Environmental Contamination and Industrial Real Estate Prices

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Abstract

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This article examines the effects of environmental contamination on the sales prices of industrial properties. Two general questions are addressed. The first is the extent to which sales prices may be impacted by contamination. The second is whether sales price effects due to contamination persist subsequent to the remediation of previously contaminated industrial properties. Using data on industrial property sales in Southern California, this study estimates sales price models that address these two questions. The results show that there are statistically significant impacts on property values in the period before and during remediation, but that these effects dissipate subsequent to cleanup.

Introduction

Environmental risk for industrial properties reflects the investment and lending risk related to uncertainties concerning cleanup requirements, liabilities and other factors. The effect of these risk factors is sometimes referred to as "stigma." Stigma has been most frequently discussed in the real estate appraisal literature (Patchin, 1988; and Mundy, 1992). As this type of risk increases, income is discounted or capitalized through higher required rates of return into lower prices and values (Jackson 1998). In addition to stigma related risk effects, industrial property prices may be directly reduced by estimated remediation costs that are to be paid from future property cash flows (Jackson, 1997). The price models in this study focus on the effects of environmental risk, although for some properties price reductions could reflect both risk and cleanup cost effects. Indeed, uncertainty about unknown future costs, and liabilities for such costs, can create risk effects. Risk effects are also related to uncertainties about potential changes in regulatory compliance requirements, potential third party claims and liabilities due to off-site migration of contamination, and other factors.

Literature Review

Relevant literature for this research falls into two categories. The first category includes the empirical studies of price impacts on industrial and other nonresidential properties due to environmental contamination. Price impacts are measured through the use of case studies in most of these studies. In only two studies are statistical techniques used to quantify the effects of adverse environmental conditions on industrial real estate prices. Literature in the second category includes several systematic studies of industrial property values and related variables where environmental impacts are not specifically addressed. Studies in this category provide a valuation framework that will be extended to the analysis of environmental price impacts in the current research. Jackson (2001a) provides a detailed review of these and other studies of environmental impacts on commercial, industrial and residential property types.

Studies of Environmental Impacts

Page and Rabinowitz (1993) offer one of the first empirical analyses of the impacts of environmental contamination on nonresidential real estate. Their study focuses on six commercial and industrial property case studies from the Midwest, as well as several residential cases impacted by groundwater contamination. The industrial case study properties they analyzed were abandoned industrial properties with ''serious toxic chemical contamination in the groundwater,'' (p. 476–77). The timeframe for these analyses is 1991 and 1992, when there was less market knowledge about the risks of contamination and none of the lender liability protections that are in place today. Nonetheless, for the contaminated commercial and industrial sites, Page and Rabinowitz find reductions on property value ranging from 10% to 50%. They do not distinguish between risk and cost effects. Interestingly, they find ''no measurable effect on property values in the residential case studies, in contrast to the commercial property cases,'' (p. 477).

Patchin (1994: 402) notes that contaminated properties are beginning to sell with increasing frequency, stating that ''a small but steadily increasing body of market data concerning the sale of contaminated real estate is now developing.'' He also notes that the market at that time was becoming increasingly accustomed to dealing with contaminated property. Patchin analyzed eight case studies consisting of various types of industrial and commercial properties, including vacant land, located in the Midwest and with a variety of contamination issues. The range of property value loss due to stigma for these case studies was estimated to have been from 21% to 94%. However, Patchin does not suggest that the case studies used in his analysis are representative of any particular market or environmental issue. Rather, his main point is that sales of contaminated properties exist and can be reasonably employed to analyze the effects of contamination on property values.

In one of the few statistical studies of environmental impacts on industrial real estate, Guntermann (1995) estimated the parameters of a price model using 153 unimproved industrial land sales from 1984 to 1994 in the Phoenix, Arizona area. The Guntermann study included both landfills (source sites) and property around landfills (proximate or adjacent sites). As for impacts on industrial properties in proximity to municipal landfills, he finds that "there is no evidence that solid waste landfills impose external costs on surrounding industrial land," since the variables measuring price impacts were "all statistically insignificant," (Guntermann, 1995: 537). On the other hand, his study found that landfills (source sites) sell for approximately 51% less than the other industrially zoned properties in his data. There were twelve landfill sales among the 153 total sales in the study.

Bell (1998) presents a framework for evaluating a variety of "detrimental conditions" including environmental contamination. His framework calls for the valuation of a property as if there were no contamination, called the "benchmark," and then this was compared to the "as is" value of the property in its actual, contaminated state. Bell distinguishes between value effects due to remediation costs and the effects of additional risk attributable to contamination, referred to in his framework as either "project incentive" or "market resistence." He analyzes eight sales of industrial and commercial properties impacted by soil contamination, and finds reductions in sales prices from 10% to 51%.

Lastly, Jackson (2001b) analyzes the effects of previous environmental contamination on the sales of industrial properties in California through a series of paired sales analyses and a multiple regression based hedonic pricing analysis. In both analyses, he found that the prices of previously contaminated industrial properties were not adversely impacted relative to comparable but uncontaminated properties. His models did not include any sales of contaminated industrial properties that sold before or during remediation, and thus questions about the impacts of contamination on properties in these conditions are not addressed. In addition, the regression models are presented in linear form only, without subsequent transformations to capture any nonlinearities in the data series.

