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Contents

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Preface

We are pleased to present the sixth volume of the *Journal of Sustainable Real Estate* (JOSRE). This issue is a combined effort with the Land Economics Foundation (LEF), with guest editors Frank A. Clayton and Daniel Winkler. Part 1 is focused on the impact of environmental influences on property value and Part 2 includes broader and more traditional topics for JOSRE. This issue and many other resources are available at www.josre.org

The LEF is a not-for-profit trust registered in the United States established by Lambda Alpha International (LAI) to provide financial assistance to research projects related to land economics. LAI is an international honorary society for the advancement of land economics established at Northwestern University in 1930. While LEF has been funding research endeavors in land economics for a number of years, this special issue marks the first time LEF has proactively sponsored research on the important topic of the environmental impact of real estate.

The idea to co-sponsor this research effort with the American Real Estate Society originated with Mike Anikeeff at the Carey Business School at Johns Hopkins University, who was a member of both LAI and ARES and a member of LEF's Research Committee at the time. I want to thank Daniel Winkler and Frank A. Clayton, the guest editors, and Myla Wilson, managing editor, for all of their help and insights in bringing this special issue to fruition.

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PART 1

Chemical Hazardous Sites and Residential Prices: Determinants of Impact

Author Perry Wisinger

Abstract The Emergency Planning and Community Right-to-Know Act (EPCRA) requires reporting of potential chemical hazardous sites to the Environmental Protection Agency (EPA). The EPA discloses some sites on the Internet while others are not. I investigate whether Internet disclosure makes a difference on the impact a hazardous site has on nearby housing prices. I also investigate the relevance of EPA-hazard classifications to understand the residential market reaction to nearby chemical hazardous sites. Data from Lubbock, Texas confirm that housing values near registered chemical hazards are lower, ceteris paribus; however, Internet-listed hazardous sites do not have a bigger impact on housing prices than do hazards not listed on the Internet. But more importantly, hazard classifications other than EPA classification better define house price behavior.

Neighborhood dangers lower residential values, but what hazards and by how much? Does Internet disclosure make a difference? Would hazardous site categorization differing from Environmental Protection Agency (EPA) definitions better explain the impact of chemical hazardous sites on house prices? I investigate public disclosure and labeling of chemical hazardous sites and the impact they have on nearby housing prices.

The United States Congress responded to the deadly Union Carbide pesticide plant accident in Bhopal, India (and other similar disasters) by enacting Title III of the Superfund Amendment Reauthorization Act of 1986, which is also known as the Emergency Planning and Community Right-to-Know Act (EPCRA). To protect Americans, EPCRA mandates every public or private facility in the U.S. that routinely has a ‘‘threshold quantity’’ of any of 600 acutely hazardous chemicals to file Emergency and Hazardous Chemical Inventory (Tier One and Tier Two) forms containing the name, amount, and location of such chemicals with federal, state, and local emergency planners and responders. As expected, EPCRA requires reporting by most industrial facilities and waste treatment plants. But most municipal swimming pools, retail cleaners, auto-repair shops, traditional printers, and even some gas stations have to report, too. Far too often slow leaks and industrial accidents occur that endanger entire neighborhoods.

Many factors, including gut feelings about neighborhood risk, figure into the final price a potential buyer is willing to pay for a home, and information for subjective risk assessments comes from several sources. Besides visual cues, risk characteristics about commercial neighbors are quickly gleaned from business names, and additional information can be obtained by checking the phone book or from a cursory Internet search. Cautious buyers can gather still more details from specific Internet sites dedicated to documenting hazards associated with various businesses. And for the very suspicious, there are other sources that are not equally available to everybody including insider information and local gossip. Real estate market efficiency is the measure of the universal availability and use of information affecting land values.

Air emissions facilities, water discharge facilities, hazardous waste handlers, and any facilities that previously reported a toxic release to the environment are all listed on the Internet, while information pertaining to Tier Two sites (sites that merely have substantial inventories of dangerous chemicals) must be requested by mail. Clearly, information available only by request is not as readily accessible as Internet information. While real estate professionals expect neighborhood risks to lower land values, does the readiness of public availability of such disclosure matter pricewise?

In this paper, I confirm the expected negative correlation between EPCRA sites and nearby housing prices in a portion of Lubbock, Texas, a city with over 225,000 residents; however, I extend economic investigation into previously uncharted areas of real estate market efficiency. I compare the differential land-value impact of Internet disclosure with non-Internet disclosure. I also investigate the price impact of commercial risk stereotypes and measure the impact of visual risk impressions. Real estate professionals, mortgage lenders, government policymakers, and other stakeholders should find the results of interest.

Literature Review

The Clean Air Act of 1970 requires listing sources of air pollution and estimating the amount each source discharges, and under the Clean Water Act of 1972, the EPA supervises direct discharges into rivers, streams, lakes, and other waterways. However, the roots of federal tracking of toxic chemicals begin with the Resource Conservation and Recovery Act of 1976, which provided for federal regulation of hazardous waste. Hazardous waste is legally defined as any by-product that potentially poses a substantial hazard to human health or the environment when improperly managed. This act makes generators, transporters, treaters, storers, and disposers report their activities to state environmental agencies, who relay this information to the EPA. To combat concerns over the health and environmental risks posed by past dumping of hazardous waste, congress added the Superfund Program in 1980 to locate, investigate, and cleanup these perilous dumpsites.

The EPA organizes environmental toxin release information into the Toxic Release Inventory (TRI) database, which stores data by facility, by year, by chemical, and by medium of release whether air, water, underground injection, land disposal, or offsite. The TRI sites listed on the website (http://www.epa.gov/enviro/) are those with a history of toxic chemical releases. Additional disclosures at this website pertain to nearby hazardous waste handlers, Superfund sites, and sites requiring either an air release permit or water discharge permit.

However, if there is no history of toxic release, stored toxic chemical inventory site information may not be readily available to the public. Instead, a specific request for Tier One or Tier Two information is required. While Tier One information may be vague, Tier Two reports contain the exact name, quantity, method of storage, and specific location of each toxic chemical (Abell, 1994). Generally, Tier Two reports are the state repository for both one-time emergency planning letters notifying the state that certain hazardous chemicals in specified amounts are stored at a facility and annual hazardous chemical inventory reports. The only public reporting requirement is that Local Emergency Planning Committees must merely publish annually in local newspapers a notice that Tier Two forms have been received (Skillern, 1995).

The negative impact of hazards on real estate values is well established in the literature as evidenced by the meta-analysis by Simons and Saginor (2006) of 75 peer-reviewed articles and case studies. Perhaps the first to investigate the impact of manmade hazards on land values was Ridker and Henning (1967), who discovered that ambient air pollution lowered property values. Numerous follow-up studies confirmed the negative impact air pollution has on land values including the meta-analysis by Smith and Huang (1993) of 37 previous studies. The negative impact of water pollution on land values was documented early by Epp and Al-Ani (1979), Rich and Moffitt (1982), Mendelsohn, et al. (1992), and more recently by Michael, Boyle, and Bouchard (2000). The suspected negative impact on real estate values caused by nearby waste disposal sites was confirmed by Smith and Desvousges (1986a, 1986b), Kohlhase (1991), Ketkar (1992), and Smolen, Moore, and Conway (1992a, 1992b). Thayer, Albers, and Rahmatian (1992) noted the distance from a designated hazardous waste site has more impact than the distance from a nonhazardous waste site does.

Market efficiency theory posits that markets incorporate all reasonably available information into prices (Fama, 1970). However, Wisinger (2006) found no immediate housing market response to EPA reporting either toxic leaks or protective regulation violations. Based on their findings of little impact on housing prices following toxic releases, Bui and Mayer (2003) questioned whether the public is capable of understanding the complex implications of chemical risk from TRI reporting. And while Decker, Nielsen, and Sindt (2005) did find that housing prices declined following TRI reporting, they too noted the public seemed unable to properly rate the degree of danger from current hazard reporting practices. Minguez, Montero, and Frenandez-Aviles (2013) suggested that housing prices respond to subjective public perception of pollution dangers rather than scientific risk assessments. In keeping with the above, Greenstone and Gallagher (2008) found that land values surrounding Superfund sites did not improve following site cleanup.

The Data

Totally within Lubbock County, Texas, and mostly within the city of Lubbock, the study area comprises four contiguous ZIP Code areas: 79404, 79405, 79411, and 79412. Together they cover about 31 square miles of Lubbock County. Exhibit 1 is a map of Lubbock, Texas, with the study area and Texas Tech University indicated. Together the four zones contain 38,044 people and 13,728 housing units according to the 2010 census. A minority-rich area, it is composed of 56.8% Hispanic and 15.8% black residents. This small area is selected for study because it has an adequate number of house sales within the study period, as well as an adequate number of chemical hazardous facilities.

Using the Lubbock MLS database, 254 house sales were identified during the 18-month period ended December 31, 2005 within the study area. Data on the sales price of each house, along with other characteristics are used for estimation of a hedonic model. The sale prices of the houses vary from $8,500 to $163,000, with a mean value of $61,950, a median of $55,000, a mode of $65,000, and a standard deviation of $32,076.

Data on chemical hazard sites were obtained from the EPA Envirofacts Data Warehouse Internet site and the Texas Tier Two Chemical Reporting Program. MapQuest (http://www.mapquest.com/), provides the longitude and latitude of the houses and business sites used in the study. A similar approach was followed by Hunter and Sutton (1995) to locate hazardous waste generators.

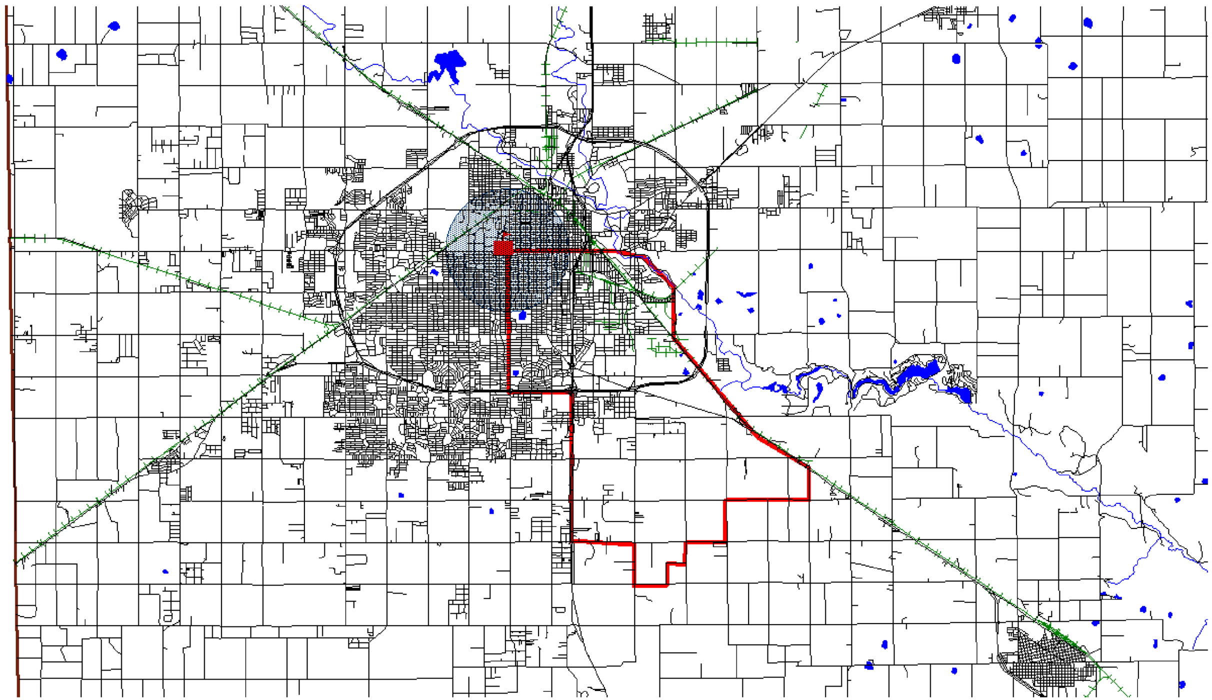
The initial focal independent variables are a) whether hazard information is available on the EPA website, b) whether the site is a Tier-Two storage site with no disclosure on the EPA website, or c) whether the site is both a TRI Internet-listed site and a Tier-Two site. Along with this category information, the inverse distance (proximity) of the site to each of the house sales is also used. All of these hazard sites within the study area plus those within one mile of the study area constitute the study zone. Hazard sites within a mile of the study area are included because they might strongly influence the sales price of homes within the study area.

Along with the 254 houses sold, there are 147 hazard sites with at least five houses within 2.5 miles of each site. The 2.5-mile distance is based on the results of Ihlanfeldt and Taylor (2004) and Smolen, Moore, and Conway (1992a, 1992b). The hazard sites consist of four air-release sites, three water-discharge sites, seven TRI sites, 95 hazardous-waste handlers, and 57 Tier Two sites. Some sites fit more than one hazard category. To ensure the residential market had time to adjust, all of the hazardous sites had been designated as such by government officials for at least two years prior to the beginning of the study period.

An additional focal variable is risk reputation. News sources consistently report explosions and other neighborhood dangers by industrial activity. To assess the impact of commercial category stereotyping on neighborhood risk assessment and home prices, each hazardous site is classified into one of 13 industry types based on information easily available.

Visual impression is important to forming emotional risk assessment. Paterson and Boyle (2002) stated that omitting important visibility attributes could lead to erroneous ideas about environment variables in a hedonic real estate model.

Exhibit 1 | Lubbock Study Area with 1½ Mile Circle around Texas Tech University



Accordingly, for this study, information pertaining to the appearance of a hazard site was gathered by visually inspecting each of the 147 chemical hazard sites. During the visual inspection of each site, the following focal-variable information was collected: a) percentage of neighborhood residential usage; b) geographic size of each site; and c) the presence of danger signs.

Methodology

This study began by questioning whether Internet disclosure of neighborhood chemical hazards had a major impact on housing prices; however, the overarching question investigated is the usefulness of various chemical hazardous site classifications to understanding and predicting real estate market behavior. The approach here is to model the impact of each site individually and then combine these different impacts in new ways testing the resulting patterns for usefulness. Traditionally hazards are grouped first and then measured and tested for significance. Here, hazards are first measured individually, then grouped and tested for significance. Statistical test results are considered significant at the 90% level.

The analysis is performed in two stages. In the first stage, a hedonic regression model is fitted with the dependent variable being the house price and the individual predictor variables being the structural attributes, location attributes, and the inverse distance from the house sold to each of the hazard sites. The estimated coefficient for the inverse-distance predictor represents the marginal impact of each individual hazard site on the price of surrounding houses. It should not be implied from the ‘‘impact’’ terminology that the hazard causes the full reduction in the house price observed. In some cases, hazards may be in their locations because of low neighborhood house prices and not the other way around.

In the second stage, the relationship between the marginal price impact of hazard sites and various hazard-information sets are investigated. Based on results from the first stage model, the three information sets investigated in the second stage are the price impact of: (1) whether the hazard is reported on the EPA website, the site is Tier Two and not listed on the EPA website, or the site is both Tier Two and reported on the EPA website; (2) the industrial classification for the commercial activities of the hazard site; and (3) visual inspection variables.

The hedonic price model, first introduced by Court (1939) and refined by Rosen (1974), is a very useful, flexible tool commonly used in econometric analysis. In this study, I use structural variables consistent with those suggested and validated by Sirmans, Macpherson, and Zietz (2005) for studies covering the southwest U.S. The structural variables selected for use are: size of house in square feet, age of house, number of fireplaces, presence of central air conditioning indicator, number of cars garage, and presence of brick exterior indicator.

For his neighborhood characteristics, Hwang (2003) selected the percentage of whites and household income and both were statistically significant at the 99% confidence level. To reduce the co-linearity between percentage of whites and household income, only one of these two variables is used in this study, that being the census-tract median value of the surrounding property.

While commonly included, an independent variable for the distance to a central business district requires the assumption of a monocentric city, and the literature indicates this is a safe assumption only for a large metropolitan area, which Lubbock, Texas is not. However, Wisinger (2006) concluded that proximity to Texas Tech University has a positive impact on housing values. The influence of Texas Tech University on housing prices is limited to 1.5 miles:

$$TTUAdj = (1.5 - (\text{Distance to TTU}))/1.5. \tag{1}$$

The study area along with the impact area of Texas Tech University is shown in Exhibit 1. Over 100 houses sold were near the university.

In stage one of the analyses, least square estimates for the parameters of the models:

$$P_h = \beta_{0,s} + \beta_{1,s} ID_{h,s} + \sum_{i=1}^{7} \theta_{i,s} S_{h,i} + \sum_{j=1}^{2} \lambda_{j,s} L_{h,j} + \varepsilon_{h,s} \tag{2}$$

are found for each hazard site, $s = 1$ to 147. In equation (2):

P_h = Selling price of house h, $h = 1, ..., 254$;
$ID_{h,s}$ = 1/(Distance of house, h, from hazard site s, $s = 1, ..., 147$);
$S_{h,i}$ = Structural variable i for house h;
$L_{h,j}$ = Location variable j for house h;
β, θ, λ = The resultant estimators; and
ε = The error term.

Regressions are calculated for each of the hazardous sites yielding 147 results. The main parameter estimates of interest are the 147 $\beta_{1,s}$. These estimate the hazardous sites marginal impact of each hazardous site on housing prices. Regression analysis does not show or prove causation. In particular, a large negative $\beta_{1,s}$ does not imply the site causes a decline in the house prices; it only indicates that houses near the site are associated with lower values. In particular, no distinction can be made between a business choosing its location because of low house values and house values being low because of the presence of the business. One or both conditions could be present. In Exhibit 2, I summarize the structural and location variables (including descriptive statistics) used in equation (2). Stage one of the analysis results in a $\hat{\beta}_{1,s}$, for each hazard site. Grouping these individual estimators allows examination by whatever categorical group the researcher desires. Here, the estimators are first grouped into Tier Two and non-Tier Two groups and t-tested for statistical difference between the group means

Exhibit 2 | Structural and Location Variables and Descriptive Statistics

	Mean	Median	Mode	Max.	Min.	Std. Dev.
Structural Variables						
Age of house	49.8	50	45	76	3	14.9
Size of house in square feet	1437	1276	1026	3369	560	539
Size of house squared						
Size of garage (number of cars)	1	1	1	3	0	0.76
Number of fireplaces	0.3	0	0	2	0	0.49
Central air indicator	0.64	1	1	1	0	0.48
Brick indicator	0.4	0	0	1	0	0.49
Location Variables						
Adjacent to Texas Tech Univ. distance adjustment	0.16	0	0	0.8	0	0.22
Census-tract median value of surrounding property	38266	39800	40100	76600	23700	6192

to determine whether the Internet disclosure group has a bigger impact than the non-Internet disclosure group.

In stage two, the investigation is confined to the relationship between the 147 $\hat{\beta}_{1,s}$, and the three additional information sets (Internet disclosure, commercial activity, and visual cues). Each of these information sets has a slightly different structure and requires a slightly different regression model to obtain the desired model fit.

There are three Internet disclosure categories to compare in the model investigating the Internet disclosure information sets. The model used to investigate this information set is:

$$\hat{\beta}_{1,s} = \sum_{i=1}^{3} \mu_i D_i, \quad (3)$$

where $i = 1$ represents Internet disclosure but not a Tier Two reporting, $i = 2$ represents Tier Two reporting, but no Internet disclosure, and $i = 3$ represents both Internet disclosure and Tier Two reporting. The D_i are indicator variables for each of these categories and μ are the three resultant estimators. An R-square for the model and t-tests for H_0: $\mu_i = 0$, $i = 1, 2, 3$ and for H_0: $\mu_i = \mu_j$ for $i, j = 1, 2, 3$, $i \neq j$ are performed to again compare sites with Internet disclosure against sites without Internet disclosure.

