Environmental Risk Premiums and Price Effects in Commercial Real Estate Transactions

by Thomas O. Jackson, PhD, MAI, and Chris Yost-Bremm, PhD

Abstract

This article presents the results of a study of the effects of environmental contamination on the sale prices and overall capitalization rates of commercial real estate. Environmental risk for commercial real estate can be related to uncertainties concerning state-mandated cleanup requirements, potential off-site liabilities, and other factors. As risk increases, income is discounted or capitalized through higher required rates of return into lower prices and values. Using a series of regression models, this study estimates price discounts and environmental risk premiums for sales of retail centers in Southern California from 1994 through 2007. Significant price discounts are evident for contaminated properties sold prior to remediation but are shown to disappear after the properties are remediated. In addition, environmental risk premiums, as measured through overall capitalization rates, are found to decline over time, presumably as market participants become more knowledgeable about and experienced with contamination-related issues. In this study, both adverse pricing effects and elevated risk premiums are shown to diminish as the properties were remediated and as the market changed over the study period.

Introduction

This article examines the effects of environmental contamination on the sale prices and overall capitalization rates of commercial real estate. Three general questions are addressed. The first question involves the extent to which sale prices and capitalization rates may be impacted at all. The second research question involves the extent to which any effects due to environmental contamination may persist after the remediation and cleanup of previously contaminated properties. The third question involves the persistence of environmental risk premiums at the same stage of the remediation life cycle over time as the real estate market may become more knowledgeable about such issues. In addition, or alternatively, more general changes in the market may have a mitigating effect on environmental risk premiums and price effects. This study will specify and estimate alternative statistical models of commercial property sale prices and overall capitalization rates that address these research questions.

The commercial properties for this study are contaminated source sites, rather than sites affected by an external source, as is typically the case with residential properties. As source sites for soil or groundwater contamination, the price and value of commercial properties may be affected by both risk and cost. Environmental risk for commercial real estate is 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 *environmental stigma*.[1] As

1. *Environmental stigma* is "An adverse effect on property value produced by the market's perception of increased environmental risk due to contamination." Appraisal Standards Board, Advisory Opinion 9, "The Appraisal of Real Property That May Be Impacted by Environmental Contamination," *USPAP Advisory Opinions*, 2018–2019 ed. (Washington, DC: The Appraisal Foundation, 2018).

risk increases, income is discounted or capitalized, through higher required rates of return, into lower prices and values. Commercial real estate prices can also be directly reduced by estimated remediation costs that are to be paid by the buyer of such properties from future property cash flows. Where remediation costs have been estimated and such estimates are available, the sale prices will be adjusted to focus on effects of environmental risk.

Most formal, empirical analyses of the impacts of environmental contamination on sale prices and property values have focused on residential real estate.[2] Studies of nonresidential properties have been based on case studies. This study quantifies these impacts on commercial properties through a series of multiple regression models based on sales of retail centers in Southern California. Risk-related effects are distinguished from price reductions due to costs for planned remediation. In addition, this analysis specifically quantifies environmental risk as an overall capitalization rate premium for properties sold prior to remediation. As will be explained, sales involving contaminated properties transact at higher capitalization rates to compensate for the increased risks associated with the properties' environmental condition.

Nature of Contaminated Property Transactions

Commercial real estate transactions involving properties that may be impacted by environmental contamination are complex.[3] Typically, those considering financing a commercial real estate transaction will require an environmental assessment, and this may reveal the presence of contamination that exceeds regulatory standards.[4] The seller and buyer are then presented with a requirement to remediate the property to the appropriate regulatory standards, which usually specify some maximum concentration level of the hazardous substance. Remediation may occur through soil or groundwater cleanup or through more passive natural attenuation processes. Further, the remediation plan and approach is typically developed to site-specific, risk-based standards, which may vary depending on surrounding land uses and other factors. Adding to the complexity is the liability and responsibility for financing the cleanup. In some cases, the seller is deemed the responsible party and funds the remedial plan. In others, the buyer will be left with the responsibility for funding and completing the cleanup to the regulatory standards and according to an approved remedial action plan.

In the research that follows, some of the properties sold prior to or before cleanup. Their sale prices were adjusted upward for cleanup costs that would be later borne by the buyer. Such an adjustment results in a price and potential price reduction that can be attributable to environmental risk, the focus of this research. This is similar to an adjustment for deferred maintenance. Environmental risk, however, could and likely would vary with uncertainties concerning such costs and completion of the remediation plan and achievement of regulatory closure.

Literature Review

Published studies of the effect of environmental contamination on the sale prices of improved commercial properties have been largely based on case studies. These studies include Page and Rabinowitz,[5] who use a case study approach to evaluate the impacts of groundwater contamination on the value of six commercial and industrial properties in Pennsylvania, California, and Wisconsin. In another application of the case study approach, Patchin[6] analyzes eight com-

2. Thomas O. Jackson, "The Effects of Environmental Contamination on Real Estate: A Literature Review," *Journal of Real Estate Literature* 9, no. 2 (2001): 93–116.
3. Thomas O. Jackson, "Investing in Contaminated Real Estate," *Real Estate Review* 26, no. 5 (Winter 1997): 38–43; Thomas O. Jackson, Mark E. Dobroski, and Trevor E. Phillips, "Analyzing Contaminated Real Estate in a Changing Market," *Journal of Real Estate Finance* 13, no. 2 (Fall 1997): 67–72.
4. Thomas O. Jackson, "The EPA's Proposed All Appropriate Inquiries Rule and the Appraisal of Contaminated Properties," *The Appraisal Journal* 73, no. 2 (Spring 2005): 146–153.
5. G. William Page and Harvey Rabinowitz, "Groundwater Contamination: Its Effects on Property Values and Cities," *Journal of the American Planning Association* 59, no. 4 (Autumn 1993): 473–481.
6. Peter J. Patchin, "Contaminated Properties and the Sales Comparison Approach," *The Appraisal Journal* 62, no. 3 (July 1994): 402–409.

mercial and industrial case studies, finding a range of property value impacts, from 21% to 94%. Bell[7] presents a framework for evaluating a variety of detrimental conditions, including environmental contamination. Bell's framework calls for the valuation of a property as if there were no contamination (the "benchmark") and then a comparison of that 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 Bell's framework as either "project incentive" or "market resistance." Bell analyzes eight case studies involving industrial and commercial properties impacted by soil contamination, and he finds reductions in sale prices ranging from 10% to 51%.

The impacts of contamination on commercial property transaction rates and financing have been studied by Simons and Sementelli.[8] They compare commercial properties with leaking underground storage tanks (LUSTs) and properties with non-leaking tanks registered with the State of Ohio (RUSTs) to other commercial properties. They find that both LUST sites and RUST sites transact at significantly lower rates than uncontaminated commercial properties.

Simons, Bowen, and Sementelli[9] also analyze the effects of leaking underground storage tanks in Cleveland on adjacent commercial properties. The authors use a paired sales analysis, comparing a sale before contamination was discovered and a resale after the contamination was known. Based on an analysis of six such sales, they conclude that the average diminution in value due to the contamination was 28% to 42%.

Thus far, empirical studies of price effects of contamination on nonresidential properties have focused on industrial real estate. Jackson[10] addresses the issue of varying impacts of contamination over the remediation cycle through an analysis of 140 industrial property sales in Southern California. In a series of multivariate regression analyses, he finds that before or during cleanup sale prices were reduced 27.8% to 30.5%. After remediation, there was no discernable effect on the prices of previously contaminated properties. An earlier study of industrial property impacts is provided by Guntermann,[11] who estimates the parameters of a price model using 153 sales of unimproved industrial land in the Phoenix, Arizona, area. The sales include landfills (source sites) as well as industrial land located proximate or adjacent to landfills. Guntermann finds that the landfill sites sold for 53% less than other industrially zoned land.