Non-Environmental Industrial Property Studies

There have been several statistical studies of industrial properties that did not address environmental issues. These studies are important to the current study because they provide a useful background for developing statistical models of industrial property prices, a necessary condition for analyzing environmental impacts through statistical procedures. The environmental and non-environmental statistical analyses of industrial property sales and related measures are summarized in Exhibit 1. The two environmental studies were discussed above. The non-environmental studies will be reviewed next.

Ambrose (1990) provides a seminal study of industrial property prices analyzed through statistical procedures. Ambrose modeled improved industrial property

Exhibit 1 | Industrial Property Sales Price Statistical Analyses

	Guntermann (1995)	Jackson (2001b)	Ambrose (1990)	Atteberry and Rutherford (1993)	Fehribach, Rutherford and Eakin (1993)	Lockwood and Rutherford (1996)	Buttimer, Rutherford and Witten (1997)
Study category	Environmental	Environmental	Non-Environmental	Non-Environmental	Non-Environmental	Non-Environmental	Non-Environmental
Property type	Industrial land	Improved industrial	Improved industrial	Improved industrial	Improved industrial	Improved industrial	Improved industrial
Dependent variable specification	Log of sales price	Sales price	Asking (list) sales price	Mean sales price per square foot time series	Sales price	Log of sales price	Real warehouse rents
Significant independent variables	Parcel size	Building size	Building size	Mean price per square foot lagged terms	Building size	Property characteristics factor (building and office space, parcel size)	Rentable SF
	Southwest Phoenix location Location in an industrial park Year of sale Rail availability Airport location Freeway location Investment or speculative sale	Office space Parcel size Building age County / year of sale indicators	Office space Drive-in loading doors Dock-high loading doors Rail availability	Monetary base time series Industrial building construction time series	Office space Building age Dock-high doors Ceiling height County Distance to airport Type of tenant Capitalization rate	Regional factor (TX employment rate, TX income, TX gross state product) Location factor (airport, CBD, freeway, rail, county)	Ceiling height Office space Building age Ground level loading doors Employment change Submarket location indicator
N of Cases	153 total sales (19 sales around landfills)	122 total sales (13 contaminated property sales)	57	764 sales; 90 mean monthly prices	170	308	848
Time period	1984–1994	1998–1999	1986–1987	1983–1991	1987–1991	1987–1991	1989–1993
Metro area	Phoenix	Los Angeles	Atlanta	Dallas / Ft. Worth	Dallas / Ft. Worth	Dallas / Ft. Worth	Dallas / Ft. Worth
Adj. R^2	0.72	0.85	0.87	0.51	0.96	n / a	0.38

asking prices as a function of various physical and locational attributes, as listed in Exhibit 1. The sample data for this analysis was collected in Atlanta from 1986 and 1987, and consisted of fifty-seven list prices and sets of property attributes. To address issues concerning the use of asking prices instead of sales prices, Ambrose regresses actual sales prices on the asking prices of ten sales. The adjusted R^2 for this bivariate relationship was .99. He then estimates the parameters of the multivariate asking price model and finds statistically significant (at the α = 0.05 level or better) and positive (prices increase) coefficients for building square footage, office square footage, dock high and drive in loading doors, and rail service. The parameter estimates for ceiling height, building age, sprinkler and build-to-suit office space did not attain significance at the 5% level. However, he determined that his initial ordinary least squares (OLS) model, with untransformed independent and dependent variables, had significant heteroscedasticity problems. To address these problems, he respecifies the model in a weighted least squares (WLS) format. In the WLS model specification, the adjusted R^2 was .76 although none of the independent variables were significant at the 5% level.

Atteberry and Rutherford (1993) provide a somewhat different perspective on industrial property valuation by focusing on the efficiency of the industrial real estate market. Using 764 transactions from 1983 to 1991 in the Dallas/Ft. Worth area, they analyzed the effect of general economic conditions, financial market conditions, industrial construction and past sales prices on a sales price per square foot time series. The variables are lagged to ascertain the effects of knowledge of this information on industrial prices. Their model explains about half (51%) of the variation in mean industrial price per square foot. Several short term (less than six months) lags for price, monetary base, industrial construction and a risk premium measure, for investor risk aversion, are significant. The authors conclude that although there is a significant relationship between current and past industrial prices, ‘‘current prices do not fully reflect past publicly available information,’’ and therefore the ‘‘market may not be efficient.’’ The models used in this study did not include the type of property specific information found in the hedonic formulations, and this property specific information has been shown by many of the other studies reviewed herein to have significant effects on price and value.

In another statistical study of improved industrial property, Fehribach, Rutherford and Eakin (1993) analyzed 170 sales in the Dallas/Ft. Worth area. Their analysis modeled sales price as a function of the physical characteristics of the buildings as well as sets of financial, locational and economic variables. OLS and WLS models are specified, although there are no reported problems with heteroscedasticity. The OLS specification, with untransformed dependent and independent variables, indicated that building size, office space, dock-high loading doors, ceiling height, county (location), distance to the D/FW airport and tenant type (single vs. multi-tenant) had the predicted signs and were significant at the 5% level. Building age was significant at the 10% level. Rail siding and date of sale were not significant. In the WLS model, which had a slightly better fit to the data, building age and overall capitalization rate variables were significant at the 5% level.