Next, because I question whether the EPA hazardous site classification scheme is optimal for generalizing about the impact of chemical hazardous sites on housing prices, an alternative grouping is tested. There is no literature guidance on alternative EPA site classifications for measuring the impact on housing, so for testing purposes the hazardous sites are divided into the following commercial 13 groups: agricultural, automotive/trucking dealers, automotive/trucking repair, city/government, cleaners, commercial bakery/food production, communications, convenience/gas and oil change, industrial, large wholesale/warehouse, printing, transportation, and other.

The commercial activity information set places each hazard site into one and only one of the 13 industry categories. The regression model:

$$\hat{\beta}_{1,s} = \sum_{i=1}^{13} \mu_i ID_i \tag{4}$$

is fit where ID_i is the distance indicator variable for the ith industry category and μ are the 13 resultant estimators. An R-square for the model and tests for H_0: $\mu_i = 0$, $i = 1, \ldots, 13$ are performed to t-test estimator means for statistical significance from zero.

Possibly there are other factors more relevant, such as visual stigma, to understanding the impact of EPA sites on housing prices. Again there is little guidance for visual variable specification. While preliminary investigation included more, I test the synergistic visual impact of three: the percentage of residential versus nonresidential land use, the size of the facility, and whether there is a danger sign present. In visiting the individual hazardous sites, it became apparent that the most verifiable division was between those sites located in areas where the land use was either more or less than 30% residential. Another variable is facility size. Facilities are arbitrarily divided into the following three sizes: less than 25% of a typical city block, 25% to one block, and facilities larger than one typical city block. The last variable investigated is whether a physical danger sign is posted. An example would be a sign posted on a surrounding fence warning people of hazards within the facility.

The model to investigate this information set is:

$$\hat{\beta}_{1,s} = \sum_{i=1}^{2} \sum_{j=1}^{3} \sum_{k=1}^{2} \mu_{ijk} VD_{ijk}, \tag{5}$$

with $i = 1$ indicating less than 30% residential and $i = 2$ indicating more than 30% residential. $j = 1$, 2 or 3 indicates less than 0.25 of a city block, between 0.25 and under 1 city block, and 1 block in size or more, respectively. $k = 1$ indicates no danger signs visible, while $k = 2$ indicates visible danger sign. An

R-square for the model and t-tests of the null hypotheses that the following marginal means are equal to zero are summarized:

$$\mu_{1..} = (\mu_{111} + \mu_{112} + \mu_{121} + \mu_{122} + \mu_{131} + \mu_{132})/6$$
$$\mu_{2..} = (\mu_{211} + \mu_{212} + \mu_{221} + \mu_{222} + \mu_{231} + \mu_{232})/6$$
$$\mu_{.1.} = (\mu_{111} + \mu_{211} + \mu_{112} + \mu_{212})/4$$
$$\mu_{.2.} = (\mu_{121} + \mu_{221} + \mu_{122} + \mu_{222})/4$$
$$\mu_{.3.} = (\mu_{131} + \mu_{231} + \mu_{132} + \mu_{232})/4$$
$$\mu_{..1} = (\mu_{111} + \mu_{121} + \mu_{131} + \mu_{211} + \mu_{221} + \mu_{231})/6$$
$$\mu_{..2} = (\mu_{112} + \mu_{122} + \mu_{132} + \mu_{212} + \mu_{222} + \mu_{232})/6. \quad (6)$$

For the investigations associated with models (3) and (4), the individual means are the quantities of interest since a site fits into one and only one of the categories. However, in model (5) the three visual dimensions represent 12 distinct combinations so it is the means for the levels of the individual dimensions that are t-tested for significance.

Results

During the first stage of the analysis, the hedonic model (2) is fitted for each of the 147 hazard sites. The goal of this stage is to obtain stable estimates of hazardous site impact on the house prices. To increase the stability of the estimates, houses sales are removed from the analysis if they can be verified to have unusual characteristics. All houses with residuals greater than \$35,000 are identified and nine house sales removed because of either disproportionate lot size or suspicious sales data. This represented 3.5% of the original house sales in the sample. The estimated regression coefficients, R-squares, and Moran's I values for model (2) for all 147 hazard sites are summarized in Exhibit 3. The models can be used to explain a large percentage of the variability in house prices, with an average R-square of 83.7%. All of the hedonic model coefficients have stable signs from site to site. According to Anselin (1992), Moran's I is the most common test for spatial autocorrelation errors. No serial correlation problem is detected with an average Moran's I of 0.0388. The estimated $\beta_{1,s}$ coefficients of model (2), representing the impact of a hazardous site on the house price, show considerable variation from site to site. The mean estimated $\beta_{1,s}$ is −62.6, but the values range from −603.7 to 1035.4.

In Exhibit 4, I summarize descriptive statistics for the $\beta_{1,s}$ coefficients for the sites in the six different EPA classifications, as well as how many are positive and significant, not significant at 90% level, and those negative and significant in the hedonic model (2). All categories have a negative average coefficient. The Tier

Exhibit 3 | Summary of the Regression Coefficients, R-squares, and Moran's I for the Hedonic Models (2)

	Coefficient Estimate		*P*-value	
Variable	Mean (Std. Dev.)	Min. (Max.)	Mean (Std. Dev.)	Min. (Max.)
Intercept	\$13,434.3 (5,529.6)	−5,870.3 (31,416.5)	0.2625 (0.1660)	0.0114 (0.9971)
Age of house (years)	−\$263.6 (37.0)	−333.9 (−176.6)	0.0048 (0.0091)	0.0000 (0.0520)
Size of house (sq. ft.)	\$11.4 (1.51)	8.2 (14.1)	0.2433 (0.0658)	0.1418 (0.3996)
Size of house^2	\$0.0074 (0.0005)	0.0062 (0.0084)	0.0111 (0.0052)	0.0038 (0.0299)
Garage size (# of cars)	\$4,046.5 (158.4)	3,688.7 (4,367.5)	0.0029 (0.0011)	0.0014 (0.0060)
Fireplace indicator	\$5,900.2 (150.9)	5,540.9 (6,255.7)	0.0108 (0.0019)	0.0067 (0.0160)
Central air indicator	\$11,227.0 (128.4)	10,973.1 (11,684.8)	0.0000 (0.0000)	0.0000 (0.0000)
Brick indicator	\$2,471.3 (237.0)	1,914.7 (3,429.2)	0.2397 (0.0430)	0.1089 (0.3580)
Adjacent to Texas Tech University	\$17,833.5 (4,388.7)	6,644.4 (27,146.0)	0.0065 (0.0295)	0.0000 (0.3474)
Census-tract median value of surrounding property	0.3284 (0.0844)	0.0542 (0.4889)	0.1213 (0.1448)	0.0078 (0.8025)
Inverse distance of house to hazard site	−\$62.6 (175.1)	−603.7 (1,035.4)	0.2656 (0.2604)	0.0020 (0.9874)
R^2	83.66 (0.0014)	83.49 (84.14)		
Moran's I	0.0388 (0.0030)	0.0067 (0.0408)		

Two sites have an average coefficient 30 points larger in magnitude than sites that are not Tier Two sites: −89.79 versus −59.72. A two-sample *t*-test comparing the mean coefficient for these two groups of sites results in a −1.40 calculated test statistic, with a *P*-value of 0.164. This finding does not support the hypothesis that hazard sites whose information is on the Internet will have a larger negative impact on house prices than those sites whose information is not on the Internet. The categories summarized in Exhibit 4 are not disjoint.

In Exhibit 5, I summarize the mean estimated coefficient for the three disjoint categories based on model (3). According to the R-square, the different site classifications represented by government sources explains only 3.06% of the

Exhibit 4 | Summary Statistics for the Estimated $\beta_{1,s}$ Coefficients

Category	*N*	Mean (Std. Dev.)	Min. (Max.)	Significance* of $\beta_{1,s}$ Negative, Not, Positive
Tier Two site	57	−89.79 (107.00)	−329.51 (259.19)	25, 29, 3
Not Tier Two site	90	−59.72 (153.01)	−603.66 (464.87)	31, 51, 8
Hazardous waste handlers	101	−67.41 (151.02)	−603.66 (464.87)	37, 56, 8
TRI sites	7	−104.49 (86.69)	−258.04 (−25.23)	2, 5, 0
Air emissions facilities	4	−146.07 (108.71)	−258.04 (−48.65)	2, 2, 0
Water discharge facilities	2	−106.08 (55.24)	−145.15 (−67.02)	0, 2, 0
Overall	147	−70.46 (155.80)	−620.49 (530.88)	56, 80, 11

Note: Coefficients represent the marginal impact of a site on the surrounding house values for the different EPA Internet hazard classification and for the Tier Two hazard sites.
*Significance is based on a 90% test.

Exhibit 5 | Summary Statistics for the Mean Estimated Coefficients for Discrete and Overlapping Categories Based on Model (3)

Internet Information Categories	*N*	Average (Std. Dev.) Impact to Surrounding House Prices	T^a (*P*-value)*	Significance* of $\beta_{1,s}$ Negative, Not, Positive
Level 1: Site listed on EPA website; not Tier Two site	90	−59.72 (153.01)	−4.16 (<0.0001)	31, 51, 8
Level 2: Site not listed on EPA website; Tier Two site	36	−66.55 (100.58)	−2.93 (0.0039)	16, 17, 3
Level 3: Site listed on EPA website; Tier Two site	21	−129.61 (108.25)	−4.36 (0.0000)	9, 12, 0

Notes: R^2 = 3.06%; no significant difference between any of the mean coefficients.
[a] Based on test of null hypotheses that mean equals zero based on equation (3).
*Significance is based on a 90% test.

variation in the marginal impact on house prices. The estimated impact of the sites that are listed on the EPA website, but are not Tier Two sites, have an average coefficient of −59.72 compared to an average coefficient of −66.55 for Tier Two sites that are not listed on the EPA website. While there is not a significant difference between these two means, the direction of the evidence is in the opposite direction of what would support the hypothesis that sites with information on the Internet have a larger negative price impact. But sites that are both listed on the EPA website and are Tier Two sites seemingly have the greatest impact, with an average coefficient of −129.61.

The results summarized in Exhibits 3 and 4 show that many sites have a negative impact on the nearby house prices that is not explained by EPA classification. In an attempt to better generalize about the impact of hazard sites on house prices, two other information sets are investigated. First, the businesses associated with the hazard sites are classified into one of 13 categories. Information used in this classification is obtained from the name of the business. If the name is not adequate to classify the business, the Internet is searched for the business name and/or address. In Exhibit 6, I summarize the average coefficient and tests based on fitting regression model (4). The business category information set explains 20.17% of the estimated site impact. Nine of the categories (Printing, Commercial Bakery/Food Producers, Agricultural, Automotive/Trucking Repair, Transportation, Industrial, Large Wholesale/Warehouse, Communications, and Other) have average coefficients significantly less than zero using a 90% test. These categories contain only 69% of the total sites, but 84% of the sites with a significantly negative coefficient. Two of the categories (Cleaners and Automotive/Trucking Dealers) have an average coefficient greater than zero and contained 55% of the sites with significantly positive coefficients. The remaining two categories (Convenience/gas or oil change and City/Government) have negative average coefficients not significantly different from zero. This business classification information set explains 6.6 times the variation in hazard site impact on nearby housing prices than do the Internet disclosure categories.

The second information set is based on a visual inspection of the hazard sites. The sites are classified based on whether the neighborhood surrounding the site was less than 30% residential versus more than 30% residential; whether the site occupied less than or equal to 25% of a city block, occupied more than 25% but less than one city block, or occupied at least one city block; and whether danger signs where present or not.[1] In Exhibit 7, I summarize the average coefficient and tests based on fitting regression model (5). The three factors of this information set explain 29.46% of the variation in the coefficient estimates, which is 9.6 times the Internet disclosure categorization. When the neighborhood surrounding the site was <30% residential, the average coefficient estimate of −124.8 is significantly different from zero. Fifty-three percent of the sites in this category have negative coefficients. When the neighborhood surrounding the site was >30% residential, the average coefficient estimate of 10.62 is not significantly different from zero. One hundred percent of the sites with a positive and significant coefficient are in this category. The average coefficients for site sizes "≤0.25 city block," ">0.25 but <1 city block," and "at least 1 city block" are −44.15, −95.84 and −81.59,

Exhibit 6 | Summary Statistics for the Estimated $\beta_{1,s}$ Coefficients

Business Type	N	Mean (Std. Dev.)	Min. (Max.)	T^a (P-Value)	Significance* of $\beta_{1,s}$ Negative, Not, Positive
Agricultural	8	−143.3 (100.3)	−258 (18.3)	−3.16 (0.0019)	5, 3, 0
Automotive / Trucking Dealers	11	24 (147.9)	−70.8 (448.5)	0.62 (0.5349)	0, 9, 2
Automotive / Trucking Repair	18	−94 (167.7)	−603.7 (309.3)	−3.11 (0.0023)	5, 12, 1
City / Government	12	−52.4 (100.9)	−278.1 (90.3)	−1.42 (0.1593)	5, 7, 0
Cleaners	12	68.8 (195.4)	−132.3 (464.9)	1.86 (0.0651)	2, 6, 4
Commercial Bakery / Food Production	11	−120.5 (113)	−329.5 (−25.2)	−3.12 (0.0022)	5, 6, 0
Communications	6	−96.6 (133.2)	−184.4 (148.8)	−1.85 (0.0672)	5, 0, 1
Convenience / Gas and Oil Change	11	−25.2 (128.5)	−217.2 (259.2)	−0.65 (0.5158)	2, 8, 1
Industrial	19	−72.5 (105.1)	−352.5 (40.7)	−2.47 (0.0149)	4, 14, 1
Large Wholesale / Warehouse	10	−108.9 (77.3)	−219.7 (−7.8)	−2.69 (0.0081)	6, 4, 0
Printing	11	−156 (72.5)	−274.4 (−37.1)	−4.04 (0.0000)	8, 3, 0
Transportation	8	−76.7 (138.3)	−205.4 (204.5)	−1.69 (0.0929)	4, 3, 1
Other	10	−114 (94.7)	−290.5 (−0.3)	−2.81 (0.0057)	5, 5, 0

Notes: The coefficients represent the marginal impact of a site on the surrounding house values. The business type categories were determined from the business name and / or an Internet search based on the business name and / or the business address.
[a] T, P-value, and R^2 are from model (4). The tests summarized are for the null hypothesis that the mean coefficient is equal to zero. $R^2 = 20.17\%$.
**Based on a 90% test of null hypothesis $\beta_{1,s} = 0$ based on hedonic model (2).

respectively. The main pattern is seen going from the smallest size to the next smallest, where the average coefficient estimate decreases by 52 units. The sites with danger signs have negative mean coefficients approximately 28 units larger then sites with no danger signs (−67.00 for sites with no signs and −94.82 for sites with danger signs).

Both the business category and the visual information sets are found to explain a significant percentage of the variation in the sites estimated impact on the sale

Exhibit 7 | Summary Statistics for the Estimated $\beta_{1,s}$ Coefficients

	N	Mean (Std. Dev.)	Min. (Max.)	T^a (P-value)	Significance* of $\beta_{1,s}$ Negative, Not, Positive
Residential					
<30%	89	−124.81 (86.9)	−352.5 (18.3)	−7.1 (<0.0000)	47, 42, 0
>30%	58	10.62 (159.3)	−603.7 (464.9)	−0.5 (0.6200)	9, 38, 11
Size					
≤0.25 block	58	−44.15 (158.4)	−603.7 (464.9)	−2.2 (0.0285)	16, 36, 6
>0.25 and <1 block	47	−95.84 (96.1)	−352.5 (100.3)	−3.25 (0.0014)	19, 26, 2
1 block or more	42	−81.59 (141.9)	−329.6 (448.5)	−2.98 (0.0034)	21, 18, 3
Danger Signs					
Not present	125	−67.00 (132.0)	−352.5 (464.9)	−4.4 (<0.0000)	34, 83, 8
Present	22	−94.82 (166.3)	−603.7 (259.2)	−3.5 (0.0007)	9, 11, 2

Notes: Coefficients represent the marginal impact of a site on the surrounding house values. The values for Residential, Size, and Danger sign was determined for each site by visually assessing the information with a drive by of the site.

[a] T, P-value, and R^2 are from model (5). The tests summarized are for the null hypothesis that the corresponding mean defined in equation (6) is equal to zero. $R^2 = 29.46\%$.

*Based on a 90% test of null hypothesis $\beta_{1,s} = 0$ based on hedonic model (2).

price of nearby houses. The units of the $\beta_{1,s}$ estimates are the change in price of the house for a unit change in the inverse distance of the house to the site. The distance is in the units defined by the Euclidean distance between house the site based on the longitude and latitude of the house and site. One mile is approximately 0.0144927 of one of these distance units. Additionally the inverse difference has a nonlinear relationship to the distance. In Exhibit 8, I summarize the estimated impact coefficients converted to dollars per specific changes in the distance in terms of miles. The average amount of decrease in house price (in dollars) for distance changes of 0.25 mile to 0.5 mile, 0.5 mile to 1 mile, and from 1 mile to 2 miles are summarized for the different business categories and for the three factors of the visual information set. The larger impact categories (Printing, Agriculture, Large Wholesale/Retail, and <30 residential) result in around a $5,000 decrease as you approach the chemical hazardous site from 2 miles away to 1 mile, around a $10,000 decrease in price going from 1 mile to 0.5 mile, and around a $20,000 decrease in price going from 0.5 mile to 0.25 mile.

Exhibit 8 | Average Decrease in House Price by Distance and Characteristic

Category	Mean Coeff.	0.25 Mile–0.5 Mile	0.5 Mile–1 Mile	1 Mile–2 Miles
Agricultural	−143.3	$19,776.16	$9,887.91	$5,142.66
Automotive / Trucking Dealers	24	−$3,312.13	−$1,656.03	−$861.30
Automotive / Trucking Repair	−94	$12,972.49	$6,486.14	$3,373.42
City / Government	−52.4	$7,231.47	$3,615.67	$1,880.51
Cleaners	68.8	−$9,494.77	−$4,747.30	−$2,469.05
Commercial Bakery / Food Production	−120.5	$16,629.63	$8,314.68	$4,324.43
Communications	−96.6	$13,331.31	$6,665.53	$3,466.72
Convenience / Gas and Oil Change	−25.2	$3,477.73	$1,738.84	$904.36
Industrial	−72.5	$10,005.38	$5,002.60	$2,601.84
Large Wholesale / Warehouse	−108.9	$15,028.78	$7,514.26	$3,908.14
Printing	−156	$21,528.82	$10,764.22	$5,598.44
Transportation	−76.7	$10,585.00	$5,292.41	$2,752.56
Other	−114	$15,732.60	$7,866.17	$4,091.17
<30% residential	−124.8	$17,224.43	$8,612.07	$4,479.11
>30% residential	10.6	−$1,465.61	−$732.79	−$381.12
≤0.25 block	−44.2	$6,092.93	$3,046.41	$1,584.44
>0.25 and <1 block	−95.8	$13,226.43	$6,613.10	$3,439.45
1 block or more	−81.6	$11,259.85	$5,629.83	$2,928.05
Danger signs not present	−67	$9,246.36	$4,623.10	$2,404.46
Danger signs present	−94.8	$13,085.66	$6,542.72	$3,402.85

As shown in Exhibit 4, I find that only 41 out of the 114 individual Internet-reported hazard sites studied correlate with reduced house sales prices. Perhaps more importantly, only 56 of the 147 EPA-designated sites actually have a negative impact with no individual site within any of the EPA categories more likely than not to produce a significant impact. Clearly, a better classification scheme is needed to generalize about the negative impact of chemical hazardous sites on housing prices.