Lastly, one published example of the application of regression techniques to commercial real estate, albeit not contaminated, is by Saderion, Smith, and Smith.[12] Using data on apartment property sales in Houston from 1978 to 1988, the authors estimate the parameters for three models: (1) a standard hedonic with price as a function of property and market characteristics, including year of sale categorical variables; (2) an income model with overall capitalization rates as a function of net operating income and the year of sale variables; and (3) a combined model with price as a function of property and market characteristics, year of sale, and net operating income. The models are estimated in logarithmic form. The combined model produced the best fit with an R^2 of 0.926. The income model had a lower explanatory power, with an R^2 of 0.752, although the *t*-statistic for net operating income of 27.97 indicates that it is a highly significant predictor.

7. Randall Bell, "The Impact of Detrimental Conditions on Property Values," *The Appraisal Journal* 66, no. 4 (October 1998): 380–391.
8. Robert A. Simons and Arthur J. Sementelli, "Liquidity Loss and Delayed Transactions with Leaking Underground Storage Tanks," *The Appraisal Journal* 65, no. 3 (July 1997): 255–260.
9. Robert A. Simons, William M. Bowen, and Arthur J. Sementelli, "The Price and Liquidity Effects of UST Leaks from Gas Stations on Adjacent Contaminated Property," *The Appraisal Journal* 67, no. 2 (April 1999): 186–194.
10. Thomas O. Jackson, "Environmental Contamination and Industrial Real Estate Prices," *Journal of Real Estate Research* 23, no. 1/2 (Jan/Apr 2002): 179–199.
11. Karl L. Guntermann, "Sanitary Landfills, Stigma and Industrial Land Values," *Journal of Real Estate Research* 10, no. 5 (1995): 531–542.
12. Zahra Saderion, Barton Smith, and Charles Smith, "An Integrated Approach to the Evaluation of Commercial Real Estate," *Journal of Real Estate Research* 9, no. 2 (Spring 1994): 151–167.

Research Framework

In this article, data on over ten years of sales of contaminated retail centers before and after remediation are analyzed and compared to the sale prices of similar but uncontaminated properties. This analysis will provide statistical evidence as to the extent of any risk-related reductions in sale prices that could be attributed to the effects of the environmental condition of the properties as of their date of sale. In addition, environmental risk premiums are quantified through increases in overall capitalization rates for contaminated properties sold prior to remediation. The analyses use multiple regression analysis and the related technique of analysis of covariance with estimated marginal mean, whereby the effects of other variables (e.g., property size, age, location, date of sale) are statistically held constant to isolate the independent effects of environmental condition on sale price. In addition, models controlling for changes in net operating income and analyzing changes in overall capitalization rates are used to further isolate the risk-related effects of environmental contamination.

Based on the literature cited and other information, three research questions are evaluated through the study presented herein. The first is whether reductions in property value (relative to baseline risk levels and prices for similar but uncontaminated properties) vary with the remediation status of the contaminated property. The second research question involves the extent to which contamination-related risk premiums and adverse property-value impacts disappear subsequent to remediation and cleanup.[13] The third question is whether contamination-related risk premiums and adverse property value impacts for unremediated properties are reduced over time. This could occur as the market becomes more experienced in quantifying environmental risk or as the more general market for commercial real estate changes. In the period under study, the market for commercial properties in Southern California improved and this improvement may mitigate risk-related effects.

These research questions, and property value impacts they suggest, will be measured through reductions in the average sale price for commercial properties that sold before, during, and after cleanup of contamination as well as increases to overall capitalization rates (environmental risk premiums). The statistical models will also allow for testing the possibility of no difference between the prices and capitalization rates of the contaminated and previously contaminated properties in comparison to otherwise similar properties that are uncontaminated.

A general model specification in linear form, with no transformations to the dependent or independent variables, is as follows:

$$\begin{aligned} PRICE = {} & \alpha + \beta_1 X_1 + \ldots + \beta_n X_n + \beta_{n+1} LOC_1 \\ & + \ldots + \beta_{n+1+p} LOC_p + \beta_{n+1+p+1} SYEAR_1 \\ & + \ldots + \beta_{n+1+p+1+q} SYEAR_q \\ & + \beta_{n+1+p+1+q+1} ENV_1 + \ldots \\ & + \beta_{n+1+p+1+q+1+r+s} ENV_s + \varepsilon \end{aligned} \quad (1)$$

where *PRICE* is the sale price of the property, adjusted for remediation costs to be paid by the buyer for contaminated properties that were unremediated when sold; $X_1 \ldots X_n$ is a collection of continuous non-environmental property characteristics, such as building size and age; $LOC_1 \ldots LOC_p$ is a set of discrete data columns indicating the location of the property to capture effects due to general market conditions that vary by location; $SYEAR_1 \ldots SYEAR_q$ is a set of discrete terms indicating the property's year of sale, to capture effects due to general market conditions that vary by year.[14] The locational

13. For this study, remediated sales were represented to only be in a No Further Action (NFA) status, and not in a Monitored Natural Attenuation (MNA) program. This ensures that the measure of post-remediation in the study is not including any properties that still have significant, ongoing environmental contamination.

14. A separate column for each area or for each year of sale is necessary because such an approach captures the individual price effects of that market or sale year, respectively. This is preferred over treating sale year as one continuous variable, because a collection of variables corresponding to each year will allow for market cycles that vary by year, as opposed to simply modeling a linear constant time trend.

and time variables will control for heterogeneity in the commercial real estate data. $ENV_1 \ldots ENV_s$ is a collection of discrete variables indicating the environmental status of the property at the time of sale. Alternative specifications will be used in the set of models based on net operating income and overall capitalization rates.

Data Collection

The data collection procedure for this analysis began with an initial search of the records of a commercial sales data service for Southern California. This search identified sales of commercial properties that had been previously contaminated. The analysis of these sales, and the question to which the analysis was addressed, was whether or not there was any remaining effect of previous contamination on sale price. Southern California was selected as the study area because of the size of the commercial real estate market and frequency of transactions. In addition, the data vendor, CoStar, Inc. (CoStar), has assembled an extensive sales database for this region.

The sales search procedure consisted of two steps, done with the assistance of the CoStar market research staff in San Diego. The first step involved a keyword search on the descriptive information on the full database for Southern California, including Los Angeles, Orange, San Diego, Riverside, San Bernardino, and Ventura Counties. Among the keywords were: remediation, contamination, toxic, environmental, synthetic, fibers, chemical, asbestos, radioactive, waste, lead, oil, petroleum, crude oil, and diesel. Several hundred sales were identified on this search. The description segment that keyed the identification was then reviewed in greater detail. Sales that only involved asbestos, sales of land only, sales of gasoline service stations, and sales for which the primary environmental issue was contamination from an adjacent property were not retained for further analysis. For the purpose of this study, properties considered to be sold as contaminated were those that were either unremediated or in the process of undergoing remediation.[15]

The second step in the data collection process was to match the selected contaminated property sales to a number of comparable properties that sold without existing or previous contamination. The goal was to match each contaminated sale to at least four or five uncontaminated comparables. Comparability was assessed based on property type (strip centers and neighborhood centers), location, size of improvements, date of sale, and age of improvements. CoStar geographically codes its sales data by county and by a number of subareas, or submarkets, within each county. For example, San Diego County has twenty subareas and Orange County has twelve subareas. Los Angeles County is divided into five main subareas: north, east, west, central, and south, and there are smaller subareas within each of these. Los Angeles County east has eight smaller subareas, and the other Los Angeles County subdivisions have seven smaller subareas each. Accordingly, each contaminated sale property was matched to other properties of the same type within each of these smaller subareas. In most of the smaller subareas, all the available uncontaminated property sales of the same property type as the contaminated property sale were selected. In areas with more data, sales of similar age and size were targeted.

