effective mortgage rate of 10.78% for 1979. This rate is reported in the 1987 Economic Report of the President. It includes prepaid points and assumes repayment after 10 years. To derive the implicit price (as described in eq. (1)), an estimate of the land rent is needed. Annual land rent is derived by assuming that land expenditure is 19.6% of housing expenditures, as estimated by Roback [2] from FHA data.

variables (LOCDUMMY) include variables for the nine Census Divisions. Also included are dummy variables for the metropolitan status of the PUMS County Group (CNTRLCITY, RURAL, with the suburban part of SMSA's as the omitted category).

Since the pioneering work of Tiebout [44], economists have recognized that property values capitalize local fiscal conditions. More recently, Gyourko and Tracy [28] established that wages can also capitalize local taxes and expenditures. To control for these influences, we include several measures in the FISCAL category in both models. Following Gyourko and Tracy, we include the marginal statewide income tax rate, evaluated for the $20,000 income bracket (INCOMETX). We also include local taxes collected per capita (LOCALTAX) and local spending per capita from two separate sources (INTERGOV and LOCALEXP). The variable INTERGOV represents spending which emanates from external sources (i.e., intergovernmental transfers to the county or group of counties from the state or federal government), whereas LOCALEXP represents spending from local revenue sources only.

Control amenities and disamenities (AMENITY) relate to climate or to other factors such as safety, air quality, and congestion in the region. The climate measures are listed first in this group in Table II, followed by other amenity and disamenity variables. Among the other amenities and disamenities controlled are the level of congestion within the PUMS County Group as measured by average commute times (COMMUTE) and the total suspended particulates (TSP). TSP is included because it is the air quality measure most strongly linked to health effects and it is moderately correlated with sulfate levels, which also reduces visibility.[16] Additionally, we include manufacturing employment concentration (PCTMANUF) to further proxy such disamenities as high traffic volume and pollution, and we also include population density (POPDENS) to proxy unmeasured amenities and disamenities that are related to urban scale. Finally, we note that the location dummies may also control for unmeasured amenity factors.

Noxious facilities are modeled in terms of facility density per 1000 square miles for each PUMS data unit. Density is used to standardize the facility impact measure because of the large range of areas covered by the PUMS data units. We include separate density variables for each of the eight separate categories of noxious facilities (NFDNSxxx), with the last three terms designating facility type.

5. EMPIRICAL FINDINGS

Because of the nonlinearity in the implicit price function, both models are estimated by using a double logarithmic functional form. This functional form is superior to the semilog form since it places fewer restrictions on the shape of the price function.[17] More flexible functional forms, such as the generalized quadratic (suggested by Rasmussen and Zuehlke [46]), were rejected because of the large number of interaction terms that would be required given the number of independent variables in each model. The resulting collinearity is likely to produce high standard errors and less precise parameter estimates.[18]

[16] In an hedonic wage study of air quality, Bayless [45] found TSP to be preferred to such measures as carbon monoxide, sulfur dioxide, nitrogen dioxide, and total hydrocarbons on several criteria. He notes that TSP is highly visible and was more completely reported by the EPA in the 1970 time period than other measures. This was also true in the 1980 time period.

[17] For example, for an amenity in the housing value equation, the semilog form imposes the restriction that the implicit price function (i.e., first derivative of the hedonic function) must be increasing at an increasing rate. By contrast, the double-log model allows the implicit price function to increase at a decreasing, constant, or increasing rate depending on the magnitude of the amenity elasticity of housing values.

5.1. *Housing Rent Model*

Results for both the housing rent and the wage models are presented in Table III for ease of comparison. In the housing rent model, the estimated parameters of the STRUCTURE variables are generally highly significant and consistent with expectations.[19] Only the sign on SEWAGE is counterintuitive. It may be reflecting disamenities associated with location in urban settings, although we do include dummy variables to measure the separate influence of central cities.