Congress enacted EPCRA to reduce community health risk posed by potentially hazardous commercial activities. But are EPCRA Internet disclosures responsible for lowering housing values near hazardous commercial activities? To increase the understanding of the economic impact this legislation has on the housing market, this study started with two questions. First, does the presence of an EPA-designated environmental hazard listed on the Internet correlate with lower nearby property values? The results of statistical analysis shown in Exhibit 4 indicate that housing values near EPA-Internet-listed hazards are lower, ceteris paribus. Second, do hazardous sites listed on the Internet have a bigger adverse impact on housing values than do hazardous sites not listed on the Internet? The results of this study indicate that EPA-Internet-listed hazards do not have a bigger impact than do non-listed hazards—even after two years of Internet disclosure. If anything, Tier Two sites seem to have a bigger impact than Internet-listed hazardous sites. In other words, the passage of EPCRA and Internet reporting does not appear to impact community housing value patterns, at least not in the short-run.

There are five possible ways to reconcile market efficiency theory with the statistical analysis of this study: (1) the housing market does not care about hazards; (2) the housing market is extremely slow to react to information; (3) because of market restrictions, housing prices are unable to react; (4) the housing market uses information sources other than the EPA to capture and factor hazard data into prices; or (5) the housing market is either unaware of or incapable of understanding the Internet disclosures. The literature indicates the first possibility is unlikely and a two-year delay in price reaction would not be consistent with an efficient market. So the only remaining explanations are either the market is unable to react, possibility due to lack of housing options, the market uses different knowledge for pricing homes, or that Internet disclosures are not fully integrated into housing markets.

The broader research question developed during this study is whether EPA classifications are optimal for understanding and predicting residential market behavior. The clear answer is that other groupings yield more insight.

Conclusion

The findings indicate the housing market does not seem efficient because EPA Internet disclosures do not appear to translate into residential price adjustments (i.e., Internet disclosure of apparent neighborhood danger does not seem to significantly influence residential consumer behavior). However, this finding does not dispute that homes near hazard sites have lower values. On the contrary, the results of statistical analysis shown in Exhibit 8 demonstrate rather startling impacts in terms of dollars so the public must be relying on other information sources for drawing conclusions about hazardous sites. As shown in Exhibit 6, printers, commercial food producers, agricultural organizations, vehicle repair centers, industrial sites, and large wholesalers and warehouses are clearly a locally undesirable land use. On the other hand, dry cleaners seemingly enhance a community. The statistical significance of whether the neighborhood is less than 30% residential, the size of the site, and the importance of danger signs all provides important evidence the public responds to visual cues in forming opinions about locally undesirable land uses. And although the Envirofacts website does not appear to be a major source of this information, these and previous research results reveal the public has strong aversion to living near environmental hazards. Suspected public information sources included newspapers, TV, radio, neighborhood gossip, employee inside information, and gut hunches formed after viewing or sometimes even smelling a suspect site and its surroundings. Thus, chemical hazardous sites should be grouped differently than EPA classifications for real estate investigations of house price impacts. The continuing challenge is to determine what the individual sites of major impact have in common.

Endnote

[1] Other visual measurements included whether the site was gated, whether there was a security fence, and whether the site was clearly dilapidated. None of these are significantly related to the impact of the hazard on surrounding housing prices.

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Value Capitalization Effect of Protected Properties: A Comparison of Conservation Easement with Mixed-Bag Open Spaces

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Abstract In this paper, I examine the impact of open space restrictions on neighboring house prices using hedonic modeling framework and GIS. The comparison is between two groups of parcels in Worcester, Massachusetts: one has a mixture of open space restrictions that limit or prohibit development and the other has a conservation easement. Conservation easement (CE) involves voluntarily restricted conservation worthy private lands from future developments in perpetuity. The sample used is single-family detached houses that were sold in 2005 to 2008. Since future development restrictions lower the property values and tax base for local communities, the findings confirm that spatially targeted CE parcels with proximity of, and visibility to CE parcels drive up the surrounding property values, thereby providing additional tax base and income to the communities.

Conservation easement (CE) is a voluntary land protection tool that has been in existence since the 1800s in United States. It is used in preserving conservation worthy private lands that otherwise have potential to change due to surmounting urban growth pressure (Whyte, 1959; Brenneman and Bates, 1984). Typically, CE entails a legal agreement between a landowner and a qualified non-profit or government organization that permanently limits future development of the land in subject. The participating private landowners either can donate, or sell their property development rights and can then claim federal tax credits (Wright, 1994; Gustanski and Squires, 2000). Barring the future development rights, the landowners continue to retain title of the property and right to enter, farm, lease, mortgage, bequeath or even sell (Whyte, 1959; Merenlendar, Huntsinger, Guthey, and Fairfax, 2004; Daniels and Lapping, 2005). CE can be tailored to the needs of each property owner, but usually limit any form of subdivisions, non-farm-based development, and other uses that hinder the conservation objective. Further, the easement agreement could be applied either to the total parcel or its partial acreage and is aimed to protect the environmental amenity. The restrictions are self-imposed and are consistent with the conservation objectives (Boyd, Caballero, and Simpson, 1999; Gustanski and Squires, 2000). A CE protects preservation-worthy lands by encouraging landowners to act in ways that further their own self-interest and the public good. Several parks, trails, waterways, and wildlife areas in the past have been protected using CE.

CE not only the most commonly used, but also the fastest growing private land protection tool in the U.S. Over 10 million acres of land has been conserved just during 2005 and 2010; over 47 million acres of land has been conserved via local, state, and national land trusts (Land Trust Alliance, 2012), which in terms of land area compares to approximately five times the size of Massachusetts and is even larger than the total land area of Ohio. Of this, 8.83 million acres is privately owned and preserved under CE agreements. The recent gain in the popularity of CE as a land-protection tool is due to its cost effectiveness owing to "shared" ownership in land where landowners and conservation agencies both share partial rights in the land. CE is less expensive to conservation agencies as compared to the fee-simple with full property rights, as no upfront acquisition costs are involved.[1] This form of private land protection involves serious public tax dollars.

Billions of dollars' worth of public money is involved in land conservation efforts; as tax abatements and in acquisition of new lands. In terms of tax abatements, over $10.21 billion in tax deductions were claimed from 2003 to 2008. In 2008 alone, CE landowners claimed about $1.21 billion in tax deductions while in 2007 it was $2.1 billion (Colinvaux, 2012). The environmental concerns and tax savings from CEs seem to be the dominant driving forces behind the importance and growth of CEs, encouraging landowners to act in ways that further their own self-interest, as well as the public good. Brenner, Lavallato, Cherry, and Hileman (2013) surveyed 513 private landowners in Finger Lakes Region of New York and found that owners' personal characteristics such as gender, education, being part of environmental organizations, and how actively are they engaged with their land and its usage are a few important attributes in predicting owners' interest in CE. Further, subsistent, passive, and recreational land use activities, if they exist on the subject land, all play important roles in predicting the potential interest from the landowners' perspective in CE.

Study Motivation and its Location Context

This form of private land protection involves serious public tax dollars. A few local communities believe that CEs lower property taxes, diminishing local revenues.[2] With billions of public dollars involved in protecting private land in terms of tax abatement and other costs, it is important to understand whether there is a measurable economic benefit to the community in terms of enhancement in the surrounding property values. Additionally, is this benefit similar to the benefit that different types of open spaces externalize or, would CE parcels externalize benefits differently to its surroundings? The City of Worcester was chosen to quantify the measurable benefits from CEs.

City of Worcester is the second largest city in Massachusetts and is 60 miles southwest of Boston. It has a population of 181,045 and median family income of $79,700 (Census, 2010). The city is situated near the headwaters of the Blackstone River that forms the John H. Chafee Blackstone River Valley National

Heritage (BRVNH) Corridor. This is one of the 49 National Heritage Areas designated by the U.S. Congress for their unique qualities and resources (National Heritage Area, 2013). This BRVNH corridor includes 22 communities and is a repository of historically, environmentally, and ecologically important sites located throughout its watershed from Worcester, MA to Providence, RI (Billington, 2004). Worcester is the largest city in this corridor and has 26 clusters of CE land parcels that are privately owned and voluntarily conserved. These CE land parcels are either in joint-ownership with private landowners, the city, and its conservation commission, or with the private non-profit land trusts such as the Greater Worcester Land Trust (GWLT) and the Massachusetts Audubon Land Trust. The 26 CE parcels range from approximately one acre to over 400 acres in size. Several parcels are scenic in nature, preserving environmental amenities such as farms, urban gardens, historic sites, rivers, streams, waterfalls, flora, and fauna. In this paper, I examine the perceptions of the house buyers and sellers in the City of Worcester regarding privately protected CE parcels.

Literature Review on Environmental Studies

Researchers have studied the relationships between various environmental amenities such as farmlands (Geoghegan, 2002; Geoghegan, Lynch, and Bucholtz, 2003), forests (Ham, Loomis, and Reich, 2012), public parks and open spaces (Crompton, 2001, 2007, 2008; National Association of Realtors, 2001; Troy and Grove, 2008), waterfronts (Lansford and Jones, 1995; Benson, Hansen, Schwartz, and Smersh, 1998; Mahan, Polasky, and Adams, 2000; Shultz and Schmitz, 2008; Conroy and Milosch, 2011; Walsh, Milon, and Scrogin, 2011) and other environmental amenities (Simons, 1999; Boyle and Kiel, 2001; Bourassa, Hoesli, and Sun, 2004; McConnell and Walls, 2005; Simons and Saginor, 2006). A few researchers have discussed the impact of various amenities on house prices; however, there are very few who have measured the impact of conserved land.

Value Capitalization Effect of Proximity

Boyle and Kiel (2001) reviewed 35 hedonic studies in relationship with pollution point sources and their effect on the home values. Most studies in this review focused on various forms of proximity measures (distance) from the pollution source. A few also focused on visibility analyses (e.g., visibility through the high suspended particulate matter (SPM), content in the air quality studies, and visibility of waste dumping sites or undesirable land uses. All studies reported that the polluting sources generate negative externality and as the proximity of homes to the polluting sites increases, home value decreases.

McConnell and Walls (2005) reviewed 60 published studies, where 40 studies just focused on the effect of general open space, parks, natural areas, green buffers, greenbelts, wildlife habitats, wetlands, forest preserves, farmlands, and golf courses on home values using hedonic framework. A generic finding was that proximity to golf courses and lakes had a significant positive effect on house prices. In general, proximity to a large natural area or wildlife habitat contributed to a 0.07%–4% increase in house prices.

The proximity variable came out as an important variable in most studies, with a general consensus that proximity of parks and open spaces increase house prices. Crompton (2001) reviewed 30 impact studies of parks and opens spaces where 25 studies reported a positive impact on surrounding property prices. The impact varied considerably with park attributes, such as the size and typology of the park, but park proximity contributed a 10%–20% increase in the nearby property prices. This effect of proximity extended to at least 500 feet in some cases, while in other cases as far as 2,000 feet into the surrounding neighborhoods. Geogheghan (2002) used a measure of 1,600 meters (5,250 feet) or a 20-minute walking distance from open spaces, while Acharya and Bennett (2001) used a 0.25 mile (2,640 feet) visual zone and a one mile (5,280 feet) increment for walking distance.

The proximity of undesirable activities adversely impact property prices (Simons, 1999; Simons and Saginor, 2006). Palmquist, Roka, and Vukina (1997) studied the effect of large-scale hog operations on surrounding property prices and developed an index of hog manure production at different distances from the houses. They concluded that proximity caused statistically significant reductions in house prices of up to 9%, depending on the number of hogs and their distance from the house.

Parks increase property prices; however, undesirable and unsafe activities such as crime, heavy traffic, and loud activities reduce it. Troy and Grove (2008) studied the relationship between property prices, parks, and crime in Baltimore, MD. They concluded that crime is a critical factor in how residents perceive parks. When crime rates are relatively low, parks have a positive impact on property prices; however, for each unit increase in the crime score estimated for a given park, there is a 0.017% decrease in the values of the homes associated with that park.

Proximity to incompatible land uses reduces property prices. Song and Knaap (2004) measured the effect of six different mixed-land uses on the prices of single-family houses in Portland, OR. They used four key explanatory variables to define the characteristics of mixed-land uses: (1) distance to land uses from each transit area zones (TAZ); (2) proportional areas of each non-residential land uses within a neighborhood; (3) diversity index; and (4) measure of job to population ratio. The control variables included structural, public sector, metro level accessibility characteristics, amenity characteristics, neighborhood socio-economic characteristics, and urban design characteristics. They concluded that prices tend to fall near multi-family houses and rise in neighborhoods dominated by single-family houses, and where non-residential land uses are evenly distributed and more service jobs are available.

Proximity of well-planned neighborhoods with amenities, availability of high-quality infrastructure services, and direct access to the amenities and infrastructure to the nearby land owners increases their property value. This land value capture effect is used extensively to finance large-scale public infrastructure projects (Mittal, 2013, 2014).

Value Capitalization Effect Varies with Environmental Amenity

The ability to place an economic price on ecosystem services is central to formulating sound environmental policy (Krupnick and Siikamäki, 2007), which is true in the case of CEs as well. Researchers have used contingent valuation (a stated preference) and hedonic valuation (a revealed preference) for valuing the contribution of environmental goods (Boyle and Kiel, 2001; Hidano, 2002; Malpezzi, 2002; McConnell and Walls, 2005; Sirmans, Macpherson, and Zietz, 2005; Boyd, 2008). The hedonic studies of various environmental amenities vary in terms of how they incorporate the amenity. For example, for open space variable, Acharya and Bennett (2001) used a single open space variable to represent all the lands with no developments. Others (Bolitzer and Netusil, 2000; Lutzenhiser and Netusil, 2001; Anderson and West, 2006) differentiated between different types such as parks, golf courses, cemeteries, and other open spaces. In most cases, researchers who made this distinction found that houses in close proximity to parks have higher property prices, all other factors held constant. Asabere and Huffman (1996), Do and Grudnitski (1997, 1995), Netusil (2005), and Bark, Osgood, Colby, and Halper (2011) estimated that the effect of golf courses on adjacent house prices range from 4.8% to 8%; however, this impact quickly diminishes as the distance from the golf course increases. Authors of an earlier impact study of four parks in Worcester, MA concluded that a house located 20 feet from a park sold for $2,675 more (1982 price) than a similar house 2,000 feet away [Stevens, More, and Allen (1982) as quoted in NPS (1995)] keeping other factors constant. Standiford and Scott (2001) used regression modeling of land price and found that property prices significantly increase around open spaces. The prices of houses adjacent to a less-developed open space increase by 23%–32%, as compared to a house a block away. Similarly, Correll, Lillydahl, and Singell (1978) and Nelson, Duncan, Mullen, and Bishop (1995) found that average price per acre increases by $1,200 if the home property is within 1,000 feet of open space. In another study of land parcels in Colorado, Loomis, Rameker, and Seidl (2004) found that a property parcel with access to water body commands a $937 higher price per acre than average, while if a similar parcel is adjacent to a park or open space, the price increases by as much as $11,039 an acre. So in theory, proximity to open space and greater accessibility to recreation opportunity and scenic view enhances property prices; however, the effects vary with the nature of the environmental amenity.

Permanent protection increases property prices while intense activities reduce prices. Le Goffe (2000) used the hedonic price method to identify and monitor the external effects of agricultural and sylvi-culture activities. The author examined the rental prices of rural self-catering cottages. Intense livestock farming caused the rental prices to decrease whereas permanent grassland had the opposite effect. In general, perpetually preserved land increases desirability; and so, the price of the surrounding property increases as amenity seekers are willing to pay a premium for the perpetual presence of open space (Brewer 2003; Thompson, 2004; Mitchell and Johnson, 2005).

Value Capitalization Effect of Views

Proximity is important but view of a desirable land use is important too. Researchers have repeatedly used view as an important variable in impact measurement. Appleton (1975) explained the appeal of views by proposing that ‘‘humans are biologically programmed to prefer vantage points where it is possible to see a good deal without necessarily being seen.’’ Homes that command scenic views have a premium price (Wolverton, 1997; Benson, Hansen, Schwartz, and Smersh, 1998; Lake, Lovett, Bateman, and Langford, 1998; Lake, Lovett, Bateman, and Day, 2000; Sirmans, Macpherson, and Zietz, 2005; Shultz and Schmitz, 2008). The proximity measure of distance from a water body is an important variable but view is even more important. For example, a one mile increase from the coast reduced the house price by $8,680 (Conroy and Milosch, 2011). Lansford and Jones (1995) estimated the marginal price of water in lake recreational and aesthetic use. A hedonic price equation indicated that lakefront location, distance to lake, and scenic views are significant in house price. Waterfront properties command a premium price for the private access they offer. Beyond the waterfront, the marginal price falls rapidly with increasing distance, becoming asymptotic to minimum. In their sample, 22% of housing prices were found to be attributable to the recreational and aesthetics that lakefronts offer.

Bourassa, Hoesli, and Sun (2004)[3] reviewed 30 studies that focus on scenic views and their effect on home values. Several types of view amenities were studied, such as water views, lake and ocean views, mountain or valley views, agriculture and farmlands, forests views, and open spaces with landscapes. Thirteen studies used distance to lake; 28 studies used a binary yes/no dummy view variable or a 1-to-5-scaled dummy view-quality variable; one study used degree of panorama; three studies used GIS or viewshed-based view scores; and three studies used land use diversity as a proxy for the view. It was concluded that the view premium was highest for the wide views of water such as lake views, with a very high premium of 89% for the lakefront abutting homes, while ocean view front homes commanded a 129% premium. The wooded areas, landscaped areas, and forest views had a relatively lower premium of 3%–8%, on average. The positive impact of view was also found to diminish with distance.

Uninterrupted quality of views increases property price. Benson, Hansen, Schwartz, and Smersh (1998) studied the estimated price of the view amenity in single family residential real estate markets in Bellingham, Washington, a city with a variety of views, including ocean, lake, and mountain. Results from a hedonic model, estimated for several years, suggested that depending on the particular view, willingness to pay for this amenity is quite high. The highest quality ocean views were found to increase the market price of an otherwise comparable home by almost 60%, while the lowest quality ocean views were found to add only about 8%. For ocean views of all quality levels, the price of a view is found to vary inversely with distance from the water.

The diversity of land use surrounding a house is important in value creation. Geoghegan, Wainger, and Bockstael (1997) enquired into the spatial patterns of land use character and how this pattern contributes to the price in Patuxent watershed counties of Washington D.C. suburbs. Developing spatial land use diversity indices for areas within a 0.1-kilometer radius, they concluded that the proportion of open space positively impacts land prices; however, within a 1-kilometer buffer, this variable negatively influences land prices. They interpreted this result to suggest that individuals price open space, like a view from their house (visual zone within 100 meters), and prefer to be able to walk to diverse land uses at the larger scale from their houses.