Lastly, the statistical models developed for this study used a multivariate technique that requires each sale to have valid, non-missing data on all the variables used in the multiple regression procedure. Thus, any sale that did not meet this criterion was excluded from the analysis. At the time of initial data collection efforts, the specification of the final statistical models was not known, so data on a number of sales was collected but subsequently excluded. The data set for the base model is summarized in Exhibit 1. The sales are listed by geographic area and by environmental status.

The 150 sales used in this study could be considered a small sample size, especially compared to the studies of environmental impacts on residential properties that are more prevalent in the literature. However, in contrast to the residential sales, commercial transactions are large and complex and must be individually researched. The total sample size in this study represents a large volume of real estate investments.

15. There were insufficient sales observations for properties currently undergoing remediation to treat them as a statistically distinct group, so these observations were combined with those that were unremediated. Perhaps because of their small number, removing properties that were undergoing remediation at the time of sale did not impact the results of this analysis.

Exhibit 1 Data Set for Retail Center Sales in Base Model

	Uncontaminated Property Sales	Contaminated Property Sales, Before or During Remediation	Contaminated Property Sales, After Remediation	Totals
Los Angeles East (*LAEAST*)	11	0	2	13
Los Angeles North (*LANORTH*)	13	1	1	15
Los Angeles South (*LASOUTH*)	40	5	3	48
Los Angeles West (*LAWEST*)	15	2	1	18
Orange County (*ORANGE*)	23	4	1	28
San Diego County (*SANDIEGO*)	22	5	1	28
Totals	124	17	9	150

Notes: Data on retail center sales analyzed in base models, excluding sales with missing data on any of the variables in the base model and 5 statistical outliers.

Retail Center Base Model

Descriptive statistics for the data used in the retail center base models are summarized in the table in Exhibit 2. The data in this table reflects the averages, standard deviations, minimums, and maximums for the 150 sales used in the model. As can be seen, the overall mean sale price is $2,840,728. This sale price represents an adjusted amount. The prices were adjusted by adding buyer-paid remediation costs to the nominal sale price. A buyer would reduce the price to be paid by the amount that they would have to pay to remediate the property. In this way, cost effects, or reductions in selling price due to remediation costs, would be eliminated to the extent possible, and the analysis will focus on risk-related effects, or reductions in sale price resulting from perceived environmental risk.

The statistical analysis and parameter estimates for the retail center base model are presented in Exhibit 3. The model used to estimate these coefficients was based on a non-linear regression procedure with price as a function of the physical characteristics of the properties, their date of sale and location. The physical characteristics were the commonly used building size and age, but also included the ratio of parking spaces to size calculated as spaces per 1,000 square feet of space. Parking spaces and the parking ratio were more significant predictors of price than land area and front feet in each lot and were also collinear with these other variables.

To account for nonlinearities in the data, a nonlinear model was developed using a power transformation with a bootstrapping procedure to estimate the power coefficients for the transformations. This model specification is shown below.

$$\begin{aligned} PRICE = {} & \alpha + \beta_1(BLDGSF)^{\beta 2} + \beta_3(AGE)^{\beta 4} \\ & + \beta_5(PRATIO)^{\beta 6} + \beta_7 LAEAST \\ & + \beta_8 LANORTH + \beta_9 LASOUTH \\ & + \beta_{10} LAWEST + \beta_{11} ORANGE \\ & + \beta_{12} S1994 + \beta_{13} S1995 + \beta_{14} S1996 \\ & + \beta_{15} S1997 + \beta_{16} S1998 + \beta_{17} S1999 \\ & + \beta_{18} S2000 + \beta_{19} S2001 + \beta_{20} 2002 \\ & + \beta_{21} S2003 + \beta_{22} S2004 + \beta_{23} S2005 \\ & + \beta_{24} S2006 + \beta_{25} BEFORE \\ & + \beta_{26} AFTER + \varepsilon \end{aligned} \quad (2)$$

where *PRICE* is the sale price of the property, adjusted for remediation costs to be paid by the buyer for contaminated properties that were unremediated when sold; *BLDGSF* is the number of square feet of building space; *AGE* is the age in years of the property when sold; *PRATIO* is the ratio of parking spaces per 1,000 square feet of building space; *LAEAST*, *LANORTH*, *LASOUTH*, *LAWEST*, and *ORANGE* are cate-

gorical variables for the submarket location of the properties, with *SANDIEGO* as the omitted or reference category; *S1994* to *S2006* is a set of discrete terms indicating the property's year of sale, to capture effects due to market conditions that vary by year, with *S2007* as the omitted or reference category. As noted, these locational and time variables are intended to control for heterogeneity in the data that might vary with general market conditions and that might interact with the environmental variables of interest. *BEFORE* and *AFTER* are indicator variables for the property's environmental condition when sold, with *BEFORE* corresponding to a contaminated property sold prior to remediation and *AFTER* corresponding to a previously but remediated property. Uncontaminated properties are the omitted or reference category.

Exhibit 2 Descriptive Statistics for Sales Used in Retail Center Base Model

Variable	Minimum	Maximum	Mean	Standard Deviation
Sale price	$260,000	$14,500,000	$2,840,728	$2,742,180
Building square footage (*BLDGSF*)	2,399	105,217	21,701.25	22,157.78
Building age in years at time of sale (*AGE*)	0.00	78.00	21.21	15.90
Los Angeles East (*LAEAST*)	0.00	1.00	0.0867	0.28229
Los Angeles North (*LANORTH*)	0.00	1.00	0.1000	0.30101
Los Angeles South (*LASOUTH*)	0.00	1.00	0.3200	0.46804
Los Angeles West (*LAWEST*)	0.00	1.00	0.1200	0.32605
Orange County (*ORANGE*)	0.00	1.00	0.1867	0.39095
San Diego County (*SANDIEGO*)	0.00	1.00	0.1867	0.39095
Sale in 1994 (*S1994*)	0.00	1.00	0.0067	0.08165
Sale in 1995 (*S1995*)	0.00	1.00	0.0133	0.11508
Sale in 1996 (*S1996*)	0.00	1.00	0.0200	0.14047
Sale in 1997 (*S1997*)	0.00	1.00	0.0333	0.18011
Sale in 1998 (*S1998*)	0.00	1.00	0.2333	0.42437
Sale in 1999 (*S1999*)	0.00	1.00	0.1067	0.30972
Sale in 2000 (*S2000*)	0.00	1.00	0.0200	0.14047
Sale in 2001 (*S2001*)	0.00	1.00	0.0400	0.19662
Sale in 2002 (*S2002*)	0.00	1.00	0.1867	0.39095
Sale in 2003 (*S2003*)	0.00	1.00	0.1667	0.37393
Sale in 2004 (*S2004*)	0.00	1.00	0.0467	0.21163
Sale in 2005 (*S2005*)	0.00	1.00	0.0200	0.14047
Sale in 2006 (*S2006*)	0.00	1.00	0.0533	0.22545
Sale in 2007 (*S2007*)	0.00	1.00	0.0533	0.22545
Sale with contamination before or during remediation (*BEFORE*)	0.00	1.00	0.1133	0.31806
Sale after remediation of previous contamination (*AFTER*)	0.00	1.00	0.0600	0.23828

Notes: Data on 150 retail center property sales with non-missing data on all variables in the regression model, excluding 6 sales subsequently identified as outliers in base model. Twenty-six properties had existing or previous contamination and 124 were uncontaminated.