Lockwood and Rutherford (1996) note that models of the determinants of industrial property value when analyzed in a hedonic framework can suffer from problems associated with multicollinearity and, most importantly, proxy variables that do not accurately measure the underlying valuation concepts. The authors use a linear structural relations (LISREL) statistical technique to more accurately measure several valuation concepts suggested in the literature. In the LISREL model, a set of constrained factors are estimated for each concept, and the log of sales price is then regressed on the resultant factors scores. In their analysis, factors are created for physical property characteristics, national economic conditions, regional economic conditions, interest rates and location in the local/metro market. Factor loadings are then estimated for several variables related a priori to these concepts. Using 308 sales in the Dallas/Ft. Worth area from 1987 to 1991, the log of price was regressed on the factor proxies for these concepts. The results indicated that the physical characteristics factor was most significant, followed by the regional/Texas factor and location. National market and interest rate factors were not significant. This study highlights the importance of the physical characteristics of industrial properties and location in predicting their price and value.

Lastly, a study by Buttimer, Rutherford and Witten (1997) analyzes the determinants of industrial warehouse rents. While their study does not deal with sales price, the determinants of rent should also have an effect on price. Among their independent variables are rentable square footage, ceiling height, percentage office space, building age, number of dock-high loading doors, rail availability, fire sprinklers and indicator variables for submarket location. The model was estimated with data on 848 warehouse properties in the Dallas/Ft. Worth area from 1989 to 1993. Each of the continuous independent variables are specified with a squared term to account for nonlinearities. The dependent variable, real rent, is not transformed. The model had an adjusted R^2 of .38.

Data Description

The database for this study was developed from sales occurring in the Southern California region from 1995 to 1999. The sales were assembled with the assistance of the COMPS, Inc. commercial data service. A keyword search was used to identify contaminated and previously contaminated industrial property sales in Los Angeles, San Diego, Orange and Ventura Counties. Sets of uncontaminated comparables were then matched to the contaminated property sales on the basis of location, age and size. The available sales data was coded by county and by smaller geographic areas. For example, San Diego County has twenty subareas and Orange County has twelve subareas. Los Angeles County was divided into five main areas: central, east, north, south and west, and each of these was divided into numerous subareas. Given the small size of most of the subareas, the process of matching uncontaminated comparables to each of the contaminated properties resulted in all or nearly all of the industrial properties sold within the subarea in the same year and of the same general age being selected as comparables for the contaminated properties. After removing non-source contaminated properties and others, there were 152 sales in the database. Missing data on one or more of the main independent variables further reduced the sales available for analysis to 140. Of this total, fifteen were contaminated properties sold before or during cleanup of on-site soil or groundwater contamination, thirteen were sales of previously contaminated industrial properties, and there were 112 sales of uncontaminated properties. Of the contaminated or previously contaminated properties, nineteen, or about two-thirds, involved soil contamination. The remainder had groundwater contamination or both groundwater and soil contamination. The distribution of these sales by area is shown in Exhibit 2.

The data source for these sales included information on a number of the independent variables discussed in the literature as being significant determinants of property value. However, a number of these variables were inconsistently coded or were missing for many of the sales. The variables that initially appeared to be most consistent across the most sales were: building square footage, land square footage, office space, year built, truss height, presence of sprinklers, date of sale, and property location within the county and sub-county areas. Information on loading doors and rail service availability were not consistently coded or were left

Exhibit 2 | Summary of Industrial Property Sales Data

	Uncontaminated Property Sales	Contaminated Property Sales, Before or During Remediation	Contaminated Property Sales, After Remediation	Total Sales
Los Angeles County				
Los Angeles central	3	0	0	3
Los Angeles east	10	1	2	13
Los Angeles north	7		0	8
Los Angeles south	46	8	5	59
Los Angeles west	5	0	2	7
Subtotal	71	10	9	90
Other Counties				
Orange County	7	3	0	10
San Diego County	28	2	3	33
Ventura County	6	0	1	7
Subtotal	41	5	4	50
Total	112	15	13	140

Note: Total available sales of 152 reduced by 12 sales that did not have complete information on all variables in base model (age, building size, location, date of sale, price).

blank on many of the sales sheets. Maintaining an adequate number of sales available for analysis, and especially the number of contaminated or previously contaminated property sales, was an important consideration in variable selection. After removing the sales with missing data, the final data set of 140 sales is consistent in number with the studies reported in the literature. These studies had data sets ranging from fifty-seven list prices (Ambrose, 1990) to 308 sales (Lockwood and Rutherford, 1996). The published statistical studies of environmental impacts on industrial properties had data sets of 153 sales (Guntermann, 1995) and 122 sales (Jackson, 2001b).