Conclusions from Past Studies

Based on the past studies, the key impact variables that were found useful include: home to CE inverse distance, weighted sum of inverse distance (accessibility index), land use diversity index (Pooler, 1987; Geoghegan, Wainger, and Bockstael, 1997; Acharya and Bennett, 2001), and view shed analysis (Wolverton, 1997; Lake, Lovett, Bateman, and Langford, 1998; Lake, Lovett, Bateman, and Day, 2000; Shultz and Schmitz, 2008). The interaction effect of the view and distance was even more important than just the view.

In most articles above, researchers used contingent valuation (a stated preference) and hedonic valuation (a revealed preference) to estimate the implicit price of the environmental amenity (Boyle and Kiel, 2001; Hidano, 2002; Malpezzi, 2002; McConnell and Walls, 2005; Sirmans, Macpherson, and Zietz, 2005; Boyd, 2008). However, the hedonic estimation technique was more commonly used.

Data and Methodology

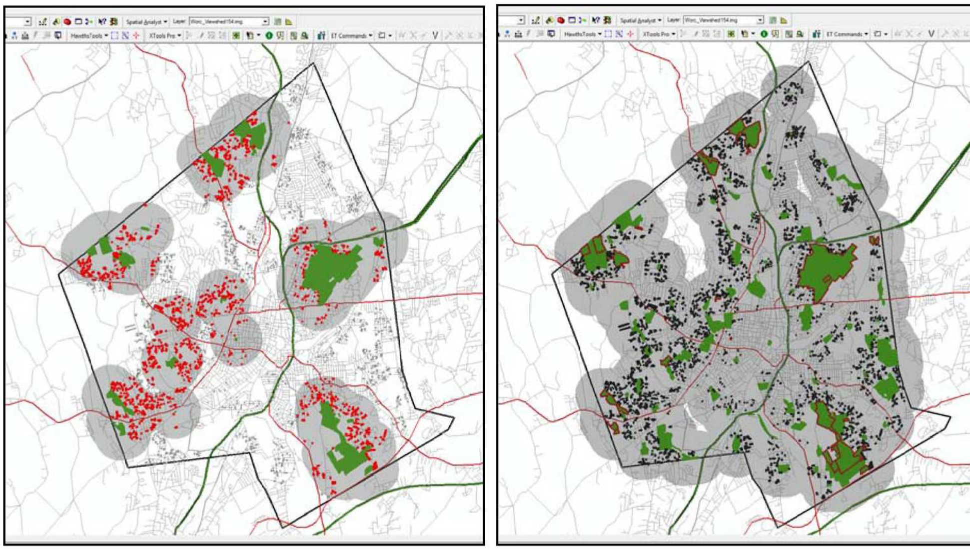
In this study, I used a hedonic framework to estimate the price capitalization effect of CEs. Two types of GIS-based data were used. One included two datasets of Environmental Amenity Generators, which included a mixed bag of open spaces in the city and its subset that only included the CE parcels. The other dataset was Environmental Amenity Absorbers, which included single-family detached (SFD) houses sold between 2005 and 2008 within a close proximity of the Environmental Amenity Generators.

Preparing Datasets for Analyses

Environmental Amenity Generators Datasets: The two datasets of Environmental Amenity Generators were available in GIS format (*.shp) from the Office of Geographic and Environmental Information (MassGIS). The first set included 54 parcels and was a larger dataset, as shown in Exhibit 1. This set included all types of ‘‘mixed-bag open spaces’’ in the City of Worcester, such as open spaces with active and passive recreation, and was used for various purposes such as public parks, golf courses, ball parks, playgrounds, and trails. This dataset also included CE parcels that city and land trusts owned. The second dataset was a smaller subset of the first one and included only 26 conservation easement parcels in the City of Worcester, as shown in the Exhibit 1 (see left map). The size of these 26 CE parcels varied from as small as one acre to as large as 400 acres (Exhibit 2). These CE parcels have environmental amenities that are scenic in nature such as waterfalls, streams, ponds, large boulders, marsh, wetlands or vernal pools, woods and vegetated lands, including a mature hardwood forest, mountain laurels, and silver beech, as well as various types of environmental amenities. Some larger CE parcels are also habitat for wildlife including deer, birds, and rare species such as spotted turtles and salamanders in the riparian region. The parcels also include

Exhibit 1 | Environmental Amenity Generators

Map with CE and 1,244 houses | Map with all open spaces and 2,406 houses



Sources: Greater Worcester Land Trust, Registry of Deeds, Worcester and City Assessor's land parcel data.

habitat for giant pileated woodpeckers, turkeys, and owls, as well as over 80 species of butterflies. There is a conservation center in one of the parcels that offers scientific, educational, and passive recreation environmental amenities to the public.

Environmental Amenity Absorbers Dataset (Houses): The effect of the environmental amenity was observed on the sale prices of SFD houses. The sales data for 2005–2008 was used for all SFD transactions within a half-mile[4] from the 54 mixed-bag open space parcels. This data set included a total of 2,406 SFD houses (mean sales price = $228,880, std. dev. = $71,242) that were sold during this period. A smaller subset of this SFD sales data was extracted for all sales within a half-mile distance from only the 26 CE parcels after eliminating all the sales that may have occurred around other mixed-bag amenities. This data set included a total of 1,244 SFD sales (mean sales price = $232,511, std. dev. = $71,318). The descriptive statistics of these two SFD sales data sets are given in Exhibit 3.

Hedonic Model for Measuring Value Capitalization Effect

Two OLS-based hedonic models were prepared using the spatial explanatory variables. One model focused only on the 26 CE-parcels as externality generator and 1,224 SFD houses as the externality absorbers. This model is called the "CE Model." The other model was for all the 54 mixed-bag open spaces as externality

Exhibit 2 | Land Under Conservation Easements

Site Name	Area (Acres)	Type of Easement	City
Land under Conservation Easements by GWLT, Mass Audubon, & City of Worcester			
Broad Meadow Brook Savannah	87.00	Conservation Easement	Worcester
Cascades East	30.86	Conservation Easement	Worcester
Coal Mine Brook Parcel	7.30	Conservation Easement	Worcester
Coal Mine Brook II Parcel	4.60	Conservation Easement	Worcester
Crow Hill	27.90	Conservation Easement	Worcester
Green Hill Park	487.00	Conservation Easement	Worcester
Parson's Cider Mill	43.08	Conservation Easement	Worcester
Ryan Ornamental	1.94	Conservation Easement	Worcester
Subtotal (8)	677.00		
Mass Audubon			
Granite Street Conservation Area	14.00	Conservation Easement	Worcester
Coes Reservoir	~12.00	Conservation Easement	Worcester
NEPC (Nr. Granite)	108.00	Conservation Easement	Worcester
Cooks Pond	~32.00	Conservation Easement	Worcester
Nr. NEPC	14.50	Fee Owned Property	
Hjeim Road	~12.00	NA	Worcester
Massasoit Rd	~3.00		Worcester
Sprague Ln	~1.80		Worcester
GWLT Owned Land (Fee Owner)			
Bovenzi Conservation Area	120.68	Fee Owned Property	Worcester
Brigham Road Parcels	2.53	Fee Owned Property	Worcester
Cascades West	122.99	Fee Owned Property	Worcester periphery / Holden / Paxton
Cascading Waters	2.40	Fee Owned Property	Worcester
Curtis Pond Parcel	±0.10	Fee Owned Property	Worcester
Kettle Brook	14.37	Fee Owned Property	Worcester
Marois Property	28.20	Fee Owned Property	Worcester / Leicester
Nick's Woods	59.76	Fee Owned Property	Worcester
Sargent's Brook Property	±5.00	Fee Owned Property	Worcester / Holden
Southwick Pond	113.77	Fee Owned Property	Paxton / Leicester
Subtotal (10)	470.00		
Government Land Preserved with GWLT Assistance			
Antell Conservation Land	280.00	Partner Massachusetts DEM	Spencer / E. Brookfield
Turkey Hill Brook Addition to Moore State Park	30.00	Partners Massachusetts DEM; Paxton Land Trust	Paxton
Subtotal (2)	310.00		

Notes: The sources are Greater Worcester Land Trust (2008) and Mittal (2011).

Exhibit 3 | Descriptive Statistics of SFD House Sales

Home Variables	1,244 Home Sales within 0.5 miles from 26 Parcels		2,406 Home Sales within 0.5 miles from 54 Parcels	
	Mean	Std. Dev.	Mean	Std. Dev.
Sale price	$232,511	$71,318	$228,880	$71,242
Time of Sale				
sl_2005 (sale year 2005)	0.32	0.465	0.32	0.47
sl_2006 (sale year 2006)	—	—	0.27	0.44
sl_2005 (sale year 2007)	0.26	0.438	0.25	0.43
sl_2007 (sale year 2008)	0.16	0.370	0.17	0.37
Structural Features				
Tula: Total utilizable area (sq. ft.)	1,401	581.49	1,368	536.66
Lotsf: Lot area (sq. ft.)	10,185	9,387.74	9,584	8,976.47
Qual: Quality of house	40.14	4.15	40.00	4.01
Age: Age of house	67.38	138.87	68.87	129.57
Beds: No. of bedrooms	2.98	0.87	2.95	0.84
Bath: No. of bathrooms	1.30	0.54	1.28	0.52
Hbath: Half bath	0.45	0.52	0.42	0.51
Deck: Deck (dummy)	0.31	0.46	0.29	0.46
Patio: Patio (dummy)	0.04	0.21	0.04	0.20
Neighborhood Variables				
hous_dens: Housing density	3.07	2.49	3.21	2.40
prc_black: Percentage of blacks	4.63	5.11	4.58	5.71
md_hs_val: Median house price	$121,794	$25,049.52	$120,611	$26,075.31

Note: The source is the city assessor's SFD house sales data.

generator and 2,406 SFD houses as the externality absorbers and is called the "OS Model OS." The OS Model is linear and is expressed as:

$$Y_i = \beta_0 + \beta_1 T_i + \beta_2 S_i + \beta_3 N_i + \beta_4 E_i + \varepsilon_i,$$

where:

Dependent Variable: Y_i = Sale price (in \$).
Independent Variables: T_i = Vector of time of sale = *sl_2005*, *sl_2006*, *sl_2007*, *sl_2008*;
S_i = Vector of structural features = *Tula*, *Lotsf*, *Beds*, *Bath*, *Qual*, *Hbath*, *Age*, *Patio*, *Deck*;
N_i = Vector of neighborhood features = *Prc_black*, *Md_hs_val*, *Hous_dens*;
E_i = Vector of environmental features: d_{ij}, V_{ij}, and A_{ij}; and
ε_i = Error term.

The three spatial explanatory variables were in a matrix form and included: (1) the visible area of each CE($_j$) parcel vertices from each HOME($_i$)—V_{ij} to measure visibility; (2) the shortest distance to the visible portion of each CE($_j$) parcel from each HOME($_i$)—d_{ij} to measure proximity; and (3) a weighted index of view and distance for each HOME($_i$)—A_{ij} to measure visual accessibility from each house to each CE parcel and mixed-bag of open space parcels.

For the proximity variable *dij*, in ArcGIS, Chasan's (2003) visual basic tool (vbtool) was used to measure multiple distances between the two data sets: between environmental amenity generators and absorbers. The first distance matrix was between SFD houses (2,406) and all 54 mixed-bag open space parcels; the second distance matrix was from the SFD homes (1,244) to the 26 CE parcels.

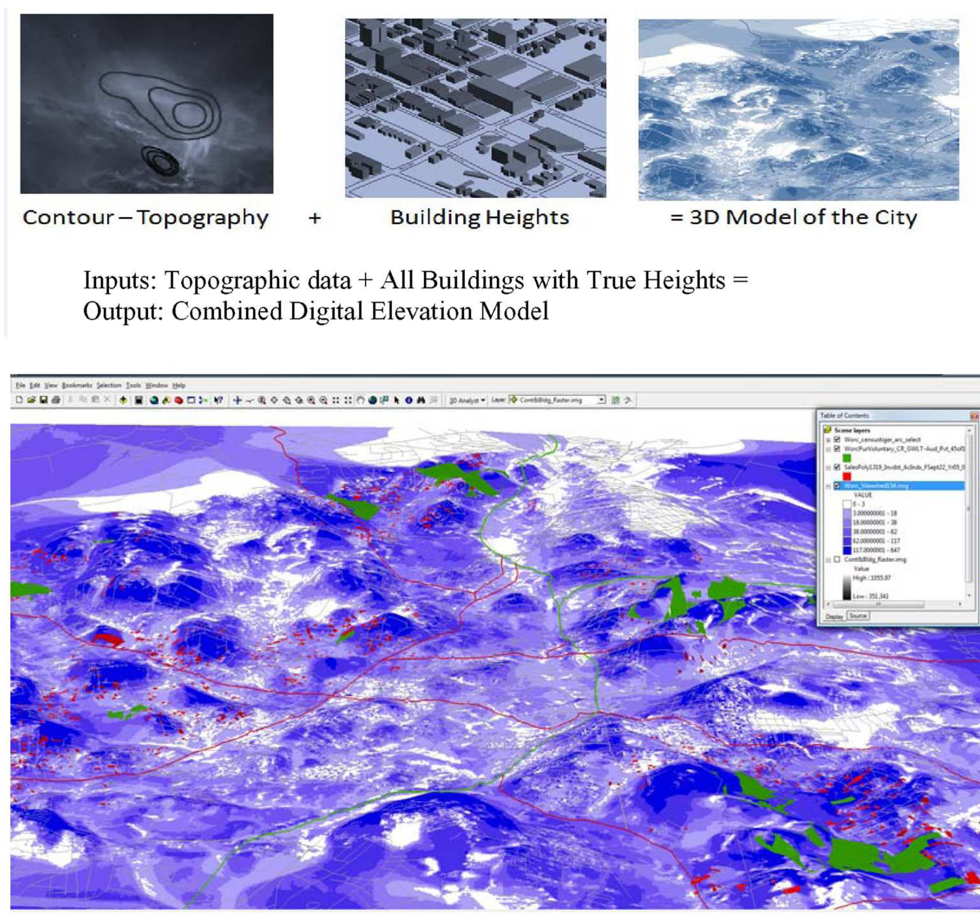
For visibility variable *Vij*, first, three-dimensional digital models for the entire city were created using topographic and building height data (Lake, Lovett, Bateman, and Langford, 1998; Lake, Lovett, Bateman, and Day, 2000; Sander and Manson, 2007; Shultz and Schmitz, 2008; Sander and Polasky, 2009). Once this data was ready, viewsheds were created from each home sample. Using the spot elevations and topographic data in ArcGIS Spatial Analyst, first digital elevation model (DEM) for the topography of the City of Worcester was created; then, the 3-D view impending built structures in the City were added to this DEM. Using the building footprints data in GIS, heights were assigned to the building footprints, to generate a 3-D surface of all the built structures in the city. Finally, the two surfaces were combined to form a seamless 3-D model for the entire city where the built structures in the city were draped over the topographic surface (Exhibit 4).

The viewsheds were then created in ArcGIS Spatial Analyst, between the two sets of SFD (2,406 houses and 1,244 houses) and the two sets of environment amenities (the 26 CE parcels and the 54 mixed-bag open space parcels). All viewsheds were calculated at human eye level—five feet above the ground. The GIS viewshed analysis generated an output Viewshed($_i$) raster for visible and non-visible areas from the observation points. This viewshed output had only two possible pixel values: a value of one indicated visible and a value of zero indicated invisible. The viewsheds were shot keeping the observer(s) at the periphery of environmental amenities. The resulting viewsheds were then summed, creating view counts ranging from 0 to 677 for SFDs, the value of zero on the viewshed output raster meant no view, while the higher value meant more view from that point to the subject environmental amenity. After categorizing the final viewshed raster into five view groups, in GIS, the entire set of SFD data parcels was then clipped with this final viewshed raster to assign view counts to the SFD datasets. The descriptive statistics for the two sets of variables are in Exhibit 5.

Model Summary

The OS Model included 2,406 SFD house sales (mean sales price = \$228,880, std. dev. = \$71,242) within a 0.5-mile distance from all 54 open-space parcels transacted between 2005 and 2008. The house sales within a 0.5-mile buffer area

Exhibit 4 | Merged Raster: DEM of Building Heights and Topographic Features of the City



from the 54 open-space parcels (environmental amenities) were used for this research. This buffer is like local submarket characteristics and is used to control for any other spatial factors (variable not accounted for in the model) that may affect the house prices. This OS Model measured the combined effect of all the 54 open-space parcels in Worcester on SFD prices. This model also included 26 CE-protected parcels. The control variables used in the hedonic model were physical home characteristics, neighborhood characteristics, and the year of house sale. The three test variables were: *dij 54*, the squared distance from the nearest open space property; *ViewInteract54*, interaction of view and squared distance; and *Vij54*, view to open space parcel vertices.

First, the test of heteroscedasticity was conducted visually. On plotting the residuals, they were found to be randomly patterned, which indicates homoscedasticity. Any linear form of heteroscedasticity can be detected using the

Exhibit 5 | Descriptive Statistics of Two SFD Sales Data Sets

	1,244 Home Sales within 0.5 Miles from CE-protected 26 Parcels			2,406 Home Sales within 0.5 Miles from all Open Spaces: Open Space, City Parks, Playgrounds, CE-protected 54 Parcels		
Home Variables	Mean	Std. Dev.	*N*	Mean	Std. Dev.	*N*
Test Variables						
dij 26: Squared distance from the nearest CE property (ft.)	779,386 (882 feet)	720,116 (849 feet)	1,244	—	—	—
dij 54: Squared distance from the nearest open spaces (ft.)	—	—	—	5,587,790,324 (74,751 feet)	125,663,110,498 (354,489 feet)	2,406
ViewInteract26: Interaction of view and squared distance of the nearest CE property	68,286	95,436	1,244	—	—	—
ViewInteract54: Interaction of view and squared distance of the nearest open spaces (ft.)	—	—	—	476,052,893,686	13,693,065,342,153	2,406
Vij 26: View to CEs	57.24	65.32	1,244	—	—	—
Vij 54: View to open spaces	—	—	—	53.85	63.98	2,406

Exhibit 6 | OS Model Summary

Model	R	R^2	Adj. R^2	Std. Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
OS	.725(a)	.53	0.522	49,280.23	.53	146.63	18	2,387	.000

Notes: Predictors: (Constant), *md_hs_val*, *sl_2006*, *patio*, *view*, *age*, *InvSq154*, *deck*, *lotsf*, *hbath*, *sl_2008*, *prc_black*, *beds*, *hous_dens_*, *bath*, *sl_2007*, *tula*, *qual*, *ViewInteract154*. The dependent variable is *saleprice*.

Breusch-Pagan test for heteroscedasticity in SPSS. After running the test, the small chi-square value indicated that heteroscedasticity was absent from the sample.

Exhibit 6 provides a summary of the OS Model and Exhibit 7 provides beta weights of the independent variables. As can be seen in the Exhibit 6, the variables have 52.2% explanatory power (adjusted R^2). As can be seen in Exhibit 7, none of the environmental externality capturing variables was significant. The open spaces used in the OS Model represented all open spaces in Worcester—both *actively used* open spaces, such as playgrounds and parks, and *passively used* open spaces, such as CE parcels. The actively used open spaces include ball parks, playgrounds, and basketball courts, which could be construed as loud, or likely to generate high traffic volume, which may be less desirable to some amenity-seeking homeowners. This effect of greater noise and intense activity levels could result in a negative externality impact on house prices, which is evident in the significance level of the explanatory variables. The OS Model potentially has a mixed effect of positive and negative externality generating various types of open spaces.