The model's fit to the retail center sales data is indicated by its adjusted R^2 of 0.843. The variables associated with the physical characteristics of the properties, *BLDGSF*, *AGE*, and *PRATIO* with the nonlinear power transformations as previously described, are all shown to be statistically significant at the 0.02 level or lower. In an untransformed version of the model, additional square footage is shown to add $103.03 to sale price, while the properties on average are reduced by $21,053 for each year of age. Chronological age is likely serving as a proxy for condition, functional obsolescence, and other factors related to accrued depreciation. Earlier tests indicated that *PRATIO* was collinear with land area but a better predictor of *PRICE* so it was retained and land area was dropped. Except for Los Angeles west (*LAWEST*), all the location variables were significant. Most of the sale year variables are statistically significant at the 0.001 level, except for *S2004* to *S2006*, which are closest to the *S2007* reference category. The environmental condition variables were not collinear with either set of fixed-effect general market variables, subarea location, and year of sale.

The estimates in Exhibit 3 for the two environmental condition variables indicate retail centers that sold before or during cleanup of existing environmental contamination had an average price discount of $890,987, which is significant at the 0.05 level. The model estimates for centers that sold after cleanup indicates a slight and insignificant discount of $5,179. This suggests increased market certainty about the environmental condition of these now remediated properties. Lastly, with an estimated marginal mean price for the uncontaminated retail centers of $2,942,017, the model's estimates indicate a 30.28% reduction in sale price due to contamination for properties sold before or during cleanup. The price premium for the previously contaminated properties indicates a near zero, 0.002% discount after cleanup relative to comparable uncontaminated properties. Thus, the previously contaminated commercial properties in this analysis have regained their full value after completion of the remedial activities and achievement of a "no further action" status with respect to regulatory requirements. This is an important and significant finding based on the largest group of sales of commercial properties systematically studied through formal mathematical and statistical analysis.

Retail Center Economic Models

The preceding sections have analyzed sale prices with models focusing on the physical characteristics of the improvements, such as building size and age, as well as the properties' location and date of sale. That base model is somewhat similar to the "standard hedonic" specification referred to by Saderion, Smith, and Smith.[16] Saderion, Smith, and Smith also suggest the use of such variables as net operating income and overall capitalization rates. These variables are usually highly correlated with the value of income-producing commercial real estate. The overall capitalization rate, denoted by the symbol R_O, reflects the relationship between net operating income and sale price and is considered to be the rate at which income is capitalized into value. As noted, it reflects the risk associated with a particular property investment, among other factors. Conceptually, the capitalization rate could be viewed as the reciprocal of a price-earnings ratio. Net operating income (*NOI*) is simply the net of property revenues less operating expenses. Dividing *NOI* by R_O equals property value. Alternatively, the ratio of *NOI* to property value, or sale price as an indicator of value, is R_O. These variables form the basis of the income capitalization approach to value that is frequently used by the market to price and value income-producing commercial real estate. The income capitalization approach is also supported in the literature as an appropriate approach for valuing contaminated commercial properties and estimating the diminution in value due to contamination.[17] Thus, consideration of these variables in this study is appropriate and well-founded from conceptual and practical perspectives.

Net Operating Income (*NOI*) Model

Exhibit 4 presents descriptive statistics for the data used to estimate the *NOI* and capitalization rate models. Since net operating income data

16. Saderion, Smith, and Smith, "Integrated Approach to Evaluation of Commercial Real Estate."

17. Thomas O. Jackson, "Environmental Risk Perceptions of Commercial and Industrial Real Estate Lenders," *Journal of Real Estate Research* 22, no. 3 (2001): 271–288

was not available for all 150 sales used in the base model, 107 sales are used in these analyses, including 15 contaminated retail centers that sold before or during remediation and 8 sales of previously contaminated properties that sold after remediation. As noted, these sales were matched to similar retail centers located in the same submarket area as the possibly impacted properties. There were approximately three to four uncontaminated property sales for each of the contaminated or previously contaminated property sales.

The model specification for this analysis is as follows:

Exhibit 3 Retail Center Sales Base Model Parameter Estimates

Variable	Parameter Estimate ($)	*t*-Statistic	*p*-Value
Intercept	1,450,063.522**	2.058	0.042
Building square footage (*BLDGSF* $^{0.6256}$)	7,982.386***	22.081	0.001
Building age in years (*AGE* $^{0.2830}$)	-599,956.806***	-3.177	0.002
Parking ratio (*PRATIO* $^{15.02}$)	0.000000004036**	2.494	0.014
Los Angeles East (*LAEAST*)	1,792,399.816***	4.502	0.001
Los Angeles North (*LANORTH*)	564,129.849	1.434	0.154
Los Angeles South (*LASOUTH*)	616,017.135**	2.117	0.036
Los Angeles West (*LAWEST*)	688,859.196*	1.769	0.079
Orange County (*ORANGE*)	1,508,610.123***	4.072	0.001
Sale in 1994 (*S1994*)	-3,463,926.368***	-2.881	0.005
Sale in 1995 (*S1995*)	-3,952,807.431***	-4.107	0.001
Sale in 1996 (*S1996*)	-3,735,169.845***	-4.581	0.001
Sale in 1997 (*S1997*)	-3,694,888.340***	-5.354	0.001
Sale in 1998 (*S1998*)	-3,740,317.259***	-8.045	0.001
Sale in 1999 (*S1999*)	-3,022,114.909***	-5.768	0.001
Sale in 2000 (*S2000*)	-2,824,735.104***	-3.394	0.001
Sale in 2001 (*S2001*)	-2,902,786.819***	-4.428	0.001
Sale in 2002 (*S2002*)	-2,756,277.518***	-5.531	0.001
Sale in 2003 (*S2003*)	-2,203,690.884***	-4.376	0.001
Sale in 2004 (*S2004*)	-815,446.560	-1.325	0.188
Sale in 2005 (*S2005*)	-1,114,309.494	-1.416	0.159
Sale in 2006 (*S2006*)	-557,750.132	-.898	0.371
Sale with contamination before or during remediation (*BEFORE*)	-890,987.485***	2.719	0.007
Sale after remediation of previous contamination (*AFTER*)	-5,179.409	-0.013	0.990
Adjusted R^2	0.843	35.720 (*F*-statistic)	0.001

Notes: Based on 150 sales, excluding 5 sales with standardized residuals greater than ±2.0. *SANDIEGO* and *S2007* were reference categories for location and sale year. Covariates of *BLDGSF*, *AGE*, and *PRATIO* transformed on the basis of nonlinear regression of $PRICE = \alpha + \beta_1 (BLDGSF)^{\beta 2} + \beta_3 (AGE)^{\beta 4} + \beta_5 (PRATIO)^{\beta 6} + other\ variables + \varepsilon$. Nonlinear model produced estimates of $\beta_2 = 0.6256$, $\beta_4 = 0.2830$, and $\beta_6 = 15.02$.