Higher unemployment (UNEMPLOY) and higher VACANCY rates are associated with lower house prices, while the cost of living (COLINDEX) is positively related to housing costs. Most of the regional dummies controlling for disequilibrium effects are significant, and they indicate that housing prices are higher in the Middle Atlantic, Pacific, and Mountain regions relative to the East North Central region. In contrast, prices are significantly lower in the New England, South Atlantic, West South Central, and West North Central regions. Homes in both central city (CNTRLCTY) and non-SMSA (RURAL) locations have significantly lower values than comparable suburban housing, with a more pronounced negative price effect due to central city location. Coastal location (COAST) is positive and significant, suggesting that it is an amenity to homeowners.

In the FISCAL category, high levels of local spending (LOCALEXP) significantly increase values, while high local taxes (LOCALTAX) have the opposite effect. High marginal income tax rates (INCOMETX) do not have a significant influence, and surprisingly, high levels of spending from state and federal sources

[18] Although the double-log model is theoretically preferred to the semilog model, we recognize that the simple and extended Box-Cox models have been used in some applications. We estimated the wage and the housing rent equations, on a 10% subsample, using four different nonlinear functional forms. These were the double-log, semi-log, linear Box–Cox with dependent variable transformed, and extended Box–Cox with both independent and dependent variables transformed by the same value of λ. A likelihood ratio test (Greene [47]) does confirm a significantly better fit for both Box–Cox models. However, Cassel and Mendelsohn [48] warn that use of the Box-Cox transformation, based on fit alone, may have some undesirable consequences. For example, they note that "the nonlinear transformation results in complex estimates of slopes and elasticities which are often too cumbersome to use properly." Moreover, they find no support (in the data they used) for the assumption that the independent variables are linear, nor that both independent and dependent variables should be transformed by the same value of λ (the Box–Cox transformation). While more flexible forms such as the Box–Tidwell technique, which permits different values for λ on the dependent variable and each independent variable, can address this problem, they could not be applied to this data set because some variables are nonpositive. In light of this controversy, we chose to use the double-log model in this application. It has the advantage of ease of interpretation, and we are more certain of the restrictions it places on the implicit price function.

[19] We tested for multicollinearity using the approach outlined in Belsley *et al.* [49]. Although multicollinearity does exist in the housing rent model, as indicated by high condition numbers, the near dependencies have not degraded coefficient estimates to the point of statistical insignificance. That is, none of the insignificant coefficients in the housing rent model resulted from multicollinearity.