In the CE Model, only the effect of CE-protected properties was measured. The model included 1,244 home sales (mean sales price = $232,511, std. dev. = $71,318) within a 0.5-mile distance from CE-protected properties in Worcester, representing sales transacted between 2005 and 2008. The control variables were the same as in the OS Model: physical home characteristics, neighborhood characteristics, time of sale. Three test variables were used to measure the CE amenity effect: *dij 26*, the squared distance from the nearest CE property; *ViewInteract26*, the interaction of view and squared distance; and *Vij26*, view to CEs.

Exhibit 8 is a summary of the CE Model and Exhibit 9 provides beta weights for various independent variables. Exhibit 8 shows that the CE Model CE has a greater explanatory power than the OS Model. Nearly 58.4% variance in the SFD house prices can be predicted from the variables used in this model. The model was also tested for multicollinearity. The VIF is < 3, which indicates that the model was stable and there was no multicollinearity detected among the variables. All variables independently contributed to the model's predictive power. The beta

Exhibit 7 | OS Model: OLS Output with 2,406 Houses within a 0.5 Mile Distance from all Open Space Properties for 2005–2008

	Unstd. Coeff.		Std. Coeff.	T	Sig.	95% Con. Inter. for β		Correlations			Collinearity Statistics	
Model	β	Std. Error	β			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
Constant	−97,699.860	15,314.637		−6.380	0.000	−127,731.225	−67,668.496					
Year of Sale (Dummy)												
*sl_2005** (Sale Year 2005)	−6,256.805	2,637.057	−0.039	−2.373	0.018	−11,427.963	−1,085.646	0.070	−0.049	−0.033	0.736	1.358
*sl_2007** (Sale Year 2007)	−21,361.873	2,709.055	−0.129	−7.885	0.000	−26,674.216	−16,049.530	−0.035	−0.159	−0.111	0.739	1.353
*sl_2008** (Sale Year 2008)	−50,174.252	3,056.659	−0.262	−16.415	0.000	−56,168.232	−44,180.271	−0.202	−0.318	−0.232	0.779	1.283
Physical Features of Houses												
*Tula**: Total utilizable area	43.099	3.017	0.325	14.285	0.000	37.183	49.015	0.579	0.281	0.201	0.385	2.596
*Lotsf**: Lot area sq. ft.	0.813	0.117	0.102	6.944	0.000	0.583	1.042	0.262	0.141	0.098	0.914	1.093
*Qual**: Quality of house	5,202.145	419.153	0.293	12.411	0.000	4,380.204	6,024.087	0.389	0.246	0.175	0.358	2.792
*Age**: Age of house	159.424	10.932	0.290	14.583	0.000	137.987	180.862	0.015	0.286	0.206	0.503	1.987
Beds: No. of bedrooms	−2,612.217	1,632.720	−0.031	−1.600	0.110	−5,813.913	589.480	0.367	−0.033	−0.023	0.538	1.859
*Bath**: No. of bathrooms	24,189.953	2,430.933	0.175	9.951	0.000	19,422.995	28,956.912	0.426	0.200	0.140	0.645	1.551
*Hbath**: Half bath	7,908.118	2,157.373	0.057	3.666	0.000	3,677.600	12,138.637	0.225	0.075	0.052	0.822	1.217
*Deck**: Deck (dummy)	6,081.108	2,266.192	0.039	2.683	0.007	1,637.199	10,525.016	0.100	0.055	0.038	0.947	1.056
Patio: Patio (dummy)	8,110.219	4,970.953	0.023	1.632	0.103	−1,637.613	17,858.050	0.032	0.033	0.023	0.997	1.003
CE Test Variables												
InvSqd54: Squared distance from the nearest CE property	−1.27E-008	0.000	−0.022	−0.945	0.345	0.000	0.000	−0.008	−0.019	−0.013	0.352	2.837
ViewInteract54: Interaction of view and squared distance	9.61E-011	0.000	0.018	0.778	0.437	0.000	0.000	0.002	0.016	0.011	0.353	2.832
View54:View to CEs	−0.181	15.912	0.000	−0.011	0.991	−31.383	31.021	0.060	0.000	0.000	0.974	1.026
Neighborhood Variables: Census Blkgroup Level												
*hous_dens_**: Housing density	−2,485.362	439.239	−0.087	−5.658	0.000	−3,346.691	−1,624.033	−0.131	−0.115	−0.080	0.847	1.181
prc_black: Percentage of blacks	−329.676	187.668	−0.026	−1.757	0.079	−697.686	38.333	−0.117	−0.036	−0.025	0.879	1.137
*md_hs_val**: Median house price	0.305	0.045	0.112	6.857	0.000	0.218	0.393	0.377	0.139	0.097	0.749	1.336

Notes: The dependent variable is *saleprice*, $n = 2{,}406$, df = 18.
* Significant at $p < .05$.

Exhibit 8 | CE Model Summary

Model	R	R^2	Adj. R^2	Std. Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
1	.768	.59	0.584	46,009.69	.59	97.87	18	1,225	.000

Notes: Predictors: (Constant), *md_hs_val, sl_2008, view, age, patio, InvSqd45, hbath, deck, lotsf, sl_2007, hous_dens_, beds, prc_black, bath, sl_2005, tula, qual, ViewInteract45*.
The dependent variable is *saleprice*.

weights, t values, and the significance levels of variables used in the model are provided in Exhibit 9. All variables used to signify the physical features of SFD were statistically significant with the right sign within $p < .05$. Similarly, all the neighborhood variables had the right signs and were found significant within $p < .02$.

All three CE test variables were found significant, but at $p < .09$, as presented in Exhibit 9. Two of the three CE test variables were significant within alpha = 0.01 and the view variables were significant with alpha = 0.09. The model output summary for these variables is: for *dij* 26, $\beta = -0.01$, $t = -2.82$, and $p < .01$; for *Vij* 26, $\beta = -60.64$, $t = -1.69$, and $p = .09$; and for the interaction effect variable of view and distance, $\beta = 0.07$, $t = 2.63$, and $p < .01$.

Except for the view variable, the beta signs for the three test variables were as expected. The proximity variable *dij* 26 is highly significant at $p < 0.01$. The distance variable has a negative sign as expected. So, for every unit change in the house sample, as measured by squared distance from the CE-protected parcel, the average SFD price reduces by 0.01. This means that if the home is abutting the CE-protected property, the price will be the highest; however, if the home is 10 feet away from the CE-protected property, the price will decline by \$1, while if it is 100 feet away, the price declines by \$100. Similarly, if a SFD house is 500 feet away, the average price reduction will be \$2,500, holding all other variables constant.

The view variable has a negative beta sign, which means that the greater the value of visible vertices, the house price reduces. This is not very intuitive, but can only be explained that more CE parcel vertices can only be seen if a house sample is located so that it can see most. This situation can only occur if the house sample has a higher elevation and can see several CE properties, but may be from a farther distance from the CE parcels. In the original regression data set with a view (mean = 57, std. dev. = 65), meaning that an average home in the house sample set views 57 vertices of the CE-protected properties, where an average CE-protected property had average of 10 vertices (a few properties were irregular in shape, or very small or large in size), the average house in the dataset can see about six protected properties. Note that view as measured using the GIS viewshed

Exhibit 9 | CE Model: OLS Output with 1,244 Houses within 0.5 Mile Distance from CE-protected Properties for 2005–2008

Model	Unstd. Coeff. β	Unstd. Coeff. Std. Error	Std. Coeff. β	T	Sig.	95% Confidence Interval for β Lower Bound	95% Confidence Interval for β Upper Bound	Correlations Zero-order	Correlations Partial	Correlations Part	Collinearity Statistics Tolerance	Collinearity Statistics VIF
Constant	−84,536.32	19,984.42		−4.23	0.000	−123,743.79	−45,328.85					
Year of Sale (dummy)												
*sl_2005** (Sale Year 2005)	7,224.75	3,469.35	0.047	2.08	0.038	418.21	14,031.28	0.120	0.059	0.04	0.65	1.53
*sl_2007** (Sale Year 2007)	−12,758.99	3,629.52	−0.078	−3.52	0.000	−19,879.76	−5,638.22	−0.026	−0.100	−0.06	0.67	1.49
*sl_2008** (Sale Year 2008)	−41,136.84	4,138.80	−0.214	−9.94	0.000	−49,256.75	−33,016.92	−0.183	−0.273	−0.18	0.72	1.38
Physical Features of Houses												
*Tula**: Total utilizable area	44.19	3.73	0.360	11.86	0.000	36.88	51.50	0.604	0.321	0.22	0.36	2.76
*Lotsf**: Lot area sq. ft.	1.02	0.15	0.134	6.81	0.000	0.73	1.31	0.326	0.191	0.13	0.86	1.16
*Qual**: Quality of house	5,244.72	539.65	0.306	9.72	0.000	4,185.98	6,303.46	0.396	0.268	0.19	0.33	2.95
*Age**: Age of house	157.07	13.58	0.306	11.57	0.000	130.43	183.72	0.018	0.314	0.21	0.47	2.09
Beds: No. of bedrooms	−5,364.50	2,128.67	−0.066	−2.52	0.012	−9,540.74	−1,188.25	0.389	−0.072	−0.05	0.49	2.02
*Bath**: No. of bathrooms	26,712.63	3,142.34	0.204	8.50	0.000	20,547.66	32,877.59	0.494	0.236	0.16	0.58	1.72
*Hbath**: Half bath	8,438.58	2,783.20	0.062	3.03	0.002	2,978.22	13,898.94	0.225	0.086	0.06	0.81	1.23
*Deck**: Deck (dummy)	7,922.04	2,941.35	0.051	2.69	0.007	2,151.40	13,692.68	0.132	0.077	0.05	0.92	1.08
Patio: Patio (dummy)	12,913.64	6,388.96	0.037	2.02	0.043	379.12	25,448.15	0.055	0.058	0.04	0.98	1.01
CE Test Variables												
*InvSqd26**: Squared distance from the nearest CE property	−0.01	0.002	−0.060	−2.82	0.005	−0.01	−0.002	−0.097	−0.080	−0.05	0.74	1.33
*ViewInteract26**: Interaction of view and squared distance	0.07	0.03	0.090	2.63	0.009	0.02	0.12	0.091	0.075	0.05	0.28	3.49
*View26****: View to CEs	−60.64	35.83	−0.056	−1.69	0.091	−130.92	9.65	0.082	−0.048	−0.03	0.31	3.21
Neighborhood Variables Census Blkgroup Level												
*hous_dens_ Housing Density**	−2,973.46	579.856	−0.104	−5.13	0.000	−4,111.08	−1,835.84	−0.148	−0.145	−0.09	0.81	1.23
*prc_black**: Percentage of blacks	−892.49	286.053	−0.064	−3.12	0.002	−1,453.69	−331.28	−0.131	−0.089	−0.06	0.79	1.25
*md_hs_val**: Median house price	0.19	0.061	0.065	3.05	0.002	0.07	0.31	0.364	0.087	0.06	0.73	1.36

Notes: The dependent variable is *saleprice;* $n = 1{,}244$, df = 18.
* Significant at $p < .05$.
** = Insignificant.
*** = Significant only at $p < 0.10$.

technique, which only generates binary view information—view is available or not available—it does not account for the quality of view. It also does not account for how far away the view generating amenity is. The view variable was developed in ArcGIS Spatial Analyst using the DEM, as discussed above. The view sheds were created from the vertices of CE properties (Edge) to capture if sample houses can see those vertices or not. This view shed also accounted for the impeding view effect due to topography and building heights, if any. The combined view shed raster provided ‘‘0’’ value for invisible areas and higher values ranging from 1 to 647 for visible areas.

The interaction effect variable *ViewInteract26* had a positive sign with $\beta = 0.07$, $t = 2.63$, and $p < .01$. This variable signified the importance of both the distance to CE from SFD houses and the visibility to the CE-protected property from the SFD houses. This means that by increasing this interaction variable by one unit, on average, the home price increases by $60, holding all other variables constant. The *ViewInteract26* variable is *View* x *Sqdist26*. Even if the property is abutting a CE-protected property or as close as 10 feet away, the impact of 0 view is dramatic, with the price effect of 0. This indicates that distance does not matter, meaning, it is not simply close proximity to protected property that creates value, but being able to see and enjoy the view of that property is important too.

Conclusion

From the OS and CE Models, it is clear that the perpetually conserved CE properties offer passive amenity effects that are unlike the mixed-bag of open spaces in Worcester, which also include some active activities within them. Based on the higher prices obtained for houses sold in areas surrounding the CE-protected properties, it appears that people place an economic price on properties with quieter, everlasting landscapes versus those that support more active recreation, which is likely to generate more noise and traffic.

The findings reveal that home prices increase the closer the properties are to CE-protected properties. This price elevation is due to the ‘‘amenity magnet’’ effect that an environmental amenity generates in the CE-protected properties. Further, as the measure of proximity was defined by a squared distance term, it shows that the home price effect reduces more rapidly as the distance from the CE-protected property increases. So, for example, holding all other variables constant, if a home is 10 feet away from a CE-protected property, the price will decline by $1. Similarly, if it is 100 feet away, the home price declines by $100. If it is 500 feet away, the average home price declines by $2,500. If it is 1,000 feet away, the average home price declines by $10,000. The view variable is insignificant at $p < .05$. The home price increase with the interaction of visibility and distance from CE-protected properties is very important. Even if a property abuts or is within 10 feet of the CE-protected property, the absence of a view means there will be no positive impact of the amenity on the sales price.

In Worcester, CE-protected properties had aesthetic, passive recreational, and bio-diversity value. Some of these CEs also provided a buffer to create habitat for wildlife, which included natural landscape features and provided support for other associated ecosystem values such as water purification, reduction in river pollution, and flood control, etc. The preservation of open spaces benefits the people living in the region. However, landowners nearest the preserved parcels receive extra direct benefits, which are capitalized into the prices of their SFD houses.

Theoretically, as the size of the open space increases, the range of it externality impact should increase as well. However, the accessibility index used in the model was insignificant. This could be due to the large range of acreage among the protected properties in the study (maximum 487 acres and minimum 1 acre). Also, if the house samples are smaller in size (square footage) and do not have their own private open space (small lot), they would price public open spaces more than the larger size houses. It would be interesting to explore how spatially grounded models could refine our understanding of the impact of CE-restricted properties on home prices. The findings support the notion that house buyers and sellers place a higher price on quieter, everlasting conserved landscapes of CE parcels as compared to more active and relatively louder open recreational spaces around the mixed-bag open spaces. The surrounding houses become desirable because of the protected viewsheds provided by adjacent CEs making some home sites more expensive, which in turn provides additional taxes to the local authority, income for investors, and neighboring landowners (Brewer, 2004; Fairfax et al., 2005; Morris, 2008; Aspen Valley Land Trust).

Endnotes

[1] Loomis, Rameker, and Seidl (2004) discuss the cost benefits and fiscal advantages of publicly funded protected land.

[2] Conservation Easements—Fact vs. Fiction, The Nature Conservancy, accessed March 12, 2011: http://www.nature.org/aboutus/privatelandsconservation/conservationeasements/conservation-easements-fact-versus-fiction.xml.

[3] Bourassa, Hoesli, and Sun (2004) provide a chronological review of 35 studies that have used view as a variable in measuring externality impact on home values. These studies and their findings are tabulated in a six-page summary (pp. 1431–36).

[4] Only homes sold within a 0.5 mile buffer area from the environmental amenities were used for this research. This 0.5 mile buffer was chosen to control for any other spatial factors (variable not accounted for in the model) that may affect the house prices and the buffer area functions as a local housing submarket around the amenity.

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Power Lines and Perceived Home Prices: Isolating Elements of Easement Rights and Noise Pollution

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Abstract This study is the first to use experimental design to look beyond the overall impact of power lines on property values by examining specific easement rights and noise pollution concerns. I find that in isolation, easement rights are associated with a non-significant reduction in property value, whereas noise pollution statistically significantly reduces property values. Interestingly, when easement rights are combined with noise pollution, the combined effect is more than additive. Results from the sample of eminent domain attorneys, who are valuation impact experts, reveals that females penalize a property more severely for being associated with power lines, and attorneys who typically represent property owners (as opposed to the condemnor) are more sympathetic to greater diminution values.

The effect of the presence of power lines on home values has been examined many times and in many different contexts (e.g., Colwell and Foley, 1979; Hamilton and Schwann, 1995; Jaconetty, 2001; Des Rosiers, 2002; Wolverton and Bottemiller, 2003). Results vary tremendously from study to study and over time as well. The reason for these disparate results stems from the fact that power lines represent a multitude of concerns for the property owner. Specifically, what researchers have been unable to isolate are individual contributors such as the impact of a view, noise pollution, and a removal of specific property rights.

The literature relating to the value of a view is voluminous, and researchers are clearly hampered by the difficulty in quantifying and standardizing what is meant by "view." As a result, even if a power line study attempted to control for the (presumably negative) impact the view of a power line has on property values, quantifying the measure is imprecise, at best. Secondly, proximity damage and noise pollution are never mentioned in power line studies.[1] There are many types of power lines, some of which have transformers that generate a hum, while others do not. Thirdly, power lines must be repaired and maintained by utility companies. When power lines cross over one's property, the local utility company is typically granted an easement right, which allows them to enter the property. While the transfer of this property right to the utility company might seem trivial, property owners are indeed restricted by such easements in a meaningful way.[2] Finally, the effect of power lines on home values is confounded by the proximity of the power lines to the home.

The purpose of this study is to control for the ever-elusive ‘‘view’’ component, among other variables, by utilizing an experimental design. First, I create two otherwise identical power line treatments[3] that only vary by ‘‘near versus distant’’ power lines. Next, I consider the near power lines and create additional treatments that hold all else constant except easement rights in one set of trials, and noise pollution in another. The findings show that power lines right behind the home (when compared to distant power lines) are associated with a $4,960 diminution in value on a $200,000 home. For the nearby power lines, noise pollution detracts from value in the amount of $3,920, whereas easement rights represent a nominal change in value. However, when combining the easement right transfer with noise pollution, the overall impact is a reduction in home value by $5,440 (a combined amount that is greater than the sum of its parts).

While the magnitude of the results is in line with past studies (e.g., Seiler, Madhavan, and Liechty, 2012a), I offer a further contribution to the literature (beyond my ability to parse out very specific power line effects such as the testing of noise pollution and easement rights, which is simply not possible using traditional methods) in that the sample consists of true experts in the field of value impaction. Specifically, the results were collected during a live experiment at the American Law Institute-American Bar Association (ALI-ABA) conference attended by eminent domain attorneys from across the United States. Since their practices center on eminent domain and partial takings law, this sample of experts is highly compelling.[4] While years of experience was not found to impact the results, attorneys who typically represent the property owner indicated a more negative impaction due to the power lines, whereas those who typically represent the condemnor (the party who takes the property and has to pay ‘‘just compensation’’ to the property owner indicated a lesser impact.[5] Finally, women penalize property values with nearby power lines significantly more so than men.

Literature Review

Because of the extreme difficulty in measuring the impact of power lines on residential property values, very little research has been undertaken in recent years. The most recent summary article by Pitts and Jackson (2007) explains that most studies find either no effect at all or a −1% to −10% diminution impact on property values. Studies that found no impact include Kinnard (1967), Kung and Seagle (1992), Cowger, Bottemiller, and Cahill (1996), and Wolverton and Bottemiller (2003). Studies that conclude a negative influence on property values include Colwell and Foley (1979), Delaney and Timmons (1992), and Kinnard and Dickey (1995).