Statistical Analysis

General Model Specification and Parameters

As noted, the variables suggested in the literature as having a significant effect on the price and value of improved industrial properties, and as was shown in Exhibit 1, included building size, office space, building age, parcel size, date of sale, property location within county and subcounty areas, availability of rail service, number of loading doors, ceiling height and the presence of sprinklers. In other studies of industrial real estate, the properties' physical characteristics were found to be primary determinants of sales price (see, Lockwood and Rutherford, 1996). Basic physical attributes include building square footage and office space. Both of these variables should have a positive effect on price. Office square footage should have a premium over warehouse space. Land area should also have an effect, although collinearity with the other size variables should be analyzed. Location and date of sale would have varying impacts on price. Except for age, the other variables should have positive effects on price. In addition, and to test the two research questions, variables indicating the properties' environmental condition at the time of sale would have negatively signed coefficients, in order to measure potential adverse effects on sales price. These generalized relationships are as follows:

$$\textit{Sales Price} = f\,(\textit{Physical Characteristics, Date of Sale, Location, Environmental Condition}). \quad (1)$$

In operationalizing this general specification, and given the available data for the study as discussed, independent variables will include:

BLDGSF: Building square footage;
LANDSF: Land square footage;
OFFICESF: Office space square footage;
AGE: The age of the property improvements or building in years;

S1995, S1996, S1997, S1998, S1999: A vector of discrete terms indicating year;
LACENT: Los Angeles County central area;
LAEAST: Los Angeles County east area;
LANORTH: Los Angeles County north area;
LAWEST: Los Angeles County west area;
ORANGE: Orange County;
SANDIEGO: San Diego County;
VENTURA: Ventura County;
BEFORE: Contaminated properties that sold before or during remediation; and
AFTER: Previously contaminated properties, with uncontaminated properties as the base category.

Exhibit 3 | Descriptive Statistics for Industrial Property Sales

Variable	Mean	Std. Dev.	Min.	Max.
Sales price				
Adjusted sales price	1,342,190.80	1,228,657.49	255,000	6,400,000
Physical characteristics				
Building square footage	30,239.08	27,622.99	1,662	120,000
Land square footage	73,116.99	75,854.66	5,662	483,516
Office space square feet	5,077.29	5,807.47	0	37,116
Age of building in years	30.70	16.29	0	76
Year of sale				
Sale in 1995	0.014	0.12	0	1
Sale in 1996	0.057	0.23	0	1
Sale in 1997	0.160	0.37	0	1
Sale in 1998	0.360	0.48	0	1
Sale in 1999	0.410	0.49	0	1
Location				
Los Angeles central	0.021	0.15	0	1
Los Angeles east	0.093	0.29	0	1
Los Angeles north	0.057	0.23	0	1
Los Angeles south	0.420	0.50	0	1
Los Angeles west	0.050	0.22	0	1
Orange County	0.071	0.26	0	1
San Diego County	0.240	0.43	0	1
Ventura County	0.050	0.22	0	1
Environmental condition				
Sale before or during remediation of contamination	0.110	0.31	0	1
Sale after remediation of previous contamination	0.093	0.29	0	1

Note: Office space statistics based on 102 sales. Statistics for other variables based on 140 sales.

Exhibit 3 presents summary statistics for the sales to be analyzed, including indicator variables for year of sale, location and environmental condition. As can be seen, average building size for the 140 sales is approximately 30,200 square feet, occupying parcels of approximately 73,000 square feet for a floor area ratio (FAR) of 0.41. This FAR is reflective of lower density development at urban fringe areas with relatively lower land costs. For the 102 sales properties with recorded office space, the average was 5,077 square feet, or about 7% of total building space. The properties had an average age of approximately thirty years at their date of sale and an average adjusted sales price of $1.3 million. The sales price adjustments are discussed below. Lastly, 20% of the sales were of contaminated or previously contaminated properties.

Although the literature indicated that office space can be a significant predictor of sales price for industrial properties, there are a substantial number of properties in the database that do not have any information on this attribute. Of the total 140 sales available for analysis, thirty-nine sales, or 28%, did not have this information. Thus, in order to ensure that the exclusion of these sales does not have an effect on the key environmental parameter estimates, two models will be retained for further analysis. They will have similar specifications, except that the first omits the term for office space. Accordingly, initial specifications of models for the analysis, without any transformations to the independent or dependent variables, are as follows:

$$\begin{aligned} PRICE_i = {} & \beta_0 + \beta_1 BLDGSF_i + \beta_2 LANDSF_i + \beta_3 AGE_i \\ & + \beta_4 S1996_i + \beta_5 S1996_i + \beta_6 S1997_i \\ & + \beta_7 S1998_i + \beta_8 LACENT_i + \beta_9 LAEAST_i \\ & + \beta_{10} LANORTH_i + \beta_{11} LAWEST_i + \beta_{12} ORANGE_i \\ & + \beta_{13} SANDIEGO_i + \beta_{14} VENTURA_i + \beta_{15} BEFORE_i \\ & + \beta_{16} AFTER_i + \varepsilon_i. \end{aligned} \tag{2}$$

$$\begin{aligned} PRICE_i = {} & \beta_0 + \beta_1 BLDGSF_i + \beta_2 LANDSF_i\ \beta_3 OFFICESF_i \\ & + \ldots \textit{other variables} \text{ as in Equation 2} \ldots + \varepsilon_i. \end{aligned} \tag{2a}$$