TABLE III

Ordinary Least-Squares Regression Results

Housing value equation			Income equation		
Variable	Coefficient	t-statistic	Variable	Coefficient	t-statistic
Intercept	−6.10586	−10.743	Intercept	0.30404	0.388
Structural variables			Human capital variables		
DETACHED	0.21606	17.892	EDUC	0.49479	26.174
WATER	−0.01484	−1.729	EXPER	0.01959	25.263
SEWAGE	−0.02053	−2.853	EXPERSQ	−0.00031	−19.291
BLDNGAGE	−0.08759	−31.124	SEX	−0.23292	−19.884
YRMOVED	−0.02466	−11.050	MARITAL	0.17246	17.512
BEDROOM	0.25424	31.824	SEXMAR	−0.25883	−19.201
BATHROOM	0.56275	62.150	WHITE	0.03188	3.447
OTHRROOM	0.28155	39.439	FULLTIME	0.01936	2.106
ACREGT1	0.11373	14.703	DISABLE	−1.10426	−6.928
HEATING	0.23014	32.380	VETERAN	0.04470	5.143
CENTAIR	0.18474	30.959	ANNHOURS	0.77672	124.331
CONDO	0.13030	7.756			
Price, disequilibrium, and location dummy variables					
UNEMPLOY	−0.31109	−27.107	UNEMPLOY	0.01527	0.970
COLINDEX	2.35875	20.204	COLINDEX	0.32431	2.184
VACANCY	−0.02533	−1.697	PCTUNION	0.10992	4.817
NEWENGL	−0.04195	−2.099	NEWENGL	−0.05252	−1.884
MIDATL	0.07014	5.800	MIDATL	−0.05098	−3.112
SOUTHATL	−0.05199	−2.712	SOUTHATL	0.04532	1.539
ESCENTR	0.02860	1.328	ESCENTR	0.04724	1.678
WNCENTR	−0.06687	−3.102	WNCENTR	0.02620	0.863
WSCENTR	−0.16808	−7.908	WSCENTR	0.04603	1.360
MOUNTAIN	0.32459	15.221	MOUNTAIN	−0.02893	−0.914
PACIFIC	0.34732	12.104	PACIFIC	−0.02516	−0.604
CNTRLCTY	−0.11479	−17.014	CNTRLCTY	−0.01055	−1.035
RURAL	−0.06545	−6.772	RURAL	−0.02536	−1.962
COAST	0.09924	9.446	COAST	0.01721	1.169
Fiscal variables					
INCOMETX	−5.8E-05	−0.015	INCOMETX	−0.00054	−0.102
LOCALTAX	−0.06424	−3.340	LOCALTAX	−0.00028	−0.011
INTERGOV	−0.04876	−3.059	INTERGOV	−0.04119	−1.817
LOCALEXP	0.10987	3.799	LOCALEXP	0.12280	3.149
Climatic amenity and disamenity variables					
PRECIP	−0.03260	−1.991	PRECIP	−0.06069	−2.865
TEMPDIFF	−0.53780	−13.404	TEMPDIFF	−0.00974	−0.170
HEATDAYS	0.30551	14.493	HEATDAYS	0.02619	0.925
COOLDAYS	0.08112	9.524	COOLDAYS	−0.00356	−0.285
AVGWIND	0.41417	15.143	AVGWIND	−0.00402	−0.101
PCTSUN	0.15361	2.746	PCTSUN	0.04590	0.583
Other amenity and disamenity variables					
POPDENS	0.02281	4.828	POPDENS	−0.00926	−1.502
COMMUTE	−0.08105	−5.313	COMMUTE	0.01534	0.679
CRIME	−0.02119	−3.142	CRIME	0.04113	4.446
PCTMANUF	−0.03338	−3.207	PCTMANUF	0.02378	1.615
TSP	−0.03220	−2.413	TSP	0.04338	2.238

TABLE III (*Continued*)

Housing value equation			Income equation		
Variable	Coefficient	t-statistic	Variable	Coefficient	t-statistic
Intercept	−6.10586	−10.743	Intercept	0.30404	0.388
Structural variables			Human capital variables		
Noxious facility variables					
NFDNSNUP	−0.00487	−2.790	NFDNSNUP	0.00657	2.688
NFDNSCOP	−0.00755	−5.264	NFDNSCOP	0.00256	1.197
NFDNSGOP	−0.00791	−3.389	NFDNSGOP	0.00096	0.320
NFDNSPCR	−0.01642	−9.950	NFDNSPCR	0.01501	6.319
NFDNSHWS	0.01453	10.151	NFDNSHWS	−0.00277	−1.354
NFDNSLNG	0.00543	3.186	NFDNSLNG	0.00433	1.817
NFDNSRAC	−0.00798	−3.635	NFDNSRAC	0.00082	0.234
NFDNSCHM	−0.02627	−7.420	NFDNSCHM	−0.00480	−0.987
F statistic = 1288.730			F statistic = 746.763		
R^2_{adj} = 0.5789			R^2_{adj} = 0.6644		
Observations = 45,899			Observations = 23,735		

(INTERGOV) actually depress values. This may reflect relatively high spending on antipoverty measures in poor regions.

All of the climate amenity variables are significant. The coefficient on TEMPDIFF is negative, while those on both COOLDAYS and HEATDAYS are positive, indicating a preference for either hot or cold climates over those with both temperature extremes.[20] The magnitude of the coefficient of HEATDAYS is larger than that of COOLDAYS, perhaps reflecting some of the higher costs of structural adaptation to cold climates. High average wind speeds increase property values, as does sunshine.