As explained in Jackson (2004), examples of the disparate results stem from such issues as view, distance to the power lines (implying varying degrees of health concerns), and even hot versus cold markets. Specifically, during upward moving, or hot markets, buyers are less concerned with the presence of power lines, whereas when the market softens, buyers can be more selective, and would prefer a home not located next to power lines. Another example includes the work by Des Rosiers (2002), who finds that higher-end custom homes are generally more sensitive to the negative impacts of power lines than lower priced homes. This may well be due to the disagreement among experts as to whether or not power lines are a health concern and/or the greater number of housing options wealthier buyers have over those who are less affluent.

In a relatively recent study by Des Rosiers (2002), which examined 507 single-family homes in a suburb of Montreal, Canada, declines in property value estimates ranged from −5% to −20%. Des Rosiers explains in great detail that there are numerous confluences that make measuring the impact difficult. He goes on to say frustratingly so that ''despite its inherent weaknesses, the hedonic model remains the most reliable tool for measuring environmental negative externalities…'' The hedonic method does have severe limitations and it is time for a new approach to be considered. This is precisely the motivation for using an experimental design and is the expressed purpose of the current investigation.

Experimental Design

Traditional studies use transactions data to identify the impact of power lines on home values. This approach requires the assumption that anything that impacts home values can be held constant by including the factors on the right-hand side of a hedonic model. While in reality the complete list of variables is unknown and many times unobservable, studies do their best to measure factors like national and local market conditions, lot size, home size (square footage, number of bedrooms, and bathrooms), property condition, construction quality, age, view, neighborhood characteristics (crime rates, school quality), and so forth. Still, no study is able to control for everything.[6]

By contrast, an experimental design creates an artificial environment where everything else is truly held constant.[7] In this sense, it is the perfect design for studies that cannot possibly control for outside influences like view and specific power line characteristics. The drawback to using an experimental design, however, is whether or not the results found in the lab translate into the real world. In short, an experimental design is an alternative approach to traditional hedonics, and should not be viewed as either absolutely superior or inferior, but instead, should be viewed as more or less preferred within the specific context of what the researcher is examining.

In the current investigation, I begin by holding constant all variables by creating a virtual home tour of a single residence with distant power lines, and then present another treatment associated with nearby power lines. A simple difference-in-difference comparison of their respective average home prices attributes a change in price to the sole attribute that was altered between the treatments (i.e., power line location—nearby vs. distant). After this effect is measured, I focus only on the nearby power line scenario. To examine the impact of easement rights, I again create two treatments: one where the attorneys are told easements are given to the local utility company and one where they are not. In a similar fashion, to examine the noise pollution aspect of power lines, participants are told that the transformers associated with the power lines do versus do not make a load humming noise.

Exhibit 1A | Home Exterior with No Power Lines

This is an image showing the exterior of the 3-D modeled home without power lines.

Exhibit 1B | Home Exterior with Distant Power Lines

This is an image showing the exterior of the 3-D modeled home with distant power lines.

In rounding out the 2 × 2 matrix, the effects are combined to create the four combinations for nearby power lines: no easement, no humming; easement, no humming; no easement, humming; and easement, humming. All data were collected using a "within subjects" design. Screen captures of the three treatments are provided in Exhibit 1.

Exhibit 1C | Home Exterior with Near Power Lines

This is an image showing the exterior of the 3-D modeled home with near power lines.

Data

All data were collected at the American Law Institute-American Bar Association (ALI-ABA) annual conference, which is attended by leading eminent domain lawyers from all across the U.S. During a regularly scheduled session, I conducted a live experiment incorporating instant feedback via technology known as an instant response device (IRD). An IRD is a credit card-sized device that allows participants to respond in real time to questions posed by the administrator. The responses to each question are received at the front of the room and stored in a Turning Technologies software program that can later be exported to Excel, and then imported into any statistical software package.

As seen in Exhibit 2, Panel A, valid responses were obtained from 82 attorneys, 62 of which typically represent the property owner in eminent domain cases, the remainder of which typically represent the condemnor. Twelve of the attorneys were females, and the average eminent domain experience was over 18 years. Seventy-nine of the 82 attorneys were current homeowners. Because of the near unity of this variable, it was dropped from all subsequent analysis.

Results

Panel B of Exhibit 2 reports the minimum, maximum, standard deviation, and mean property diminution values for a base case (a home without power lines) value of $200,000 on a scale from 1 ($204,000) to 9 (less than $172,000).[8] When I consider the overall impact of power lines versus no power lines, I observe an effect no less than −4.9% (by comparing distant power lines to no power lines).[9]

Exhibit 2 | Descriptive Statistics

	Min.	Max.	Std. Dev.	Mean
Panel A: Sample demographic variables				
Current Homeowner	1	2	0.19	1.04
Gender	1	2	0.36	1.15
Years of Eminent Domain Experience	1	7	2.12	4.04
Attorney Type	1	2	0.43	1.24
Panel B: Power Line control variables				
Distant Power Lines	2	9	2.08	5.56
Near Power Lines—No easement; No humming	2	9	2.23	6.80
Near Power Lines—Easement; No humming	2	9	2.43	6.83
Near Power Lines—No easement; Humming	2	9	1.63	7.78
Near Power Lines—Easement; Humming	2	9	1.44	8.16

Notes: This exhibit displays minimum, maximum, standard deviation, and mean values for the five power line control variables, as well as for the four demographic control variables. *Current Homeowner* is set to 1 for those who currently own a home; 2 otherwise; *Gender* is set to 1 for males, and 2 for females; *Years of Eminent Domain Experience* is on a scale from 1 = 0–5 years, to 7 = more than 30 years; and *Attorney Type* is set to 1 for attorneys who typically represent the property owner, and 2 if the attorney typically represents the condemnor. The overall mean scores from each column (C1 ~ C5) are compared using a series of paired-samples *t*-tests. Pair C2 & C3 is not statistically different from each other. Pair C4 & C5 is significant at 95%. All other pairings are significantly different at 99%.

In a strictly within power line examination, nearby power lines are associated with a significantly greater mean diminution value when compared to distant power lines.[10] When specifically examining easement and noise pollution effects, noise pollution significantly lowers property values, whereas a loss of easement rights does not.[11] Taken together, the combined effect of noise pollution and easement loss is greater than the individual additive effects.[12]

Having confirmed my central supposition that more than the mere presence or absence of power lines matters, I now take a deeper examination of the responses in Exhibit 3. Exhibit 3 reports a breakdown of property value estimate responses by power line treatment. When moving from C1 to C5, there is a consistent downward shift in answers from prior ranges. Modal responses follow this general trend as the mode for C1 is −4%, the mode for C2 is −10%, and the modes for C3–C5 are less than −14%. But, might it be possible that the demographic characteristics of the attorneys are partially responsible for variations in these columns? To answer this question, I turn to Exhibit 4.

Exhibit 4 segments the results from the prior exhibit by attorney type (whether the attorney typically represents the property owner or the condemnor) in Panel

Exhibit 3 | Breakdown of Power Line Controls by Frequency of Price Decline

	Distant	Near			
Estimated Home Value	C1	C2	C3	C4	C5
$204,000 (+2%)	0.0%	0.0%	0.0%	0.0%	0.0%
$200,000 (0%)	8.8%	7.6%	7.5%	1.3%	1.3%
$196,000 (−2%)	8.8%	0.0%	6.3%	0.0%	0.0%
$192,000 (−4%)	21.3%	15.2%	12.5%	3.8%	2.5%
$188,000 (−6%)	7.5%	5.1%	1.3%	7.5%	2.5%
$184,000 (−8%)	13.8%	5.1%	7.5%	5.0%	5.1%
$180,000 (−10%)	18.8%	20.3%	12.5%	13.8%	12.7%
$176,000 (−12%)	15.0%	15.2%	12.5%	12.5%	11.4%
Less than $176,000 (−14%)	6.3%	31.6%	40.0%	56.3%	64.6%
Overall Mean Score	5.56	6.80	6.83	7.78	8.16

Notes: This exhibit reports the respondents' opinion of the impact of each power line treatment on the value of the home. C1 represents Distant Power Lines; C2 represents Near Power Lines—No easement and No humming; C3 represents Near Power Lines—Easement, but No humming; C4 represents Near Power Lines—No easement, but with Humming; and C5 represents Near Power Lines—Easement and Humming. The overall mean scores from each column are compared using a series of paired-samples *t*-tests. Pair C2 & C3 is not statistically different from each other. Pair C4 & C5 is significant at 95%. All other pairings are significantly different at 99%.

A and by gender in Panel B. As hypothesized, in Panel A, all mean property diminution scores are more severe for attorneys who typically represent the property owner. This can be seen in a downward shifting of values across home estimation values or by a simple comparison of overall mean scores. When comparing results by gender in Panel B, these differences are even more pronounced as evidenced by being statistically significant in four of the five comparisons.

Until now, consistent with the experimental design methodology, univariate statistics have been used to measure the effects of the hypotheses. While these are sufficient given that an experimental design holds all else constant, I now turn to a traditional hedonic model to address the potential differences that exist amongst the respondents. Specifically, in Exhibit 5, I examine via regression if gender, years of experience in eminent domain, or attorney type (property owner vs. condemnor) influences the results. Consistent with the prior exhibit, the multivariate analysis confirms the univariate statistics that females significantly penalize more severely properties associated with power lines. Moreover, attorneys who typically represent property owners appear more sympathetic to the magnitude of valuation impaction, while experience with eminent domain has no effect.

Exhibit 4 | Breakdown of Power Line Controls by Frequency of Price Decline, Attorney Type, and Gender

Estimated Home Value	C1-P	C1-C	C2-P	C2-C	C3-P	C3-C	C4-P	C4-C	C5-P	C5-C
Panel A: Attorney type										
$204,000 (+2%)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
$200,000 (0%)	6.7%	15.0%	8.5%	5.0%	6.5%	11.1%	1.6%	0.0%	1.7%	0.0%
$196,000 (−2%)	6.7%	15.0%	0.0%	0.0%	6.5%	5.6%	0.0%	0.0%	0.0%	0.0%
$192,000 (−4%)	25.0%	10.0%	8.5%	35.0%	8.1%	27.8%	1.6%	11.1%	1.7%	5.3%
$188,000 (−6%)	6.7%	10.0%	5.1%	5.0%	1.6%	0.0%	6.5%	11.1%	1.7%	5.3%
$184,000 (−8%)	16.7%	5.0%	6.8%	0.0%	8.1%	5.6%	4.8%	5.6%	5.0%	5.3%
$180,000 (−10%)	15.0%	30.0%	25.4%	5.0%	16.1%	0.0%	14.5%	11.1%	11.7%	15.8%
$176,000 (−12%)	18.3%	5.0%	10.2%	30.0%	9.7%	22.2%	12.9%	11.1%	11.7%	10.5%
Less than $176,000 (−14%)	5.0%	10.0%	35.6%	20.0%	43.5%	27.8%	58.1%	50.0%	66.7%	57.9%
Overall Mean Score	5.63	5.35	6.97	6.30	7.03	6.11	7.98	7.50	8.23	7.95

Exhibit 4 | (continued)

Breakdown of Power Line Controls by Frequency of Price Decline, Attorney Type, and Gender

Estimated Home Value	C1-M	C1-F	C2-M	C2-F	C3-M	C3-F	C4-M	C4-F	C5-M	C5-F
Panel B: Gender										
$204,000 (+2%)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
$200,000 (0%)	9.1%	8.3%	7.7%	8.3%	9.0%	0.0%	1.5%	0.0%	1.5%	0.0%
$196,000 (−2%)	9.1%	8.3%	0.0%	0.0%	6.0%	0.0%	0.0%	0.0%	0.0%	0.0%
$192,000 (−4%)	24.2%	0.0%	18.5%	0.0%	14.9%	0.0%	4.5%	0.0%	3.1%	0.0%
$188,000 (−6%)	6.1%	16.7%	6.2%	0.0%	0.0%	9.1%	7.5%	9.1%	3.1%	0.0%
$184,000 (−8%)	12.1%	25.0%	6.2%	0.0%	9.0%	0.0%	6.0%	0.0%	6.2%	0.0%
$180,000 (−10%)	19.7%	8.3%	18.5%	16.7%	14.9%	0.0%	14.9%	0.0%	12.3%	8.3%
$176,000 (−12%)	16.7%	8.3%	13.8%	25.0%	10.4%	27.3%	14.9%	0.0%	13.8%	0.0%
Less than $176,000 (−14%)	3.0%	25.0%	29.2%	50.0%	35.8%	63.6%	50.7%	90.9%	60.0%	91.7%
Overall Mean Score	5.44[c]	6.25[c]	6.60	7.83	6.60*	8.36*	7.75**	8.64**	8.05*	8.83*

Notes: This exhibit reports the respondents' opinion of the impact of each power line treatment on the value of the home. C1 represents Distant Power Lines; C2 represents Near Power Lines—No easement and No humming; C3 represents Near Power Lines—Easement, but No humming; C4 represents Near Power Lines—No easement, but with Humming; and C5 represents Near Power Lines—Easement and Humming. Panel A parses the results by attorney type where, *P* represents attorneys who represent property owners and *C* represents attorneys who represent the condemnor. Panel B segments the results by gender where *M* is for males and *F* is for females. Tests of statistically significant differences are performed between each Overall Mean Score pair (e.g., C1-P versus C1-C; C2-P versus C2-C, etc.) in both panels. All significance tests are based on independent samples *t*-tests after a Levene statistic is calculated to determine the appropriate assumption concerning homogeneity of variance.

*Significant at the 1% level.

**Significant at the 5% level.

Exhibit 5 | Regression Results for Power Line Controls

	Distant	Near			
Estimated Home Value	C1	C2	C3	C4	C5
Intercept	4.34*	5.71*	6.21*	6.79*	7.55*
	(1.22)	(1.32)	(1.45)	(1.00)	(0.83)
Gender	1.08	1.53**	1.90**	1.17**	0.91***
	(0.69)	(0.74)	(0.81)	(0.56)	(0.47)
Years of Eminent Domain Experience	0.10	0.08	−0.02	−0.10	0.02
	(0.12)	(0.13)	(0.13)	(0.09)	(0.08)
Attorney Type	−0.34	−0.82	−1.17***	−0.53	−0.41
	(0.55)	(0.59)	(0.64)	(0.44)	(0.39)
R^2	0.370	0.072	0.108	0.074	0.056
P-value	0.434	0.144	0.039**	0.130	0.239
F-Statistic	0.92	1.86	2.94	1.94	1.44

Notes: This exhibit reports regression estimates where the dependent variable is one of the five power line control variables and the independent variables represent respondent demographics. Specifically, C1 represents Distant Power Lines; C2 represents Near Power Lines—No easement and No humming; C3 represents Near Power Lines—Easement, but No humming; C4 represents Near Power Lines—No easement, but with Humming; and C5 represents Near Power Lines—Easement and Humming. *Gender* is set to 1 for males, and 2 for females; *Years of Eminent Domain Experience* is on a scale from 1 = 0–5 years, to 7 = more than 30 years; and *Attorney Type* is set to 1 for attorneys who typically represent the property owner, and 2 if the attorney typically represents the condemnor.
*Significant at the 1% level.
**Significant at the 5% level.
***Significant at the 10% level.

In an exploratory vein, in Panel A of Exhibit 6, I examine what might explain the differences in responses when moving from the treatment where power lines are distant versus when they are near. None of the respondent demographics are significant. As a robustness check, the same idea is measured as dummy variables where one represents the case where the respondent answered the same in both treatments, and zero otherwise. Again, none of the explanatory variables are significant.

Exhibit 6 | Regression Results for Differences in Power Line Controls

Estimated Home Value	C2-C1	C3-C1	C4-C1	C5-C1
Panel A: Difference scores				
Intercept	1.65***	0.10	1.00	1.77
	(0.09)	(1.17)	(0.91)	(1.15)
Gender	0.38	0.58	−0.24	−0.57
	(0.51)	(0.64)	(0.50)	(0.64)
Years of Eminent Domain Experience	−0.03	−0.09	0.01	−0.08
	(0.09)	(0.11)	(0.08)	(0.11)
Attorney Type	−0.54	−0.31	0.27	0.41
	(0.41)	(0.51)	(0.39)	(0.52)
R^2	0.031	0.033	0.010	0.022
P-value	0.516	0.503	0.874	0.661
F-Statistic	0.77	0.79	0.23	0.53
Panel B: Logistic regression dummy difference scores				
Intercept	4.26*	−0.23	−0.72	−0.01
	(1.56)	(1.31)	(1.32)	(1.24)
Gender	−1.05	−0.01	−0.02	−0.68
	(0.78)	(0.72)	(0.72)	(0.69)
Years of Eminent Domain Experience	−0.25***	0.07	0.08	0.06
	(0.15)	(0.12)	(0.12)	(0.12)
Attorney Type	−0.55	−0.35	0.08	0.85
	(0.63)	(0.58)	(0.60)	(0.61)
−2 Log Likelihood	76.11	98.97	97.56	95.04
Cox & Snell R^2	0.060	0.013	0.031	0.041
Negelkerke R^2	0.091	0.017	0.042	0.056
Predicted Correct Percentage	77.6%	59.5%	59.5%	62.2%

Notes: This exhibit reports regression estimates where the dependent variable is the difference between two of the five power line control variables and the independent variables represent respondent demographics. Specifically, C1 represents Distant Power Lines; C2 represents Near Power Lines—No easement and No humming; C3 represents Near Power Lines—Easement, but No humming; C4 represents Near Power Lines—No easement, but with Humming; and C5 represents Near Power Lines—Easement and Humming. *Gender* is set to 1 for males, and 2 for females; *Years of Eminent Domain Experience* is on a scale from 1 = 0–5 years, to 7 = more than 30 years; and *Attorney Type* is set to 1 for attorneys who typically represent the property owner, and 2 if the attorney typically represents the condemnor. Panel A reports results for first difference scores, while Panel B reports the results from logistic regressions where the dependent variables in Panel A are dummied where 1 means the scores changed between the power line treatments, 0 otherwise.
*Significant at the 1% level.
***Significant at the 10% level.

Conclusion

This study is the first to use an experimental design to more deeply examine the impact of power lines on property values. By using an experimental design, I am able to hold constant all outside factors and isolate the differential impact of power line location (near vs. far), easement rights, and noise pollution. In an examination of the overall impact of power lines, the findings show a diminution in value of as small as −4.9% (between no power lines and distant power lines). The distance from the home variable resulted in a price decline of approximately −2.5% ($4,960 on a $200,000 home), while noise pollution was closer to −2% ($3,920 on a $200,000 home). Easement rights are not statistically significantly different ($120), but interestingly, when combined with noise pollution, the result is more than the sum of its parts ($5,440 vs. $4,040).

Because I examined very specific attributes of power lines, it is difficult to directly compare the results to other studies, which are unable to truly isolate each variable. Moreover, like any study attempting to quantify subjective pricing component variables such as power lines, view, or property rights, I am careful not to claim this one study answers all power line value questions in all geographic areas for all time to come. Instead, readers are cautioned to think of this study as the first step in what I hope other researchers will help turn into a portfolio of examinations in order to create an entire picture of the elusive relations among power lines, easement rights, noise pollution, and so forth.

It should also be noted as a limitation that as demonstrated within the study, results can vary based upon the composition of the sample. I demonstrated the different responses from those attorneys who represent the property owner versus the condemnor. Might there also be differences between the buyers and sellers of these same properties? In general, it is reasonable to suppose that parties with a stake in the outcome of such an investigation might have different views on the magnitude of each effect. As such, readers are cautioned as to this possibility.