The dependent variable in these equations, sales price (*PRICE*), represents the nominal price for reported remediation costs to be borne by the buyer for properties in the *BEFORE* condition. Rational and knowledgeable buyers would discount the price to be paid by their cost to cure/remediate and for risk (stigma). Thus, in order to focus on risk effects, estimated remediation costs to be paid by the buyer were added to the unadjusted sales prices, where such costs were known or had been estimated as of the date of sale. Costs used in these adjustments were provided by parties to each transaction and verified by the commercial data service providing the sales data and/or by research personnel involved in this project. The prices were not adjusted for seller paid remediation costs, since adjustments for the sellers' costs would already be reflected in the transaction prices. For example, in cases where the property was to be remediated the seller would have adjusted the sales price to reflect these costs and the property's improved condition as of the date of sale. Of the twenty-eight contaminated properties in the analysis, the seller was responsible for remediation in eighteen cases and the buyer was responsible in eight cases. In two cases, the responsible party was not reported.

Accordingly, the adjusted sales prices for the contaminated and previously contaminated properties in the analysis should primarily reflect the buyer's perceptions of future risk associated with the properties' environmental condition. For unremediated properties, this could include price reductions that reflect uncertainty about future remediation costs that may be bourne by the buyer and paid from property cash flows, but were unknown or not estimated as of the date of sale. Remediation costs to be paid by the buyer, and that had been estimated and reported as of the date of sale, were approximately 5.7% of the unadjusted sales price. The average unadjusted price for properties in the *BEFORE* condition and for which the buyer was responsible for paying remediation costs was $621,125. Estimated remediation costs for these properties averaged $35,250. Undoubtedly, the buyers made additional price reductions for uncertainties about unknown future costs beyond the reductions for the stated costs. These additional reductions could be ascribed to actual realized future costs and/or to uncertainty with respect to knowledge about these future costs. The reductions would also reflect uncertainties related to other risk factors such as changing regulations and potential third party liabilities.

In preliminary testing of various models, date of sale variables were determined not to be individually significant. However, they will be retained in the model in order to control for any potential interactive effects with the environmental variables. In testing other variables, truss height was not a significant predictor. Building age, computed from year built, and sprinklers were significant individually, but not in combination. A possible explanation for this is that newer buildings tend to have sprinkler systems and older buildings do not. Age, overall, is a better predictor of sales price than sprinklers, and was also recorded on a greater number of sales properties, so it was retained. In a stepwise selection procedure, the only locational variables in the final step were for Orange and San Diego Counties, where properties sold at a premium relative to Los Angeles and Ventura Counties. Nevertheless, to control for any potential interactive effects with the environmental variables, location variables for all of the county areas will be retained in the subsequent models.

Transformations

Dependent Variable Transformation. To determine appropriate transformations to the dependent variable, a Box-Cox procedure was used to identify the appropriate lambda (λ) for the transformation, $Y_{transformed} = Y^{\lambda}$ for non-zero values of λ. The procedure calculated a series of RMSEs (root mean square errors) and associated lambdas, with the minimum RMSE corresponding to the appropriate maximum likelihood λ for the transformation. The point at which RMSE was minimized corresponded to the λ of 0.00, which indicates a Y transformation of $Y_{transformed}$ = logarithm of Y, or log of sales price, as the new dependent variable. A similar analysis for the office model confirmed the appropriateness of this dependent variable transformation. Thus, a base model was estimated using the log of sales price as the dependent variable. To test for the presence of heteroscedasticity after this transformation, a Breusch-Pagan statistic was calculated with the following formula:

$$\textit{Breusch-Pagan test statistic} = (SSR \div 2) \div (SSE \div n)^2 \qquad (3)$$

With an SSR of 0.685 and an SSE of 18.495, the test statistic is 19.63, which does not exceed the chi-square critical value of 26.30, indicating that the null hypothesis of constant residual variance cannot be rejected at the 5% level. In addition, a Kolmogorov-Smirnov test statistic was calculated at 0.052, which with a *p*-value of .200 indicated that the null hypothesis of residual normality cannot be rejected. Thus, these results suggest that after the dependent variable transformations, the model residuals have constant variance and are normally distributed. The resulting hypothesis tests concerning parameter estimates should be reliable. Similar results were obtained for the model with the office space parameter, estimated with a smaller number of cases. Accordingly, all subsequent analyses will be based on this transformation.