The other amenity variables give the anticipated results. High levels of total suspended particulates and violent crime as well as lengthy commutes are viewed as disamenities. Higher POPDENS increases housing values. This is not surprising, because although we include numerous disamenities which are correlated with city size, we do not include specific size-related amenities. Finally, high concentrations of manufacturing employment in the region depress property values.

The coefficients for most facility types are negative and significant. Only hazardous waste sites (NFDNSHWS)[21] and liquefied natural gas facilities (NFDNSLNG) are positive and both are significantly different from zero. The public may not have been aware of the hazardous waste site locations since they were not identified as Superfund sites until after 1980; thus the positive sign is not unreasonable given the association of these sites with industrial activity. Though the LNG facilities are typically located on the outskirts of urban areas, they should not reflect suburban location since we control for metropolitan status by including

[20] There is corroborating evidence for these findings in the migration literature. Graves [50] and Clark and Hunter [51] find migrants are attracted to areas with either very warm or very cold climates, but they avoid locations with large temperature variations. However, Blomquist *et al.* [3] find that both temperature extremes negatively affect housing expenditures.

[21] Blomquist *et al.* [3] also found Superfund sites to positively affect housing expenditures, although they did find an overall negative implicit price.

CNTRLCTY and RURAL. Furthermore, these facilities typically have a small number of employees, so it is unlikely that they proxy decentralized employment centers. We are unsure why this variable is found to positively affect annual housing rents.

5.2. *Wage Model*

In the wage model, the estimated parameters for the human capital and industry control variables are all highly significant, consistent with prior expectations as to sign, and highly stable across model specifications. The PRICE control variable (COLINDEX) is significant and positively related to wages, as is the disequilibrium control variable PCTUNION. Both CNTRLCTY and RURAL are negative, with the latter significant at the 95% level of confidence. COAST is positive though insignificant. Most of the regional dummies indicate that wage levels are not significantly different from those in the East North Central region (the omitted category). However, wages are significantly lower in the Middle Atlantic region and marginally lower in New England.

Of the variables in the FISCAL category, high levels of intergovernmental spending significantly (at the 90% level of confidence) decrease wages, but high local spending increases wages. This suggests that workers prefer spending from nonlocal sources over spending from local sources. Neither of the tax measures is significant. Among the AMENITY control variables for climate characteristics, only precipitation (PRECIP) is significant[22] and it is classified as an amenity.[23] Both CRIME and TSP are disamenities to workers, significantly raising wages. The remaining AMENITY measures are nonsignificant.

The significant coefficients on NOXIOUS facility density variables are positive. These include nuclear plants (NFDNSNUP), refineries (NFDNSPCR), and liquefied natural gas storage facilities (NFDNSLNG), although the latter is only significant at the 90% level. In addition, coal-fired plants (NFDNSCOP), gas- and oil-fired plants (NFDNSGOP), and radioactive contaminated sites (NFDNSRAC) have positive signs, indicating an association with higher wage rates, though these are nonsignificant.

5.3 *Implicit Price Estimates*

Implicit prices are derived for variables in the NOXIOUS, PRICE, AMENITY, and FISCAL categories which appear in both models. Selected variables in the DISEQ classification are also examined. We assumed average values for individual variables in the HC & IND and STRUCTURE categories. All other site-specific variables are evaluated at their actual levels. Although it would be useful to derive standard errors on the implicit prices, this is not possible since the wage and property value models were run on separate samples, which prevents calculation of the covariance term between coefficients.[24]

[22] Multicollinearity did contribute to the insignificant coefficients on the climate variables HEATDAYS and PCTSUN and also reduced the significance of the coefficient on COMMUTE.

[23] This finding is perhaps not surprising, given that we control for the available sunshine. Indeed, Blomquist *et al.* [3] also find a negative effect of precipitation on wages and a positive implicit price overall. Note, however, that at least one study, Clark and Cosgrove [52], finds that precipitation positively affects wages.