Finally, while I was careful to design an experimental environment where everything is held constant, it is always possible that what is found in the lab might not translate into the real world. Further, not all power lines are the same in terms of size, noise, view impaction, and so forth. As such, the results are no more generalizable than any other study (such as those that use transactions data). Where the study makes a contribution is in my ability to parse out very specific power line effects, such as the testing of noise pollution and easement rights, which is simply not possible using traditional methods.

Endnotes

1 The impact of proximity has been examined in reference to railways and similar means of transit in such studies as Gatzlaff and Smith (1993), Chen, Rufolo, and Dueker (1997), Haider and Miller (2000), Knaap, Ding, and Hopkins (2001), Weinberger (2001), Lin and Hwang (2003), Weinstein and Clower (2003), McMillien and McDonald (2004), Celik and Yankaya (2006), Hess and Almedia (2007), and Pan and Zhang (2008).

[2] For example, consider a property owner who wants to build a fence around his property. The local utility firm has power lines that hang high overhead across the corner of his property. If the owner fences in the yard, he is responsible for taking the fence down to grant access to the power company whenever they need to repair/maintain their power lines. As a result, the property owner will either bear the expense of removing and reinstalling the fence each time the utility company wants access, or more likely, will reluctantly not build the fence. Either way, the easement right should diminish the value of the property because it restricts the use/enjoyment of the property or requires extra cost to maintain it (in the scenario where the property owner builds the fence).

[3] In experimental designs, "treatments" represent specific scenarios that differ only by the variable of interest. It is a way to hold everything else constant in the model except the variable being tested.

[4] See Turnbull (2012) for a discussion of eminent domain practices.

[5] It seems to be the case then that (1) attorneys gravitate to the legal side that is truly consistent with their underlying valuation impaction beliefs, (2) attorneys have come to believe the position they sell in court every day, or (3) respondents were hoping to sway public opinion by providing answers that would help support their legal positions. Based on the analyses to follow, it seems reasonable to discount the likelihood that (3) is responsible for the results.

[6] In addition to common sense, evidence that important variables may be missing include a low adjusted-R^2 value associated with the hedonic model.

[7] For a detailed methodological discussion on behavioral methods, see Seiler, Madhavan, and Liechty (2012b) and Seiler (2014).

[8] Note that attorneys are offered the opportunity to indicate the property could either go up or down in value.

[9] The value for distant power lines is 5.56. Extrapolating, the 0.56 translates into $2,240 (0.56 × $4,000). The "5" corresponds to the price of $188,000. Taken together, the estimated value is equal to $190,240 ($188,000 + $2,240). Overall diminution is then equal to 4.9% ([$200,000 − $190,240]/$200,000).

[10] $4,000 × (6.80 − 5.56) = $4,960.

[11] The noise pollution effect is measured as $4,000 × (7.78 − 6.80) = $3,920; the easement effect is quantified as $4,000 × (6.83 − 6.80) = $120.

[12] $5,440 ($4,000 × [8.16 − 6.80]) > $4,040 ($4,000 × [7.78 − 6.80]) + $120 ($4,000 × [6.83 − 6.80]).

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"Not in My Backyard": The Effect of Substance Abuse Treatment Centers on Property Values

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Abstract Residential treatment centers offer the most intense form of treatment for substance abuse and are often embedded in residential neighborhoods. As a result of the Patient Protection and Affordable Care Act, the number of treatment centers has been forecasted to burgeon. We examine the external effect of residential rehab centers on nearby real estate. As addiction treatment centers are planned, a common response of nearby property owners is "not in my backyard" (NIMBY). Using a large MLS dataset from central Virginia, we estimate the impact of substance abuse treatment centers on nearby home prices and liquidity (as measured by time on market). We find that a neighboring treatment center is associated with an 8% reduction in nearby home prices, and that this discount is magnified for treatment centers that specifically treat opiate addiction (as much as 17%).

The primary residence is perhaps the greatest single investment made by an individual and the mantra "location, location, location" is an ever-present concern of a prospective buyer. Before purchasing a home, a savvy buyer will frequently research the community and the school system, as well as the crime statistics. When homeowners are made aware of an application for a special use permit for the possibility of an addiction treatment center being located in their neighborhood, initial concern for personal and household safety, followed by the stark realization that home values in their neighborhood may be adversely affected, almost always lead homeowners to the universal response of "not in my backyard" (NIMBY). The typical opposition to a proposed substance abuse treatment facility is based on two visceral concerns: an increase in crime risk and a related decrease in property values. The primary purpose of this paper is to examine the latter claim empirically, determining whether there is significant evidence that treatment centers have a negative impact on nearby real estate.

Ex ante, it is not clear that substance abuse treatment centers will adversely impact neighboring real estate, which motivates our empirical examination of this externality. On one hand, there may be a priori reasons to suspect that treatment facilities will not have much of an impact on neighboring real estate. Locating addiction treatment centers in residential areas has become commonplace.

Treatment centers tend to be inconspicuous and may have blackout curtains and minimal signage (or no sign). The housing is often gated and locked at a certain time of the day. Generally, clients enrolled in residential treatment programs are not allowed to interact with the ''locals'' of the neighborhood or leave the premises. Under current law (discussed in the next section), despite their challenges, residential treatment centers have relatively few limitations on where they are sited.

On the other hand, like many negative externalities or NIMBY issues, there are reasons to suspect that rehab facilities may adversely impact neighboring real estate. Substance abuse is a multifaceted health issue and many patients in residential treatment have a dual diagnosis: a mental health issue and an addiction (Connery, 2011). The Substance Abuse Mental Health Services Administration (SAMHSA, 2008) surveyed 14,423 facilities in 2008 and had a response rate of 94.1%. The SAMHSA survey indicated that 39% of the clients in treatment centers had a dual diagnosis. In addition, concurrent alcohol and drug addiction accounted for approximately 45%, while clients in treatment solely for drug abuse accounted for 34%–36% and 18%–20% of the patients only abused alcohol (SAMHSA, 2008).

One consequence of locating drug and alcohol rehabilitation centers in residential areas is that patients in substance abuse treatment programs frequently leave or are administratively discharged before successful completion. At some point, experts say that, ''relapse is an almost unavoidable—and potentially useful—step in recovery'' (Shaffer, 2012). For many, intensive residential treatment is a ''last resort.'' A healthy family of an addict will decline to ''enable'' negative behavior and, instead, will insist that the alcoholic/addict experience the ''consequence'' of the decision to use again and refuse treatment. In other words, the family will often not offer any form of financial support and the addict will have to fend for himself or herself. In addition to having a substance abuse disorder and possibly a dual diagnosis, those who relapse and leave treatment prior to completion often have limited job skills and perhaps even a criminal record—factors that make employment a challenge. Thus, as a practical matter, nearby neighbors may have valid concerns that the presence of a treatment center will be accompanied by additional unemployed or even homeless addicts on the street near the area in which the treatment center is located. This perception of elevated risk in these areas may then be reflected in the market prices of nearby real estate.

The likely occurrence of relapse combined with the probability of criminal charges and/or convictions associated with substance abuse corroborates the argument that the presence of a treatment center may bring objectionable consequences into a community. The purpose of this paper is to use market data to assess whether there is substantial evidence of nearby real estate being adversely impacted by the presence of treatment centers, consistent with the potential risks that proximity to these facilities may bring. As a clear-cut NIMBY issue, this paper contributes to the broader literature of examining the market effects of specific externalities or environmental factors in real estate. Our study contributes to the literature by being the first to examine the effect of substance abuse treatment centers on the surrounding real estate market and, more generally, adding to our understanding of external factors that impact home prices.

Substance Abuse Treatment: Salient Issues, Recent Trends, and Related Literature

It is anticipated that the impact of the July 1, 2014 changes to insurance coverage under the Affordable Care Act (ACA) will cause the number of treatment centers to burgeon and thus, a study of the effect of nearby addiction treatment centers on real estate is timely. Prior to investigating treatment centers' effects on nearby real estate, it is crucial to understand the background of substance abuse treatment and why the current issues motivate the examination of potential real estate externalities.

Although accurate statistics of drug or alcohol disorders are difficult to obtain, according to a Harvard Medical School Special Health Report, between 15% and 28% of Americans will have a substance use disorder sometime during their lifetime and this estimate does not include addiction to nicotine (Shaffer, 2012). Residential treatment has become a more common way to treat addiction and, like many areas in healthcare services, residential rehabilitation has become a growth industry.

Broadly speaking, there are three types of treatment centers: intensive outpatient program (IOP), inpatient treatment, and partial hospitalization program (PHP). Typically, IOP treatment centers offer each client nine hours of group therapy, one hour of individual therapy, and one hour of case management (managing auxiliary services) per week. IOP clients either live in a halfway house or at home with strict guidelines established by their primary therapist. Although halfway houses can vary greatly, they generally have full-time house managers and mandatory, random urinalysis. Inpatient programs require clients to live at the facility in which all treatment takes place and may either be freestanding or hospital-based. PHP, also known as the ''Florida model,'' is a hybrid version of inpatient treatment and intensive outpatient treatment: individuals go to a counseling center during the day, and after a full day of therapy sessions return to off-site housing located in a neighborhood. Behavioral health technicians work at the off-site facilities around the clock.

Mandatory addiction treatment (commitment) does not exist under the law. An addict must choose to be in a recovery program. It is interesting to note that all three of the substance abuse treatment models include the possibility of group housing in neighborhood settings.

Projected Increase in SUD Treatment Facilities: MHPAEA and the ACA

The Patient Protection and Affordable Care Act (PPACA), also known as Obama Care, made sweeping changes to Mental Health/Substance Use Disorder

(MH/SUD) insurance coverage that went into effect on July 1, 2014. To understand the ramifications for residential treatment centers, it is necessary to briefly examine the legislative history of MH/SUD insurance coverage. Prior to July 1, 2014, the high cost of MH/SUD treatment meant that it was only available to patients with (or whose families have) considerable means, or those whose health insurance provided coverage. The Mental Health Parity and Addiction Equity Act of 2008 (MHPAEA) attempted to address the unequal treatment of MH/SUD health insurance coverage and legislated equal treatment between MH /SUD benefits and medical/surgical benefits. If a plan had MH/SUD coverage, then it must be on par with the medical/surgical benefits offered under that policy. The MHPAEA did not mandate that an insurance policy must cover MH/SUD and only applied to group health plans sponsored by employers with 50 or more employees. Both individual and small employer group policies were specifically exempted from coverage (MHPAEA Fact Sheet).

The PPACA mandates that MH/SUD coverage be included in marketplace health insurance policies as an ‘‘essential health benefit’’ as of July 1, 2014 (MHPAEA Fact Sheet). The effect of inclusion of MH/SUD coverage as an essential health benefit is that the MH/SUD parity rules now apply to non-grandfathered individual and small group plans (Beronio, Po, Skopec, and Glied, 2013). With expansion of the ‘‘parity rules’’ and inclusion of MH/SUD coverage as an essential health benefit under the ACA, it is anticipated that the number of patients having access to expensive addiction treatment options will grow exponentially, as will the number of treatment centers.

Antidiscrimination Housing Laws

When a proposed treatment center is sited, concerned members of the community frequently pressure lawmakers or hire attorneys, causing treatment centers to fight protracted legal battles that attempt to prevent the opening of the center. However, numerous laws hinder such NIMBY efforts, providing legal basis for treatment centers to be located just about anywhere. There are several federal laws that prohibit discrimination in housing based on a ‘‘disability’’ and define disability as: ‘‘Any person who has a physical or mental impairment that substantially limits one or more major life activities; has a record of such impairment; or is regarded as having such impairment’’ (HUD).

Substance abuse disorders are clearly recognized disabilities and thus are covered under fair housing laws. Federal housing laws that prohibit disability-based discrimination and ensure equal housing opportunities are briefly discussed below.

Fair Housing Act. The Fair Housing Act (FHA) was designed to prohibit discrimination in housing. In 1988, the FHA was amended to include persons with handicaps to the protected classes under the FHA, 42 U.S.C. §3604(f)(3)(B). The definition of ‘‘handicap’’ under the FHA is very broad, and drug addiction and alcoholism are considered to be disabilities that are covered. The FHA also has a provision (42 U.S.C. §3604(f)(9)) that permits the exclusion of those ‘‘whose tenancy would constitute a direct threat to the health or safety of other individuals or ... would result in substantial physical damage to the property of others.’’ Thus, the FHA does not protect an individual currently using illegal drugs or a person with a conviction of distributing or illegally manufacturing a controlled substance.

The FHA covers almost every aspect of a real estate transaction. According to the Act, it is illegal to discriminate in the sale or rental of a dwelling against a person with a disability. Thus, an alcoholic/addict cannot be denied housing based solely on his or her addiction. The Act does permit ''reasonable local, State or Federal restriction regarding the maximum number of occupants permitted to occupy a dwelling'' 42 U.S.C. §3607(b)(1). This exemption is for living space per occupant and is intended to promote health and safety, not exclude group homes from residential areas.

Although a person with a conviction for dealing or illegally manufacturing a controlled substance is not protected under the FHA, a drug distribution conviction does not automatically exclude a person from invoking the Rehabilitation Act or the Americans with Disabilities Act.

Rehabilitation Act. §504 (45 CFR Part 84) of the Rehabilitation Act of 1973 prohibits any entity from receiving federal funds from discriminating on the basis of a disability. Drug addiction and alcoholism are covered under this act as well. Communities have attempted to use zoning laws to exclude treatment centers. Under §504, if a community's zoning regulation excludes substance abuse treatment centers, that community risks losing its federal funds.

Americans with Disabilities Act. Among other things, the purpose of Title II of the Americans with Disabilities Act (ADA) is to eliminate discrimination in housing against people with disabilities. This Act has further reach than §504 of the Rehabilitation Act because the receipt of federal funds is not required for Title II of the ADA to apply.

Zoning and Case Law. Zoning regulations create perhaps the biggest barrier to entry for a substance abuse center. As a practical matter, when considering a proposed site for a treatment center, the owners prefer to avoid spending a lot of time and money fighting a protracted court battle associated with a zoning ordinance. This mindset, however, did not stop a significant case from being appealed to the United States Supreme Court by Oxford House, a self-supporting, resident-run, residential treatment program. In the landmark case of *City of Edmonds v. Oxford House, Inc.*, et al., 514 U.S. 725 (1995), the City of Edmonds attempted to use an occupancy restriction in a zoning ordinance to exclude treatment centers from residential areas. The zoning ordinance in question allowed an unlimited number of related persons to live in a home and attempted to restrict the number of unrelated persons living in a single-family dwelling to five. The City of Edmonds claimed that the §3607(b)(1) exemption to the FHA applied to the city's zoning ordinance. In a 5–4 decision, the Supreme Court held that a zoning ordinance that defined a family in such a way as to exclude treatment centers was unlawful. The ordinance was not a maximum occupancy provision but a provision describing who may compose a ''family'' and, thus, it violated the FHA. This case was a critical victory for the ''Oxford House Model'' because this community-based treatment program leases houses located in upscale neighborhoods across the U.S.

The bottom line is that there must be a ''rational basis'' for zoning regulation to be valid and localities have consistently been prohibited from discriminating against substance abuse treatment centers. Absent drastic changes to the laws outlined above, it is clear that residential centers are here to stay, and that if challenged in court, NIMBY proponents will have an uphill battle. Thus, given the growth trends in this industry, the potential risks posed to neighbors, and the laws that protect the treatment centers' rights to locate almost anywhere, what is the consequence for real estate when a treatment center is located in one's ''backyard,'' so to speak?

Related Literature in Real Estate

Researchers have long recognized that numerous externalities impact the marketing outcomes of residential real estate. These externalities may include, for example, neighboring pollution,[1] or even the condition of adjoining or nearby properties and/or the tenant's behavior living in such properties. Real property has intangible benefits or disamenities, which are determined largely by public perception and capitalized into the pricing and marketing duration of residential properties. Furthermore, negative externalities are likely to significantly impact the marketing outcomes of properties in close proximity to the properties being marketed for sale, as well as impact the desirability of the overall neighborhood. Such ''stigma'' events are likely to be correlated with an exodus of higher income residents causing a ''snowball'' effect in declining property values (McCluskey and Rausser, 2003).

There are a number of researchers who analyze the degree to which external or neighborhood factors, both positive and negative, are capitalized in residential real estate marketing outcomes. For example, Thaler (1978) finds a negative relationship between neighborhood crime rates and property values. Gibbons (2004) finds an inverse relationship between vandalism and property values in London. As one would expect, robbery and aggravated assault rates have a significant and negative impact on property values (Ihanfeldt and Mayock, 2010). Pope (2012) found that decrease in crime rates had a positive effect on property values, particularly in those cities with substantial decreases in crime rates. Using a microspatial approach, Rosiers (2002) examined the impact of the visual encumbrance of power lines on property value and finds that on average it negatively impacts value by approximately 10%, but increases to 14% in areas where setback in property lines are less.

As a result of the recent economic and housing collapse, there are several studies that have examined the impact of foreclosed properties. Foreclosed properties may present a variety of negative effects on neighboring properties, including (but not limited to) the ''eyesore effect'' where neighboring foreclosures that have long been vacant adversely impact the aesthetic appeal of the neighborhood. Such studies include Harding, Rosenblatt, and Yao (2009), Lin, Rosenblatt, and Yao (2009), Daneshvary, Clauretie, and Kader (2011), Daneshvary and Clauretie (2012), and Agarwal, Ambrose, Chomsisengphet, and Sanders (2013). Generally, these studies find negative neighborhood spillovers from foreclosed or distressed properties.

A review of the literature does not reveal any specific examples of residential drug rehabilitation centers and their impact on neighboring property values. However, there is analogous literature of undesirable neighbors impacting property values. For example, Congdon-Hohman (2013) finds a significant and negative effect on home values located within one-eighth of a mile of a methamphetamine lab. The effect dissipates both as time passes after the discovery of and distance from a meth lab. Reichert, Small, and Mohanty (1992) estimate the impact of landfills on nearby real estate, finding a negative impact when located within several blocks of an expensive housing area. They find an effect that ranges from 5.5% to 7.3%, depending on the distance from the landfill. Indeed, the authors find that the percentage impact on older, less expensive properties to be significantly less (3%–4%) relative to the more expensive properties. Similarly, Hite, Chern, Hitzusen, and Randall (2001) find significant differences in property values located within 3.25 miles of a landfill.

Other studies have shown that a variety of other external factors affect real estate market outcomes. Coulson and Leichenko (2001) find that designated properties, as well as neighboring properties, are significantly impacted by historical designations. Other examples include the impact of registered sex offenders on the marketing outcomes of neighboring properties. Three recent studies have examined the impact as to the proximity of registered sex offenders. Most recently, Wentland, Waller, and Brastow (2014) found that close proximity to sex offenders rendered large price and liquidity effects, declining but significant out to one mile. The authors also found amplified effects for homes with more bedrooms, a proxy for children, and whether the nearby offender was convicted of a violent sex offense. Linden and Rockoff (2008) found significant reductions in home prices across radii of less than 0.1 miles and 0.1 to 0.3 miles when an offender moves in. Pope (2008) found properties located within 0.1 miles of a sex offender significantly reduced home values.