***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels, respectively.

$$LNPRICE = \alpha + \beta_1(NOI)^{\beta 2} + \beta_3 LAEAST + \beta_4 LANORTH + \beta_5 LASOUTH + \beta_6 LAWEST + \beta_7 ORANGE + \beta_8 S1994 + \beta_9 S1995 + \beta_{10} S1996 + \beta_{11} S1997 + \beta_{12} S1998 + \beta_{13} S1999 + \beta_{14} S2000 + \beta_{15} S2001 + \beta_{16} 2002 + \beta_{17} S2003 + \beta_{18} S2004 + \beta_{19} S2005 + \beta_{20} S2006 + \beta_{21} BEFORE + \beta_{22} AFTER + \varepsilon \quad (3)$$

where *LNPRICE* is the natural logarithm of sale price of the property, adjusted for remediation costs to be paid by the buyer for contaminated properties that were unremediated when sold; *NOI* is the estimated net operating income generated by the property at the time of sale; *LAEAST*, *LANORTH*, *LASOUTH*, *LAWEST*, and *ORANGE* are categorical variables for the submarket location of the properties, with *SANDIEGO* as the omitted or reference category; *S1994* to *S2006* is a collection of discrete terms indicating the property's year of sale, to capture effects due to market conditions that vary by year, with *S2007* as the omitted or reference category. *BEFORE* and *AFTER* are indicator variables for the property's environmental condition when sold, with *BEFORE* corresponding to a contaminated property sold prior to remediation and *AFTER* corresponding to a previously but remediated property. Uncontaminated properties are the omitted or reference category.

Exhibit 5 presents the estimated results of the *NOI* model applied to the Southern California retail center sales and income data with the two environmental condition variables. The dependent variable in the model specification is the logarithm of sale price as this form was found to best fit the data. In this specification, the *NOI* covariate is transformed using a power transformation estimated through a nonlinear model and bootstrap resampling procedure.[18] The transformations suggested by the nonlinear model were statistically significant at the 0.001 level. Transformation of the dependent variable, sale price into logarithmic form was not shown to improve the model's fit. After performing the indicated power transformations to the independent variables, the base model was then reestimated. As shown in Exhibit 5, this model specification has an adjusted R^2 of 0.962, indicating that these variables explain more than 96% of the variation in sale price. The significance and explanatory power of this simple model highlights the strong relationship between *NOI* and sale price. The transformed *NOI* variable is significant at the 0.001 level.

The parameters of interest for the first two research questions, sales before remediation and sales after cleanup, show the same pattern found in the base model. That is, the effect of contamination before cleanup is statistically significant, and the effect after cleanup is not significant. For the centers in the *NOI* model, the effect before cleanup is to reduce sale price by 12.80%, calculated by raising the parameter estimate for *BEFORE* of -0.1372 to the power of base *e* and then subtracting the result from one and multiplying by 100. The coefficient for the sales in the *AFTER* condition is not significant although it is positive and indicates a price premium of 4.08%. Thus, the null hypothesis of no effect is rejected in favor of the first research hypothesis that contamination before cleanup affects price. Further, the *NOI* model estimate for price effects after cleanup indicate that although the null hypothesis of no effect cannot be rejected, there is an indication of a positive price effect resulting from the cleanup. This raises the possibility that after remediation and when sold "clean," the properties not only regain their unimpaired values but can sell at premiums similar to uncontaminated properties.

18. Bootstrapping is a more statistically rigorous approach in studies utilizing a small amount of sales observations. The thresholds for statistical significance are developed according to the distribution of the actual data, rather than a standard normal distribution. This has the effect of making it more difficult to inadvertently find statistical significance in the results if they do not actually exist. A more detailed discussion of the bootstrap resampling procedure may be found in Thomas O. Jackson, "Environmental Contamination and Industrial Real Estate Prices," *Journal of Real Estate Research* 23, no. 1/2 (Jan/Apr 2002): 179–199.

Exhibit 4 Descriptive Statistics for Sales Used in Net Operating Income (*NOI*) and Overall Capitalization Rate (*CAPRATE* or R_O) Models

Variable	Minimum	Maximum	Mean	Standard Deviation
Sale price	$260,000	$22,700,000	$3,622,632	$3,818,746
Net Operating Income (*NOI*)	$34,020	$1,541,330	$292,326	$282,071
Overall Capitalization Rate (*CAPRATE*)	0.0243	0.1625	0.088285	0.0234119
Los Angeles East (*LAEAST*)	0.00	1.00	0.1028	0.30513
Los Angeles North (*LANORTH*)	0.00	1.00	0.1121	0.31704
Los Angeles South (*LASOUTH*)	0.00	1.00	0.2804	0.45130
Los Angeles West (*LAWEST*)	0.00	1.00	0.1215	0.32824
Orange County (*ORANGE*)	0.00	1.00	0.1869	0.39168
San Diego County (*SANDIEGO*)	0.00	1.00	0.1963	0.39904
Sale in 1994 (*S1994*)	0.00	1.00	0.0093	0.09667
Sale in 1995 (*S1995*)	0.00	1.00	0.0093	0.09667
Sale in 1996 (*S1996*)	0.00	1.00	0.0280	0.16586
Sale in 1997 (*S1997*)	0.00	1.00	0.0467	0.21205
Sale in 1998 (*S1998*)	0.00	1.00	0.2056	0.40605
Sale in 1999 (*S1999*)	0.00	1.00	0.1215	0.32824
Sale in 2000 (*S2000*)	0.00	1.00	0.0093	0.09667
Sale in 2001 (*S2001*)	0.00	1.00	0.0187	0.13607
Sale in 2002 (*S2002*)	0.00	1.00	0.1495	0.35829
Sale in 2003 (*S2003*)	0.00	1.00	0.1495	0.35829
Sale in 2004 (*S2004*)	0.00	1.00	0.0654	0.24843
Sale in 2005 (*S2005*)	0.00	1.00	0.0280	0.16586
Sale in 2006 (*S2006*)	0.00	1.00	0.0748	0.26425
Sale in 2007 (*S2007*)	0.00	1.00	0.0841	0.27886
Sale with contamination before or during remediation (*BEFORE*)	0.00	1.00	0.1402	0.34881
Sale after remediation of previous contamination (*AFTER*)	0.00	1.00	0.0748	0.26425

Notes: Data on 107 retail center property sales with non-missing data on all variables in the regression models. Fifteen properties had existing contamination and sold prior to remediation, 8 were sales of previously contaminated properties that sold after remediation and 84 properties were uncontaminated when sold.

Exhibit 5 *NOI* Model Parameter Estimates with Logarithmic Specification and Covariate Transformation

Variable	Parameter Estimate	*t*-Statistic	*p*-Value
Intercept	-90.4776***	-34.884	0.001
Net Operating Income ($NOI^{0.009004708}$)	94.6307***	40.837	0.001
Los Angeles East (*LAEAST*)	0.1093	1.563	0.122
Los Angeles North (*LANORTH*)	-0.0361	-0.527	0.600
Los Angeles South (*LASOUTH*)	0.0112	0.206	0.837
Los Angeles West (*LAWEST*)	-0.0484	-0.684	0.496
Orange County (*ORANGE*)	0.0769	1.177	0.243
Sale in 1994 (*S1994*)	-0.7736***	-4.197	0.001
Sale in 1995 (*S1995*)	-0.7692***	-3.882	0.001
Sale in 1996 (*S1996*)	-0.7596***	-6.059	0.001
Sale in 1997 (*S1997*)	-0.7254***	-6.894	0.001
Sale in 1998 (*S1998*)	-0.6641***	-9.230	0.001
Sale in 1999 (*S1999*)	-0.6169***	-7.715	0.001
Sale in 2000 (*S2000*)	-0.8222***	-4.248	0.001
Sale in 2001 (*S2001*)	-0.6439***	-4.716	0.001
Sale in 2002 (*S2002*)	-0.5902***	-7.411	0.001
Sale in 2003 (*S2003*)	-0.4528***	-5.787	0.001
Sale in 2004 (*S2004*)	-0.1934**	-2.074	0.041
Sale in 2005 (*S2005*)	-0.1468	-1.233	0.221
Sale in 2006 (*S2006*)	-0.0635	-0.712	0.478
Sale with contamination before or during remediation (*BEFORE*)	-0.1372**	-2.568	0.012
Sale after remediation of previous contamination (*AFTER*)	0.0399	0.583	0.562
Adjusted R^2	0.962		
F-value	103.205		
p-value	0.0001		