TABLE IV

Implicit Prices for key variables

Variable	Variable mean value	Mean implicit price (1980 $)	Coefficient sign and significance: Income	Coefficient sign and significance: Rent
Nuclear plants/1000 sq. miles	0.25	−142.68	+**	−**
Coal-fired plants/1000 sq. miles	0.58	−45.13	+	−**
Gas/oil-fired plants/1000 sq. miles	1.60	−35.41	+	−**
Chemical weapons/1000 sq. miles	0.08	45.82	−	−**
Hazardous waste/1000 sq. miles	2.08	58.48	−	+**
Petrochemical refineries/1000 sq. miles	0.68	−267.88	+**	−**
Radioactive contaminated/1000 sq. miles	0.20	−10.64	+	−**
LNG/1000 sq. miles	0.61	−29.12	+	+**
Population density (persons/square mile)	880.15	1.80	−	+**
Manufacturing employment (in percent)	22.84	−15.99	+	−**
Cost of living index	101.25	−2.77	+*	+**
Mean commute time (in minutes)	23.01	−13.20	+	−**
Unemployment rate (in percent)	6.87	−102.72	+	−**
Coastal location (percent of total)	32.89	−0.17	+	+**
Violent crimes per 100,000 population	450.30	−1.85	+**	−**
Percentage sunny days	58.59	−5.11	+	+**
Precipitation	38.15	20.84	−**	−*
Temperature difference	40.93	−19.19	−	−**
Cooling degree days	134.34	2.44	−	+**
Heating degree days	452.58	0.45	+	+**
Total suspended particulates	65.83	−9.31	+*	−*
Average wind speed	9.11	72.66	−	+**
Marginal state income tax rate (evaluated at $20,000)	1.80	3.06	−	−
Local tax per capita ($1000)	0.29	−358.38	−	−**
Local expenditures per capita ($1000)	0.44	−2976.70	+**	+**
Intergovernmental transfers per capita ($1000)	0.25	1836.34	−	−**

Before discussing the specific findings on the implicit prices, a few comments are warranted. First, we believe that caution should be exercised in interpreting prices which are derived from insignificant coefficients in the wage or housing rent equation. Likewise, prices which are derived from inconsistently signed coefficients should also be interpreted with care. Second, after deriving implicit prices on noxious facilities, amenities, and fiscal variables, we report the mean values in Table IV. A comparison of the mean noxious facility prices with the median values showed that the means are only slightly higher. Moreover, the ordinal ranking of

[24] In some circumstances, the covariance term can be assumed to be zero, and the standard error is then simply the sum of the individual standard errors on the coefficient of facility density in the wage equation and the corresponding coefficient in the housing value equation. This assumption is not reasonable in this case, and such a calculation would result in an increased probability of a Type 1 error.

impact levels is the same, except in the case of chemical weapons storage and hazardous waste sites, which are reversed in order.

For comparative purposes, we present the findings for various other variables in the model. Among the urban size-related variables, suspended particulates and violent crimes are the two disamenities which are consistently (and significantly) classified as disamenities in both the wage and the housing rent equations. Local residents are willing to pay $9.31 per year to avoid a 1.5% increase in the level of particulates and $1.85 per year to reduce the number of violent crimes per thousand by 1 (which implies about $8.32 to reduce it by 1% of the mean). In addition, they would be willing to pay $103 per year to reduce the local unemployment rate by 1%, but only $2.77 to reduce the cost of living by about 1%. A one-minute reduction in the mean commute is worth $13.20 annually. Given that the hourly wage for the sample is $6.98, this implies that commuting time is valued at approximately 24.1% of the wage.