Independent Variable Transformations. The next step in model development involves potential transformations to the continuous independent variables. These transformations are made to reflect potential nonlinear relationships between the independent variables and the dependent variable. The dependent variable transformation was done to address problems with non-constant residual variance and non-normality. The independent variable transformations are done to reflect underlying nonlinearities in the data, and should improve the models' fit to the data. In order to determine appropriate and statistically supported transformations to the continuous independent variables in the base and office model, except age, a nonlinear regression procedure was used to estimate the following equations:

$$LNPRICE_i = \beta_0 + \beta_1(BLDGSF_i)^{\beta 2} + \beta_3(LANDSF_i)^{\beta 4} + \ldots \textit{other variables} \ldots + \varepsilon_i. \quad (4)$$

$$LNPRICE_i = \beta_0 + \beta_1(BLDGSF_i)^{\beta 2} + \beta_3(LANDSF_i)^{\beta 4} + \beta_5(OFFICESF_i)^{\beta 6} + \ldots \textit{other variables} \ldots + \varepsilon_i. \quad (4a)$$

Prior nonlinear models and linear models with transformations had not identified any significant transformations for building age. Tested transformations to age included first-, second- and third-order polynomials as well as power transformations. The results of the nonlinear regression estimates of the power transformations for building, land and office square footage are presented in Exhibits 4 and 5. The significance of these estimates were tested through a case resampling bootstrap procedure, with 2,000 resampling iterations. The resulting 95% confidence intervals for each estimate are also shown in the two exhibits.

The bootstrap confidence bounds indicate that all of the parameter estimates are significant at the 5% level. The bootstrap confidence intervals are generally regarded as more accurate than the asymptotic confidence intervals produced by the unconstrained nonlinear regression procedures. However, the point parameter estimates were the same in the unconstrained nonlinear regression model and in the constrained (bootstrap) nonlinear models.

Parameter Estimates for the Transformed Models

The final models, with the transformed dependent and independent variables, as explained, were estimated using the following equations:

Exhibit 4 | Nonlinear Regression Parameter Estimates for Base Model (Equation 4) with Bootstrap Confidence Intervals

Parameter	Estimate	95% Confidence Bounds Lower Limit	95% Confidence Bounds Upper Limit
β	0.2951	0.1419	0.4861
β_2	0.2001	0.1667	0.2507
β_3	0.0498	0.0162	0.1067
β_4	0.2828	0.2304	0.3612

Note: Model specified as $LNPRICE = \beta_0 + \beta_1(BLDGSF)^{\beta 2} + \beta_3(LANDSF)^{\beta 4} + \textit{other variables} + \varepsilon$.

Exhibit 5 | Nonlinear Regression Parameter Estimates for Office Model (Equation 4a) with Bootstrap Confidence Intervals

Parameter	Estimate	95% Confidence Bounds Lower Limit	95% Confidence Bounds Upper Limit
β_1	0.0949	0.0648	0.1364
β_2	0.2727	0.2383	0.3090
β_3	0.5566	0.4385	0.6946
β_4	0.1245	0.1044	0.1462
β_5	0.0002	0.00004	0.0020
β_6	0.7834	0.5331	0.9795

Note: Model specified as $LNPRICE = \beta_0 + \beta_1(BLDGSF)^{\beta 2} + \beta_3(LANDSF)^{\beta 4} + \beta_5(OFFICESF)^{\beta 6} + other\ variables + \varepsilon$.

$$LNPRICE_i = \beta_0 + \beta_1(BLDGSF_i)^{0.20013} + \beta_2(LANDSF_i)^{0.28282} + \ldots other\ variables \ldots + \varepsilon_i. \quad (5)$$

$$LNPRICE_i = \beta_0 + \beta_1(BLDGSF_i)^{0.2727} + \beta_2(LANDSF_i)^{0.1245} + \beta_3(OFFICESF_i)^{0.7834} + \ldots other\ variables \ldots + \varepsilon_i. \quad (5a)$$

The parameter estimates and other statistics for the final model specifications are presented in Exhibit 6.

The predictor variables, significant at the 5% level in both models, are: building square footage; land square footage; age of building; the locational indicator for sales in Los Angeles County north, Orange County and San Diego County; and the environmental indicator for properties that sold before or during remediation. In the base model, without the office space parameter, building age and the locational indicator for sales in Los Angeles County west are also significant. In the office space model, building age is not significant, but office space is significant, with a *t*-Statistic of 3.69. The office space model is also a slightly better predictor of sales price, with an adjusted R^2 of .886, as compared to the adjusted R^2 for the base model of .814. As explained, the office model was estimated with thirty-nine fewer sales due to missing data.

All of these coefficients for both models are in the anticipated directions, with building space, office space and land square footage increasing price, and price

Exhibit 6 | Parameter Estimates for Industrial Property Models

Variable	Base Model	Variance Inflation Factors	Office Model	Variance Inflation Factors
Intercept	10.576**		10.119**	
	(47.82)		(27.64)	
BLDGSF	0.295**	5.040	0.095**	6.182
	(6.28)		(5.09)	
LANDSF	0.498**	4.999	0.557**	6.184
	(4.72)		(3.69)	
OFFICESF	—	—	0.0002**	1.891
			(4.01)	
AGE	−0.005**	1.450	−0.003	1.607
	(−2.62)		(−1.44)	
S1995	−0.105	1.058	−0.225	1.100
	(−0.44)		(−1.08)	
S1996	0.034	1.388	0.005	1.446
	(0.24)		(0.03)	
S1997	−0.166*	1.692	−0.165*	1.990
	(−1.72)		(−1.75)	
S1998	−0.017	1.412	−0.033	1.657
	(0.80)		(−0.44)	
LACENT	0.381*	1.097	0.190	1.051
	(1.91)		(0.67)	
LAEAST	0.209*	1.401	0.116	1.640
	(1.87)		(0.98)	
LANORTH	0.337**	1.199	0.309**	1.173
	(2.60)		(2.24)	