Notes: Dependent variable is the logarithm of sale price (*LNPRICE*). NOI transformed on the basis of nonlinear regression of $PRICE = \beta_0 + \beta_1 (NOI)^{\beta 2} + other\ variables + \varepsilon$. Nonlinear model produced an estimated of $\beta_2 = 0.009004708$ and had an adjusted R^2 of 0.96. *SANDIEGO* and *S2007* were reference categories for location and sale date.

*** and ** indicate significance at the 0.01 and 0.05 level, respectively.

Capitalization Rate Model

In the next model, overall capitalization rates for the retail center sales are modeled as a function of property location, year of sale variables, and the environmental condition of the properties as of their date of sale. Again, the time over which the analysis was conducted was 1994 to 2007. Using this data, 107 retail center sales with sufficient information to estimate or calculate an overall capitalization rate were identified. Adjustments were made to sale prices where buyers had paid remediation costs (adjusted sale price, as previously described) before the calculation of the capitalization rates. A model specification for this analysis is as follows:

$$\begin{aligned} CAPRATE = {} & \alpha + \beta_1 LAEAST + \beta_2 LANORTH \\ & + \beta_3 LASOUTH + \beta_4 LAWEST \\ & + \beta_5 ORANGE + \beta_7 S1994 \\ & + \beta_8 S1995 + \beta_9 S1996 + \beta_{10} S1997 \\ & + \beta_{11} S1998 + \beta_{12} S1999 \\ & + \beta_{13} S2000 + \beta_{14} S2001 \\ & + \beta_{15} 2002 + \beta_{16} S2003 \\ & + \beta_{17} S2004 + \beta_{18} S2005 \\ & + \beta_{19} S2006 + \beta_{20} BEFORE \\ & + \beta_{21} AFTER + \varepsilon \end{aligned} \quad (4)$$

where *CAPRATE* is the overall capitalization rate (also referred to by the symbol R_O) as estimated for the property when sold based on *NOI*, or I_O, and sale price adjusted for remediation costs to be paid by the buyer for contaminated properties that were unremediated when sold; *LAEAST*, *LANORTH*, *LASOUTH*, *LAWEST*, and *ORANGE* are categorical variables for the submarket location of the properties, with *SANDIEGO* as the omitted or reference category; *S1994* to *S2006* is a set of discrete terms indicating the property's year of sale, to capture effects due to market conditions that vary by year, with *S2007* as the omitted or reference category. *BEFORE* and *AFTER* are indicator variables for the property's environmental condition when sold, with *BEFORE* corresponding to a contaminated property sold prior to remediation and *AFTER* corresponding to a previously but remediated property. Uncontaminated properties are the omitted or reference category.

The analysis of this data is presented in Exhibit 6. Again, the reference group for the two environmental variables is the uncontaminated property sales. Accordingly, the *BEFORE* parameter estimate for properties sold with unremediated contamination represents the increased capitalization rate for this environmental condition relative to the capitalization rates for uncontaminated properties. From another perspective, this coefficient corresponds to the environmental risk premium for properties with unremediated contamination. With a coefficient of 0.015641, the risk premium is approximately 156 basis points. This premium corresponds to the additional return (unleveraged) required to compensate for the risk and uncertainty associated with a contaminated commercial sold prior to cleanup.

As also shown in Exhibit 6, the 156.41-basis-point risk premium estimated in the capitalization rate model is significant at the 0.001 level. The estimate for the *AFTER* cleanup condition is not significant. In this model, the null hypothesis that environmental condition has no effect on overall capitalization rates can be rejected for the *BEFORE* cleanup condition, in favor of an alternative hypothesis, that prior to remediation contamination increases environmental risk and it reduces sale prices (through higher capitalization rates).

The estimated environmental risk premium can be used to calculate a corresponding sale price reduction. Adding the risk premium of 156.41 basis points to the 8.56% capitalization rate (R_O) for uncontaminated properties equates to an impaired capitalization rate (impaired R_O) of 0.101242, or 10.12%. With an average net operating income of $223,927 (calculated by applying the R_O of 8.56% to the average sale price for the uncontaminated properties in this analysis of $2,615,968), the risk premium of 156.41 basis points equates to a price reduction of $404,170, or 15.45%. The 15.45% price reduction, as estimated through the capitalization rate model, is slightly higher than the 12.80% reduction in sale price estimated through the *NOI* model. A similar procedure was used to calculate the premium for previously

contaminated properties sold after remediation. This percentage increase in price effect was estimated at 1.66%.

All the estimates of premiums and discounts for the commercial property sales in the three models are summarized in Exhibit 7. As can be seen, the price discounts for contaminated properties sold prior to remediation range from 12.80% to 30.28% relative to otherwise similar but contaminated properties. These estimates were all shown to be statistically significant. On the other hand, properties sold in the after condition were shown in all three models to have recovered, with a near-zero to slightly positive price and risk effects relative to uncontaminated properties. This could be related to the increased knowledge about these properties' environmental condition after remediation. It also shows

Exhibit 6 Capitalization Rate Model Parameter Estimates

Variable	Parameter Estimate	*t*-Statistic	*p*-Value
Intercept	0.054203***	11.331	0.001
Los Angeles East (*LAEAST*)	-0.011716**	-2.205	0.030
Los Angeles North (*LANORTH*)	0.001990	0.369	0.173
Los Angeles South (*LASOUTH*)	-0.002738	-0.644	0.521
Los Angeles West (*LAWEST*)	-0.003393	-0.608	0.545
Orange County (*ORANGE*)	0.008721*	-1.694	0.094
Sale in 1994 (*S1994*)	0.060418***	4.166	0.001
Sale in 1995 (*S1995*)	0.055915***	3.591	0.001
Sale in 1996 (*S1996*)	0.055785***	5.737	0.001
Sale in 1997 (*S1997*)	0.058915***	7.109	0.001
Sale in 1998 (*S1998*)	0.051767***	9.181	0.001
Sale in 1999 (*S1999*)	0.047101***	7.596	0.001
Sale in 2000 (*S2000*)	0.058178***	3.876	0.001
Sale in 2001 (*S2001*)	0.051392***	4.779	0.001
Sale in 2002 (*S2002*)	0.040081***	6.435	0.001
Sale in 2003 (*S2003*)	0.032790***	5.337	0.001
Sale in 2004 (*S2004*)	0.013732*	1.870	0.065
Sale in 2005 (*S2005*)	0.012053	1.289	0.201
Sale in 2006 (*S2006*)	0.005048	0.722	0.472
Sale with contamination before or during remediation (*BEFORE*)	0.015641***	3.726	0.001
Sale after remediation of previous contamination (*AFTER*)	-0.001397	-0.256	0.756
Adjusted R^2	0.683		
F-value	12.432		
p-value	0.0001		

Notes: Dependent variable is the overall capitalization rate at which the property sold (*CAPRATE*). ***, **, and * indicate significance at the 0.01, 0.05 and 0.10 level, respectively. Reference category for location is San Diego County. Reference category for sale year is 2007. Effect of contamination for properties that sold before or during remediation is significant at the 0.001 level and indicates an environmental risk premium of 156 basis points over the cap rate for an otherwise similar property without current (as of the sale date) or previous contamination.