The implicit prices on the FISCAL variables should be interpreted with care since none of them are derived from correctly signed and significant coefficients in both wage and housing rent equations. Indeed, the magnitudes of these prices are surprising in some cases. Residents appear to dislike local taxes (they would pay $358 to avoid a $1000 increase in taxes per capita) and spending from local sources (they would pay $2977 to avoid a $1000 dollar increase in spending). It is possible that they see an annual increase in local spending as a permanent increase in spending, and hence are willing to pay relatively large sums to avoid the additional spending. However, an implicit price that is more than three times the increase in spending certainly casts doubt on the precision of the estimate. Another somewhat surprising finding is that spending from nonlocal sources is treated as a good, worth $1836 per year per $1000 of additional spending. Again, the magnitude of the effect appears to be well above what is expected. One potential problem with the variables in this category may be related to the data itself. Unfortunately, given the level of aggregation of the PUMS data, we were forced to use community-wide average expenditure and tax measures. Given that local fiscal conditions can vary widely within metropolitan areas, it is possible that community-wide averages are a poor proxy for data that is jurisdiction specific.

In the NOXIOUS category, the implicit prices for only two types of facilities, nuclear power plants and petrochemical refineries, are based on significant coefficients in both models. The mean implicit price for petrochemical refineries ($468) is the largest for the facility types studied. Since refineries are major air emission sources of sulfur oxides and volatile organic compounds (United States EPA [53]), the implicit price may reflect the deleterious effect of these emissions on air quality and cancer risks. We find that nuclear plants also have a relatively strong negative influence on local economies ($143 for a representative household per facility in a 1000-square-mile area). This finding is inconsistent with results of authors who have applied an intracity modeling approach to data for relatively small local areas (Gamble and Downing [13, 14], Nelson [15]) and found little significant effect. Such studies have generally sought to identify an impact gradient that varies with distance from the plant and have not been structured in a manner that could reveal broad area impacts. Our results are consistent with the psychometric literature on public aversion to living or working near noxious facilities. Maderthaner *et al.* [54], Lindell and Earle [55], and Mountain West [56] all find relatively strong public aversion to proximity to nuclear plants. Of the nonnuclear power plants (which are also consistently signed, though only significant in the housing model), coal-fired plants have a mean implicit price that is slightly larger than that on gas- and oil-fired plants. This may be due to a perception of greater air quality degradation associated with coal-fired plants because of their higher emission levels of sulfur oxides and particulates (United States EPA [53]).

The implicit price estimated for the radioactively contaminated sites is slightly smaller than the implicit price for gas- and oil-fired plants, and also is consistently signed and significant in one model. The radioactively contaminated sites have undergone initial decontamination efforts and are slated for further remediation. There is no ongoing activity at these sites and, in some cases, few visual clues are apparent as to their status so the relatively low impact level is reasonable.

We have less confidence in the findings for the remaining three facility types. The implicit price for LNG sites is based on inconsistently signed coefficients and the value of the insignificant coefficient dominates. The implicit prices of chemical weapons storage and hazardous waste sites are positive ($46 and $58, respectively). Coefficients for the chemical weapons sites are inconsistent and the nonsignificant value dominates. However, it is possible that impacts are actually positive since the chemical weapon storage sites present few visual reminders of their existence. They are situated within restricted-access military facilities with large buffer zones and may be major employers in the local area. The positive implicit price for hazardous waste sites may indicate a lack of public awareness of these sites in 1980, prior to development of the National Priorities List of Superfund sites. In contrast, Blomquist *et al.* [3] found a negative implicit price for Superfund sites using 1980 data, but did not control for the range of noxious facilities and other factors included in this study. These excluded factors may be correlated with Superfund site locations.

Overall, the results indicate that five of the eight facility types are disamenities with no effect on productivity. Increased wages and decreased property values are associated with increasing density of petrochemical refineries, nuclear power plants, coal-fired plants, gas- and oil-fired plants, and radioactive contaminated sites. These include the two cases for which there are significant coefficients in both equations (NUP and PCR). Of the remaining three facility types, chemical weapons storage sites fit the classification of an unproductive disamenity since both housing values and wages decrease.

Recent methodological development has shown the importance of explicitly modeling migration in applying a hedonic framework to amenity valuation (Greenwood *et al.* [29], Berger and Blomquist [57], Herzog and Schlottmann [32]). Use of this approach is a logical next step in examining the impacts of noxious facilities. Nonetheless, we believe the findings of this study can be useful to policymakers as they consider regional development policy and strategies for siting of noxious facilities.

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