Exhibit 6 | (continued)

Parameter Estimates for Industrial Property Models

Variable	Base Model	Variance Inflation Factors	Office Model	Variance Inflation Factors
LAWEST	0.324** (2.12)	1.461	0.192 (1.32)	1.548
ORANGE	0.434** (3.39)	1.434	0.365** (3.02)	1.563
SANDIEGO	0.364** (4.35)	1.667	0.247** (2.90)	2.038
VENTURA	0.044 (0.30)	1.323	0.014 (0.09)	1.487
BEFORE	−0.326** (−3.18)	1.330	−0.364** (−3.34)	1.513
AFTER	−0.0658 (−0.63)	1.224	−0.100 (−1.00)	1.377
Adj. R^2	0.814		0.886	
F-Statistic	39.105**		39.495**	

Notes: Base model estimated with 140 sales. Office model estimated with 102 sales. *t*-Statistics in parentheses.
*Significant at the 0.10 level.
**Significant at the 0.05 level.

decreasing with increasing age. For the vector of year of sale indicator variables 1998 is the base year, so all of the parameter estimates are relative to 1998. For the locational categorical variables, Los Angeles County south is the base. An analysis of covariance was used to test for any potential interaction effect between location and year of sale, and none was indicated ($F = 1.106$, $p = .363$ for the interaction term). Since there is a general concern with multicollinearity in additive hedonic price models, variance inflation factors (VIFs) are also presented in Exhibit 6. Neter, Kutner, Nachtsheim and Wasserman (1996) suggest that a VIF in excess of ten indicates that ''multicollinearity may be unduly influencing the least squares estimates.'' None of the VIFs for any of the parameter estimates in any the models reported herein approach these values.

Lastly, and most importantly, the environmental condition variables indicate that the contaminated industrial properties sold at a statistically significant discount before and during cleanup, but after cleanup the price effect was not significant and the null hypothesis of no effect could not be rejected in either model. The parameter estimate for the indicator variable for contaminated properties that sold before or during remediation (*BEFORE*) from the final model is -0.326 ($t = -3.18$), which is significant at the 0.003 level. This estimate can be converted to an estimated percentage reduction in sales price by raising it to base e, subtracting 1.0 and multiplying the result by 100. Accordingly, the estimates from the final transformed base model indicate a reduction in price for contaminated properties that sold before or during cleanup of 27.8%. For the final transformed office model, the coefficient estimate of -0.364 ($t = -3.34$) equals a price reduction for properties sold in the before or during cleanup condition of 30.5%. Thus, the range of indicated environmental contamination related reductions in price is from 27.8% to 30.5%. After cleanup, the estimate for environmental condition in both models is not statistically significant, indicating that the adverse price effects of the contamination dissipated subsequent to remediation. The range of indicated environmental risk-related reductions in price, from 27.8% to 30.5%, is generally consistent with the literature that reported price effects of 21% to 94% by Patchin (1994), 51% by Guntermann (1995) and 10% to 51% by Bell (1998).

Other Tests and Estimates

Additional tests for potential problems with heteroscedasticity and residual non-normality were also performed. The Breusch-Pagan test statistic for non-constant residual variance, with an SSR of 0.456 and an SSE of 13.051 from the final transformed base model, is 26.24. This is less than the critical chi-squared value of 26.30. Residual normality can be evaluated with the Kolmogorov-Smirnov statistic, which for the fully transformed model is 0.061, with a p-value of 0.200, indicating that the null hypothesis that the residuals are normal cannot be rejected, and that they are normally distributed. Likewise, the Breusch-Pagan test statistic for the fully transformed office model (Equation 5a) presented in Exhibit 6 was calculated at 11.265, which is also less than the chi-squared critical value of 27.59 at $\alpha = 0.05$. The Kolmogorov-Smirnov statistic for the transformed office model of 0.068 (p-value = .20) also indicates that there is no evidence of a pattern of non-normally distributed residuals.

There were several variables noted in the literature as having a significant effect on industrial property prices that were not included in the model specifications utilized herein. These included the availability of rail service and the number and type of loading doors. These variables were initially omitted from this analysis due to missing data and inconsistent coding problems. However, to test the impact of omitting these variables on the final model estimates, the transformed base model was re-estimated using a subset of sales for which rail service, overhead doors and grade level doors ($n = 51$) had been coded. The resulting estimates indicated that these were not significant predictors (rail service, $t = -0.57$; grade level doors, $t = -0.69$; and overhead doors, $t = 0.79$). A more comprehensive sample of sales with this information might reveal higher levels of significance. More importantly, though, the inclusion of these variables (and with the lower number of sales) would not effect inferences about the key environmental parameters. As was shown in Exhibit 6, in the final base model, with log of price as the dependent variable, the parameter estimates for contaminated properties sold before cleanup was -0.33 ($t = -3.18$) and for previously contaminated properties was -0.066 ($t = -0.63$). With the added parameters for rail service, overhead and grade doors, and with the lower n, the coefficient for the *BEFORE* condition indicator was -0.34 ($t = -2.49$) and for remediated properties the *AFTER* condition indicator variable was -0.17 ($t = -1.19$), with an adjusted R^2 of .73 ($F = 14.45$, $p = 0.001$). Thus, the inclusion of these insignificant variables has relatively little effect on the key environmental variables.