Exhibit 7 Summary of Estimated Price and Risk Effects by Model

	Percent Price Effect	Adjusted R^2	No. of Sales
Base Model			
Before Condition	-30.28%	84.3%	150
After Condition	-0.002%	(Exhibit 3)	
***NOI* Model**			
Before Condition	-12.80%	96.2%	107
After Condition	+4.08%	(Exhibit 5)	
Capitalization Rate Model			
Before Condition	-15.45%	68.3%	107
After Condition	+1.66%	(Exhibit 6)	

Notes: Indicates an overall range of price effects from -12.80% to -30.28% in the before remediation condition and from -0.002% to +4.08% in the after-remediation condition. All the estimates of the before condition impacts are statistically significant at the 0.05 level, while the estimates for the after condition effect were not statistically significant. Estimates are relative to otherwise similar but uncontaminated properties.

positive market effects and benefits from the cleanup and remediation of these sites.

As also shown in Exhibit 7, the price effects for properties in the before condition are considerably less in the *NOI* and capitalization rate models than the base model. While the latter focuses on the physical characteristics of the properties, the *NOI* and *CAPRATE* models consider the income each property generates and the rate at which that income is capitalized into value. In addition, NOI more directly considers vacancy and rent levels, with less focus on the properties' hedonic, physical characteristics. Perhaps the income data and the risk effects in the capitalization rates are more direct measures of the risk and diminution constructs.

Risk Premiums over Time

The third research question, whether contamination-related risk premiums are reduced over time as the market becomes more familiar with quantifying environmental risks, can be examined by analyzing changes in environmental risk premiums in overall capitalization rates over time. Exhibit 8 presents summary data on these sales, including mean or average capitalization rates by each of three periods and by remediation status. The periods were delineated in part to have a reasonably similar and sufficient number of sales and, more importantly, to provide a way to test this hypothesis given the sales data that was available.

As can be seen in Exhibit 8, all the capitalization rates for uncontaminated properties are less than for the properties that were contaminated and sold prior to remediation. For example, in period 1 (1994 to 1998) the unimpaired rate was 10.16% compared the impaired before condition rate of 12.67%. This is consistent with the findings from other analyses discussed in the preceding pages. Importantly, this data also shows that the difference between the capitalization rates for the contaminated and uncontaminated properties narrows over time. In the third period, 2003 to 2007, the before condition (unremediated) capitalization rate is 7.14% compared to the unimpaired rate of 6.82%. The differentials between the unimpaired and after condition (remediated) properties also narrow.

Results of the overall capitalization rate modeling procedure using the three periods are presented in Exhibit 9. The capitalization rate risk premiums associated with the properties' environmental condition at sale is statistically significant for periods 1 and 2 but not for period 3. This provides evidence that the risk premiums have declined over time, supporting the hypothesis that increased market knowledge about and familiarity with environmental contamination

Exhibit 8 Capitalization Rate Data for Three Periods

	Property Sales	Mean Overall Capitalization Rate	Standard Deviation
Period 1 (Before Condition)	6	0.126700 (R_O = 12.67%)	0.0185143
Period 1 (After Condition)	3	0.094933 (R_O = 9.49%)	0.0077597
Period 1 (Uncontaminated)	23	0.101622 (R_O = 10.16%)	0.0146433
Period 2 (Before Condition)	4	0.116025 (R_O = 11.60%)	0.0166968
Period 2 (After Condition)	2	0.096100 (R_O = 9.61%)	0.0055154
Period 2 (Uncontaminated)	26	0.094831 (R_O = 9.48%)	0.0125926
Period 3 (Before Condition)	5	0.071420 (R_O = 7.14%)	0.0168550
Period 3 (After Condition)	3	0.065867 (R_O = 6.58%)	0.0254052
Period 3 (Uncontaminated)	35	0.068217 (R_O = 6.82%)	0.0170408
Totals (Before, After, and Uncontaminated)	107	0.088285 (R_O = 8.83%)	0.0234119

Notes: Data on retail center sales for each of three periods and by remediation status at time of sale, excluding sales with missing data or for which a capitalization rate could not be estimated. Sale price used in capitalization rate estimates adjusted for remediation costs to be paid by buyer. Period 1 is from 1994 to 1998. Period 2 is from 1999 to 2002. Period 3 is from 2003 to 2007. Data used in models presented in Exhibits 9 and 10.

issues has mitigated these risks. Lastly, and as also shown in Exhibit 9, the premiums for previously contaminated properties (after remediation) are not significantly different from the uncontaminated properties.

Lastly, Exhibit 10 presents a summary of the risk premium findings from the model in Exhibit 9. Again, the decline in premiums is evident. As shown, in the first period the risk premium is 217.4 basis points over the unimpaired capitalization rate for that period and with a *p*-value of 0.003 is statistically significant at the 0.05 level. In the second period the risk premium has declined to 173.4 basis points but is still significant at the 0.10 level. By the third period, this premium has declined further to 92.7 basis points and although positive (slightly higher risk) is not statistically significant (p = 0.172). As explained, this supports the hypothesis that these risk premiums do change over time and the direction of change is toward a reduction in contamination-related risks for commercial properties sold prior to remediation. The decomposition of these premiums by period provides perspective on the commercial real estate market and how it prices risk associated with environmental contamination.

Exhibit 9 Capitalization Rate Model, Three Periods

Variable	Parameter Estimate	*t*-Statistic	*p*-Value
Intercept	0.055***	11.194	0.001
Los Angeles East (*LAEAST*)	-0.010*	-1.746	0.085
Los Angeles North (*LANORTH*)	0.002	0.437	0.663
Los Angeles South (*LASOUTH*)	-0.002	-0.566	0.573
Orange County (*ORANGE*)	-0.008	-1.413	0.161
Sale in 1994 (*S1994*)	0.058***	3.916	0.001
Sale in 1995 (*S1995*)	0.054**	2.970	0.004
Sale in 1996 (*S1996*)	0.053***	5.310	0.001
Sale in 1997 (*S1997*)	0.049***	5.511	0.001
Sale in 1998 (*S1998*)	0.049***	8.075	0.001
Sale in 1999 (*S1999*)	0.045***	6.784	0.001
Sale in 2000 (*S2000*)	0.054**	3.079	0.003
Sale in 2001 (*S2001*)	0.049***	4.129	0.001
Sale in 2002 (*S2002*)	0.038***	5.690	0.001
Sale in 2003 (*S2003*)	0.032***	5.009	0.001
Sale in 2004 (*S2004*)	0.013*	1.684	0.096
Sale in 2005 (*S2005*)	0.012	1.296	0.199
Sale in 2006 (*S2006*)	0.004	0.492	0.624
Period 1 (Before Remediation)	**0.021740****	**3.067**	**0.003**
Period 1 (After Remediation)	-0.001921	-0.178	0.859
Period 2 (Before Remediation)	**0.017342***	**1.950**	**0.055**
Period 2 (After Remediation)	0.002876	0.283	0.778
Period 3 (Before Remediation)	**0.009268**	**1.377**	**0.172**
Period 3 (After Remediation)	-0.003866	-0.465	0.643
Adjusted R^2	0.675	10.183 (*F*-statistic)	0.001

Notes: Dependent variable is the overall capitalization rate. Reference category for location is San Diego County. Reference category for sale year is 2007. Reference category for each period (before and after remediation) is otherwise similar sales of uncontaminated properties in the same period. Coefficient interpretation for period variables is the basis point risk premium over the unimpaired overall capitalization rate for that period.

Exhibit 10 Basis Point Risk Premiums in Overall Capitalization Rates (R_O) for Retail Centers with Unremediated Contamination (Sold Before Remediation)

Period	Basis Point Risk Premium to Unimpaired Overall Capitalization Rate	*p*-Value
1994 to 1998	217.4	0.003
1999 to 2002	173.4	0.055
2003 to 2007	92.7	0.172
Overall	156.4	0.001

Notes: Based on regression results in Exhibit 6 (overall risk premium) and Exhibit 9 (risk premiums for each study period).

Summary and Conclusions

Nearly all the adverse price effects estimated through the preceding analyses, with the exception of the period 3 estimate, found parameter estimates that attained significance at the 0.05 level or better associated with the environmental condition of the contaminated properties sold before or during remediation. In all the models, the effect of contamination on sale price after remediation was found not to be statistically significant. Therefore, the first two research questions involving whether price and risk change as properties are remediated are answered in the affirmative and clearly supported in this analysis. Price impacts are significant and negative in the before condition and insignificant in the after condition. In addition, the analyses indicate the risk premiums and adverse property value impacts disappear after remediation. Indeed, two of the models estimated a price premium for previously contaminated and remediated properties relative to otherwise comparable but uncontaminated properties.

As noted, the analyses presented herein resulted in estimates of reductions in sale prices of contaminated properties before remediation ranging from 12.80% to 15.45% for the economic models and 30.28% for the base model. These estimates can be compared to the limited number of published empirical studies on the impacts of contamination or hazards on commercial or industrial property. The first, by Page and Rabinowitz,[19] analyzed six contaminated commercial properties in Pennsylvania, California and Wisconsin and found a range of property value reductions from 10% to 50%. Another study, by Patchin,[20] analyzed eight "case studies" and found a range of reductions in value from 20.9% to 93.7%. Bell[21] analyzed eight commercial and industrial properties and found risk-related reductions in price from 10% to 51%. Simon, Bowen, and Sementelli,[22] also used a case study approach to analyze the effects of proximity to leaking underground storage tank sites in Cleveland. That study of six commercial properties found an average reduction of 28% to 42%, depending on the weighting of the results. Jackson[23] found that the sale prices of contaminated, source-site industrial properties were reduced from 27.8% to 30.5% prior to remediation. The other study of industrial properties cited herein, by Guntermann,[24] found that industrial land used as a municipal landfill sold for 53% less than other industrially zoned land in Phoenix, Arizona.

Once the income generation potential of the property was considered in the *NOI* model, the discounts in the before period were reduced to a still significant -12.80%. In the after period, though, the discount was reversed to a positive 4.08% albeit not statistically significant. Accordingly, this indicates that all of the risk-related

19. Page and Rabinowitz, "Groundwater Contamination."

20. Patchin, "Contaminated Properties."

21. Bell, "Impact of Detrimental Conditions."

22. Simons, Bowen, and Sementelli, "Price and Liquidity Effects of UST Leaks."

23. Jackson, "Environmental Contamination."

24. Guntermann, "Sanitary Landfills."

diminution was not present in the after condition along with some evidence of a rebound to a level slightly above otherwise similar properties were uncontaminated. Since the *NOI* variable was not collinear with the environmental condition indicators, this suggests that some of the diminution evident in the base model specification may be due to differences in the net income of the properties under study. Although the time and area fixed effects variable should have controlled for temporal and locational differences, this could be a topic for further study.

The capitalization rate models offer the most direct measure of environmental risk of the specifications used herein, given its definition and usage by the market in pricing risk. To further evaluate these premiums another analysis measured them over time to address the third research question, that contamination-related risk premiums and adverse property value impacts are reduced over time as the market becomes more experienced in quantifying environmental risk. While market knowledge is not specifically tested, the analyses, presented in Exhibits 8, 9, and 10, show a decline in risk premiums, measured as basis point differences in overall capitalization rates between contaminated properties that sold prior to remediation and uncontaminated properties. In earlier periods, this premium was statistically significant and in later periods was smaller and not statistically significant. The trend in the change showed a decline over time for each of the periods analyzed and also for properties that had been remediated prior to sale.

In conclusion, the analysis of these two dimensions—changes in impact and value as contaminated properties are remediated and changes over time as the market and its environmental risk perceptions change—offer significant and new insight as to how and to what extent environmental risks are reflected in commercial real estate pricing and investment criteria. Findings concerning changes over the remediation life cycle are consistent with findings and research addressing lender and investor perceptions of commercial and industrial properties over the remediation life cycle.[25] Reductions in risk premiums over time for contaminated properties have not been previously addressed, but as presented herein, show additional diminishing risk perceptions and premiums. This could be attributed to improving general market conditions, although the area and sale year fixed effects variables would have controlled for this. It is also likely due to the market's increasing familiarly and certainty concerning contamination and its remediation. This research finds that both sets of changes seem to be occurring simultaneously. This first of its kind systematic and formal research should provide a framework and starting point for further investigation.

About the Authors

Thomas O. Jackson, PhD, MAI, CRE, is the president of Real Property Analytics, Inc. based in College Station, Texas, where he specializes in analyzing real estate that may be impacted by environmental contamination as well as other complex valuation related issues. Previously, Jackson was the G. Steven Dawson Fellow in Real Estate and a clinical associate professor in the Department of Finance of the Mays Business School at Texas A&M University, where he taught real property valuation in the Master of Real Estate Program. **Contact: tomjackson@real-analytics.com**

Chris Yost-Bremm, PhD, is an assistant professor of finance at San Francisco State University and the chief econometrician at Real Property Analytics, Inc. He has a PhD in finance from the Mays Business School at Texas A&M University, and holds an MBA (with distinction) as well as undergraduate degrees in management and international economics (with honors) from California State University, Chico. His interests include econometrics and statistical modeling. **Contact: cyb@sfsu.edu**

Acknowledgment

The authors gratefully acknowledge that funding for this research was provided by the National Science Foundation, Lincoln Institute of Land Policy, and The Appraisers Research Foundation.

25. Jackson, "Environmental Risk Perceptions"; Thomas O. Jackson, "Groundwater Contamination and Real Estate Investment Risk," *Journal of Real Estate Practice and Education* 8, no. 1 (2005): 115–131.

Additional Resources

Suggested by the Y. T. and Louise Lee Lum Library

Appraisal Institute

- *Guide Note 6, Consideration of Hazardous Substances in the Appraisal Process*
  https://www.appraisalinstitute.org/assets/1/7/guide-note-6.pdf

- **Lum Library, External Resources [Login required]**
  - Information Files—Real estate damages/environmental hazards
  - Information Files—Real estate damages/proximity impact

- **Publications**
  - *Valuing Contaminated Properties: An Appraisal Institute Anthology*, vol. 1 and 2

Appraisal Standards Board

Advisory Opinion 9, "The Appraisal of Real Property That May Be Impacted by Environmental Contamination"

CCIM Institute, articles and monographs on commercial property environmental issues

https://www.ccim.com/search/?srchtext=environmental&gmSsoPc=1

US Environmental Protection Agency—Environmental Topics

https://www.epa.gov/environmental-topics