Another issue involves the potential intervening effect of deferred maintenance on the sales price data. As noted, the average age of the properties in the analysis was over thirty years. These older industrial buildings probably suffer from some degree of deferred maintenance. From an appraisal perspective, though, the question is not whether an older property has deferred maintenance, but rather whether its level of deferred maintenance is atypical for properties of its age and class. Nevertheless, to test whether deferred maintenance had an effect on price independent of the age variable, and, more importantly, whether this effect may confound the effect of the environmental condition parameters, the base model, with log of price dependent, was estimated with a categorical/indicator (0,1) variable for deferred maintenance. Deferred maintenance was coded as one for properties that had such uncured and atypical deferred maintenance at their time of sale, as reported by parties to the transaction. Deferred maintenance was reported in twenty-one cases. The deferred maintenance parameter estimate was not significant at the 0.05 level, however. Further, the environmental condition parameter estimates were relatively unaffected by the inclusion of the deferred maintenance variable, which had a VIF of 1.19. In the base model with the deferred maintenance dummy variable, the coefficient for the *BEFORE* condition indicator variable was significant ($t = -3.10$) and the coefficient for the *AFTER* condition variable was not significant ($t = 0.14$).

A final issue to be evaluated involves the presence of potential outliers that may influence the results of the analysis and inferences drawn from the key environmental variables. An important issue with respect to outliers is whether or not they unduly influence the fit of the model. A graphical analysis of the absolute value of the DF Fit statistic indicated that none of the sales reached the critical cutoff level. The largest spike in the graph was the sale of a high priced industrial building in Orange County for $4.2 million, which was simply well above the average price for all sales of $1.3 million. The absolute DF Fit for this sale, though, at 0.584 was significantly less than the cutoff of 0.676.

For purposes of the current research, the key question with respect to outliers is whether they influence the estimates of the environmental condition parameters. The higher priced property, discussed above, was sold in an uncontaminated condition. An influential uncontaminated sale could influence the estimates for the environmental condition parameters. A graphical analysis was performed of absolute value of the DF Beta statistics for the indicator variable corresponding to properties that sold before or during remediation. None of the DF Beta statistics for the 140 cases approach the DF Beta cutoff. A similar analysis for the indicator variable for previously contaminated properties had the same pattern. Accordingly, all of the 140 cases in the base model analysis were retained, and none were determined to unduly influence the modeling results. This test was also performed on the office model with similar results.

Conclusion

In addition to the model estimates previously presented and discussed, a bootstrap/constrained nonlinear regression was also utilized to estimate the *BEFORE* condition environmental parameters for the two models. The bootstrap procedure re-estimated the environmental parameters based on 2,000 case resamplings. For the base model, the nonlinear bootstrap model produced a consistent coefficient estimate of −0.326 for this parameter, with a 95% confidence interval from −0.154 to −0.485. For the office model, the bootstrap model estimated the *BEFORE* condition coefficient at −0.364, with a 95% confidence interval from −0.203 to −0.525, again confirming the results of the previous analyses. On the other hand, and as presented in Exhibit 6 and confirmed though the nonlinear bootstrap procedure, the parameter estimate for previously contaminated properties (*AFTER*) in the base model was −0.066, which is not statistically significant at any acceptable level ($t = -0.63$). For the office model, the estimate for this parameter was −0.10, with a t-Statistic of −1.00. Again, the parameter is found not to be statistically significant from zero, and the null hypotheses of no difference cannot be rejected. Thus, for previously contaminated and remediated properties, this analysis finds no statistically significant sales price differences from otherwise comparable but uncontaminated properties.

These findings have practical significance for researchers involved in industrial property valuation and for those involved in the acquisition and remediation of such properties. The study finds that industrial properties with unremediated contamination transact at prices approximately 30% less than unimpaired levels and then recover to be indistinguishable from comparable uncontaminated properties. This price reduction and rebound provides investment opportunity to venture capital and opportunity funds having investment objectives consistent with these levels of risk. Furthermore, this study provides strong statistical evidence for the temporary nature of market adjustments and the stigma effect for contaminated industrial real estate. In none of the models analyzed was there any indication that the price effects of environmental contamination persist subsequent to remediation and cleanup. This is also consistent with findings from survey research on lender risk perceptions and willingness to loan on property before, during and after cleanup (Jackson, 2001c).

These findings should be good news for brownfield cleanup programs concerned with reducing environmental related investment risk within areas impacted or previously impacted by contamination. These findings should also aid courts of law and triers of fact that consider allegations of property damages due to contamination in environmental litigation matters. The temporary nature of the risk-related impacts on price and value, and lack of persistence of these impacts following cleanup, would indicate that reductions in property value and associated damages are temporary in nature and should not be considered permanent.

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