Data

We use residential real estate data from a multiple listing service (MLS) located in central Virginia, including Richmond and other surrounding areas. MLS data are critical for any externality study, particularly those that analyze both time on market and price, because it contains both the list date and sell date (or withdraw date) of residential properties, while tax data and other publically available data usually only include the property's date of sale. This is critical because nearby amenities or disamenities may be capitalized into a home's price, liquidity, or some combination of the two. In this study, we examine both. While the expected sign of living near a potential disamenity is likely negative for the price estimates, the estimated impact on liquidity is theoretically ambiguous. While the disamenity may lower the arrival rate of potential buyers, lengthening the time on market, the seller may be willing to discount the home in part to counteract this effect.

The sample is composed of listings in the residential real estate market over approximately a decade, between 2001 and 2011. The initial housing data contains 207,793 observations (including both sold and unsold properties). Among others, Levitt and Syverson (2008) point out that MLS data are entered by real estate agents and can be incorrect or incomplete. The data were carefully examined in light of common issues prevalent in the data. After culling for incomplete, missing or illogical data that suggest data entry errors or extravagant outliers, the final data set consists of approximately 194,983 homes on the market, with approximately 111,580 that eventually sold.[2] The MLS data include numerous property characteristics (square footage, bedrooms, baths, age, acreage, etc.) and, of course, each property's location.

Our MLS data are a fairly representative housing market in the U.S., which includes urban, suburban, and rural sales. Richmond is a medium-sized city located in the eastern part of central Virginia and the MLS covers much of the ''Greater Richmond'' area (or Richmond MSA). The average property in this MLS has a listing and selling price of $263,641 and $242,116, respectively. The average listed property was 25 years of age, with 2,143 square feet, 3.6 bedrooms, and 2.4 bathrooms with an average time on market of 85 days. During this time period, there were 36 substance abuse treatment centers located within the broader region encompassing the listings in our data, and nine were located within the city limits of Richmond specifically.[3] See Exhibit 1 for additional descriptive statistics.

The primary source of the treatment center externality is its proximity to a given home on the market. Intuitively, there is likely an increasing NIMBY sentiment as the proximity to the center is closer in distance. Thus, we compute the distance from a given home in the MLS and each treatment center, using address data to code the longitude and latitude from which the straight-line distance is calculated using the great-circle formula. While NIMBY does not literally refer to one's ''backyard,'' it is usually taken to mean very close proximity, but the definition of what qualifies as ''very close proximity'' may be different depending on the person and the issue. Below we examine the effect of nearby substance abuse treatment centers on nearby real estate, using different spatial proximities (e.g., 0.175 miles, 0.15 miles, and 0.125 miles) as a robustness check.[4]

Empirical Methodology

Our primary goal is to isolate the effect of a treatment center on neighborhood real estate outcomes. Numerous studies have examined other neighborhood externalities, using a variety of empirical approaches.[5] Initially, we focus on a treatment center's effect on the sale price and liquidity of a home, utilizing a cross-sectional OLS hedonic pricing model as the baseline. While hedonic pricing models are commonly used to determine the value of specific property attributes and surrounding (dis)amenities by estimating marginal effects on the sale price of the property,[6] we also explore a simultaneous equation model to account for the joint determination of both price and liquidity. The purpose of exploring multiple approaches is to demonstrate that the results are not particularly sensitive to the choice of modeling technique.

Baseline OLS Hedonic Models

Beginning with a simple cross-sectional approach, we provide a baseline estimate of the effect of a nearby substance abuse treatment center, employing a traditional

Exhibit 1 | Summary Statistics

Variable	Mean	Std. Dev.
List Price ($)	263,641	142,300
Sale Price ($)	242,116	127,608
Time on Market (in Days)	85.45	79.99
Rehab Center (Dummy Var. = 1 if the home is near a rehab center (distance specified in each table), 0 otherwise)	0.0003	0.02
Age (in Years)	24.99	26.16
Acreage	0.79	1.91
Square Feet	2,143.29	888.25
Bedrooms	3.60	0.77
Bathrooms	2.38	0.82
Foreclosure (Dummy Var. = 1 if foreclosure, 0 otherwise)	0.02	0.12
Number of levels	1.83	0.65
Pool (Dummy Var. = 1 if the home has a pool, 0 otherwise)	0.05	0.23
Basement (Dummy Var. = 1 if they have a basement, 0 otherwise)	0.17	0.38
Short Sale (Dummy Var. = 1 if short sale, 0 otherwise)	0.02	0.13
Tenant (Dummy Var. = 1 if it has a tenant at listing, 0 otherwise)	0.03	0.16
Vacant (Dummy Var. = 1 if the home is vacant, 0 otherwise)	0.36	0.48
Taxes	1,779.95	1,311.74
HOA Fees (Dummy Var. = 1 if it has HOA fees, 0 otherwise)	0.32	0.47
Listing Density	64.41	577.40
Competition	582.22	1,062.08

Note: Location and year fixed effects summary stats omitted.

hedonic model that accounts for heterogeneous characteristics of both homes and their locations. We estimate the following functional forms:

$$SP_i = \varphi_P(X_i, LOC_i, T_i, TOM_i) + \varepsilon \quad (1)$$

and

$$TOM_i = \varphi_P(X_i, LOC_i, T_i, LP_i) + \varepsilon, \quad (2)$$

where SP_i is a vector for property selling price,[7] LP_i is a vector for property listing price X_i is a vector of property specific characteristics,[8] LOC_i is a vector for location control using ZIP Codes (see below), T_i, the variable of interest, equals

1 if a treatment center is located nearby of a given $home_i$ and is 0 otherwise, TOM_i is the time on market (in days), which the literature also calls marketing duration or a measure of liquidity, and ε is an error term that is heteroskedastic-consistent and clustered by ZIP Code.[9]

Hedonic analysis of the housing market requires some control for spatial heterogeneity because location itself is a key source of differences in housing prices. The goal is to disentangle specific proximity to a treatment center from broader location differences that explain real estate prices. Following numerous studies in the real estate and urban economics literature, we chose ZIP Code fixed effects to control for unobserved heterogeneity *across* these areas so that the explanatory variables' effects are identified from variation *within* a given area (or even in a given year, as is the case for time fixed effects). In effect, our results may then be interpreted as the treatment center's effect on home prices given comparable homes within the same ZIP Code, but located further away. In this sense, we are attempting to disentangle the broader location effect from the proximity to a treatment center by essentially comparing homes within a certain ZIP Code. Further, we explore alternative location controls (census tracts, block groups, and blocks) in a similar vein, as well as altering the control group itself by confining it to narrow bands around a rehab facility. Appropriate location controls can disentangle the negative externality effect from simply a ''bad neighborhood'' or ''bad part of town'' effect.

Simultaneous Equations Approach: System Identification

Numerous studies in real estate and urban economics model price and time on market in a simultaneous system (like 2SLS or 3SLS) given likely joint determination of these factors. A seller can always lower price to increase liquidity, and vice versa. Yet, a home's sale price and time on market are determined by virtually identical factors. Econometrically, this creates an identification problem because if one wants to model this simultaneity with a system of equations, then, by definition, such a system could not be identified using identical exogenous variables. While a number of empirical studies acknowledge this simultaneity,[10] Turnbull and Dombrow (2006) and Zahirovic-Herbert and Turnbull (2008) have identified a novel way of overcoming this identification problem through their incorporation of variables that represent market conditions from other listings on the market. Below we summarize a solution to this identification issue, as we utilize an adapted form of this approach to model price and liquidity in a simultaneous system.

Following Krainer's (2001) search market model, one can model a home's expected liquidity, $E[TOM]$, (measured as a home's marketing duration or time on market) and expected house sale price, $E[SP]$, as simultaneously determined and implicitly defined as:

$$F(E[SP], E[TOM], T, X, LOC, C) = 0, \tag{3}$$

where T is an indicator of whether a home is near a rehab treatment center, X is a vector of house (and market) characteristics, LOC is location controls, and C are neighborhood market conditions. The latter variable, C, represents neighborhood market conditions that have an ambiguous external effect on local properties. On one hand, when the number of nearby homes that go on the market increases, the supply of additional homes on the market ought to negatively impact the price and liquidity of a nearby home (i.e., "a competition effect"). On the other hand, the increased traffic generated from additional nearby homes on the market could actually positively impact a home's price and liquidity, which is termed "a shopping externality effect." Empirically, the sales price and time on market can be represented as separate functions with jointly distributed stochastic errors ε_p and ε_T:

$$SP = \varphi_p(TOM, T, LOC, X, C) + \varepsilon_p \tag{4}$$

and

$$TOM = \varphi_T(SP, T, LOC, X, C) + \varepsilon_T. \tag{5}$$

The vector C (i.e., market conditions or neighborhood competition) and another vector, L (i.e., listing density), are the keys to Turnbull and Dombrow's (2006) solution to over-identifying this system of equations (since equations 3 and 4 are not yet identified). Neighborhood competition, C, is a measure that accounts for "nearby houses for sale as long as each competing listed house overlaps with the period that this house is on the market, inversely weighted by the distance between the houses to reflect the assumption that nearby houses will have stronger effects on the sale of this house than houses that are farther away" (Zahirovic-Herbert and Turnbull, 2008).[11] Listing density, L, is similarly defined as "the measure of competing overlapping listings per day on the market" (Zahirovic-Herbert and Turnbull, 2008), where: $L(i) = \Sigma_j(1 - D(i, j))^2\{\min[s(i), s(j)] - \max[l(i), l(j)]\}/s(i) - l(i) + 1$. Essentially, both measures capture neighborhood market conditions by quantifying the marketing overlap of nearby homes on the market simultaneously, however, listing density is weighted by time on market. Turnbull and Dombrow (2006) point out that a change in competition while holding selling time constant is also the partial derivative with respect to listing density (and it is easy to see that $\partial\varphi_p/\partial C \equiv \partial\varphi_p/\partial L$). Therefore, we can rewrite our system of equations to reflect:

$$SP = \varphi_p(TOM, T, LOC, X, L) + \varepsilon_p \tag{6}$$

and

$$TOM = \varphi_T(SP, T, LOC, X, C) + \varepsilon_T. \quad (7)$$

Both L and C vectors uniquely identify the simultaneous system. Further, we supplement this approach by using different location controls across equations.[12] We estimate the system of equations (5) and (6) using three-stage least squares (3SLS) in the next section to generate a coefficient estimate of the effect of a nearby treatment center on price and time on market. We model simultaneity using a 3SLS approach because it incorporates an additional step with seemingly unrelated regression (SUR) estimation to control for correlations between error terms.[13]

Alternative Specifications and Robustness

While the baseline results include location controls, an additional way to isolate the treatment effect of a rehab facility is by limiting the control group to homes closer to rehab facilities more generally (i.e., omitting observations sufficiently far from any rehab facility). Methodologically, the comparison is then between homes that are near a rehab treatment facility and homes just outside a given range. Specifically, we explore the effect of a rehab center (within 1/8 mile) on nearby real estate as compared to similar homes further out (i.e., within 1.5 miles, 1 mile, and 2/3 mile, respectively). This approach allows us to further homogenize location as a robustness check, and to provide additional evidence that the external effect is specific to the rehab facility, and not simply the part of town in which it is located.

We also examine whether facilities that only treat opiate addicts (commonly known as methadone clinics) have a larger impact on nearby real estate. Clinics that treat heroin or prescription addicts, for example, often use buprenorphine or methadone as part of the rehabilitation process. Nearby residents may perceive patients who are still intoxicated, albeit at a lower dose, as an elevated crime risk. Approximately half of the 36 treatment centers in our sample only treat opiate addiction (hereinafter referred to as methadone clinics). We examine whether nearby real estate is more affected by methadone clinics specifically.

Results

Baseline OLS Results

The baseline OLS results provide evidence that nearby treatment centers adversely impact surrounding home values, but have little if any impact on property liquidity. Estimating equations (1) and (2), Exhibit 2 shows that this adverse effect is not qualitatively sensitive to the choice of the definition of "nearby." Column 1 shows that the presence of a rehab center within 0.125 (1/8) miles is associated with

Exhibit 2 | Effect of a Nearby Rehab Center on a Home's Price and Liquidity: Baseline OLS Results

	Dependent Variable: *ln*(*Sale Price*)			Dependent Variable: *ln*(*Days on Market*)		
	(1)	(2)	(3)	(4)	(5)	(6)
Rehab Center ≤ 0.125 Mile	−0.0796**			−0.0513		
	(−1.97)			(−0.28)		
Rehab Center ≤ 0.15 Mile		−0.0623**			0.1101	
		(−2.20)			(0.76)	
Rehab Center ≤ 0.175 Mile			−0.0517**			0.1190
			(−2.49)			(1.10)
ln(Age of Home)	−0.0649***	−0.0649***	−0.0649***	0.0213***	0.0213***	0.0213***
	(−19.07)	(−19.07)	(−19.08)	(2.71)	(2.71)	(2.71)
Acreage	0.0206***	0.0206***	0.0206***	0.0203***	0.0203***	0.0203***
	(13.39)	(13.39)	(13.39)	(4.47)	(4.46)	(4.46)
Sq. Ft.	0.0003***	0.0003***	0.0003***	−0.0000	−0.0000	−0.0000
	(15.38)	(15.38)	(15.38)	(−0.50)	(−0.50)	(−0.50)
Bedrooms	−0.0075	−0.0075	−0.0075	0.0441***	0.0441***	0.0441***
	(−0.99)	(−0.99)	(−0.99)	(5.06)	(5.07)	(5.06)
Bathrooms	0.0390***	0.0390***	0.0390***	−0.0517***	−0.0517***	−0.0517***
	(6.30)	(6.30)	(6.30)	(−5.34)	(−5.34)	(−5.33)
Foreclosure	−0.1691***	−0.1691***	−0.1691***	−0.3936***	−0.3938***	−0.3939***
	(−20.60)	(−20.60)	(−20.60)	(−15.90)	(−15.91)	(−15.93)
Number of Levels	−0.0055	−0.0055	−0.0055	0.0419***	0.0418***	0.0418***
	(−1.17)	(−1.17)	(−1.17)	(4.93)	(4.93)	(4.93)
Pool	0.0334***	0.0334***	0.0334***	0.0060	0.0060	0.0060
	(3.61)	(3.61)	(3.60)	(0.18)	(0.18)	(0.18)
Basement	0.0418***	0.0418***	0.0418***	0.0045	0.0046	0.0046
	(3.15)	(3.15)	(3.15)	(0.23)	(0.23)	(0.23)

Exhibit 2 | (continued)

Effect of a Nearby Rehab Center on a Home's Price and Liquidity: Baseline OLS Results

	Dependent Variable: *ln*(*Sale Price*)			Dependent Variable: *ln*(*Days on Market*)		
	(1)	(2)	(3)	(4)	(5)	(6)
Short Sale	−0.0935***	−0.0935***	−0.0935***	0.3775***	0.3775***	0.3775***
	(−12.68)	(−12.68)	(−12.67)	(18.07)	(18.08)	(18.07)
Tenant	−0.0815***	−0.0815***	−0.0815***	0.2479***	0.2479***	0.2479***
	(−10.10)	(−10.10)	(−10.10)	(11.82)	(11.81)	(11.81)
Vacant	−0.0279***	−0.0279***	−0.0279***	0.1207***	0.1207***	0.1207***
	(−6.56)	(−6.56)	(−6.57)	(7.44)	(7.43)	(7.43)
Taxes ($)	0.0001***	0.0001***	0.0001***	−0.0000	−0.0000	−0.0000
	(6.81)	(6.81)	(6.81)	(−1.23)	(−1.23)	(−1.23)
HOA Fee	0.0715***	0.0715***	0.0715***	−0.0690***	−0.0691***	−0.0690***
	(7.11)	(7.11)	(7.11)	(−3.26)	(−3.26)	(−3.26)
ln(*Days on Market*)	0.0003	0.0003	0.0003			
	(0.21)	(0.21)	(0.21)			
ln(*List Price*)				0.6486***	0.6487***	0.6487***
				(9.34)	(9.34)	(9.34)
Constant	11.4723***	11.4723***	11.6581	−5.6213***	−5.6222***	−5.6225***
	(171.71)	(171.70)	(0.07)	(−6.69)	(−6.69)	(−6.69)
Location Controls (ZIP Code)	√	√	√	√	√	√
Year Fixed Effects	√	√	√	√	√	√

Notes: This table presents results of hedonic OLS models showing the effect of a nearby (i.e., within 0.125 mile, 0.15 mile, and 0.175 mile) rehab facility on a property's sale price and time on market (errors clustered by ZIP Code). *T*-statistics are in parentheses. The number of observation in columns 1–3 is 117,187; the number of observation in columns 4–6 is 206,420.

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

approximately an 8% reduction in home values. The corresponding impact on time on market is not statistically significant at any conventional level, providing initial evidence that the externality is primarily capitalized into home prices, rather than liquidity. Indeed, columns 2 and 3 show that homes sold for approximately 6% or 5% less if they were located within 0.15 miles or 0.175 miles of a rehab center, respectively. While qualitatively similar, these coefficient estimates also provide some evidence that the externality may be diminishing in distance, as additional, further properties are included in the latter estimates. The regressions tabulated in columns 5 and 6 tell approximately the same story as column 4, in that there is little evidence that rehab centers have a statistically significant impact on a home's liquidity.

The real estate literature has not adopted a single way to control for spatial heterogeneity. In Exhibit 3 we examine a few common alternatives to controlling for location. The initial estimates in Exhibit 2 use ZIP Codes to control for spatial heterogeneity. In Exhibit 3, we use census tract fixed effects (columns 1 and 4), block group fixed effect (columns 2 and 5), and block fixed effects (columns 3 and 6). Census tracts, according to the U.S. Census, are ''small, relatively permanent statistical subdivisions of a county ... designed to be homogenous with respect to population characteristics, economic status, and living conditions.''[14] Census block groups are subsets of census tracts; and, blocks are further subsets of block groups. One can think of these as different measures of ''neighborhoods,'' broadly to more narrowly defined. The results from the price regressions in Exhibit 3 are consistent with Exhibit 2, falling within a fraction of a percentage point of one another, with an effect of approximately 7.2% to 7.9%. Columns 4–6 in Exhibit 3 also show that substance abuse treatment centers are not associated with a statistically significant impact on nearby property liquidity. Overall, it is clear that the estimates of the effect of a substance abuse treatment center on nearby real estate is not particularly sensitive to the choice of location controls, providing evidence that the external effect of substance abuse treatment centers is robust.

Simultaneous Equation Results

When price and time on market are modeled within a simultaneous 3SLS system of equations, the estimated effect of a nearby substance abuse treatment center on home price and liquidity are similar to the OLS results, finding that nearby substance abuse treatment centers are associated with an approximately 8% drop in home values (within 1/8 mile). Column 1 in Exhibit 4 displays this result. Like the initial OLS results, the 3SLS estimations also show that substance abuse treatment centers have little impact on nearby property liquidity, as the externality appears to be capitalized into price exclusively. Exhibit 4 provides additional evidence that the external impact of substance abuse treatment centers is robust to multiple modeling approaches that are common in empirical real estate studies.

Exhibit 4 also provides evidence that not all substance abuse treatment centers may be perceived by nearby residents as presenting equal risk. It is possible that methadone clinics have a greater NIMBY sentiment from the broader community. We test this proposition empirically by exclusively examining the effect of

Exhibit 3 | Effect of a Nearby Rehab Center on a Home's Price and Liquidity with Different Location Controls

	Dependent Variable: *ln*(*Sale Price*)			Dependent Variable: *ln*(*Days on Market*)		
	(1)	(2)	(3)	(4)	(5)	(6)
Rehab Center ≤ *1/8 Mile*	−0.0720**	−0.0787**	−0.0744**	−0.0695	−0.0919	−0.0520
	(−2.01)	(−2.16)	(−2.25)	(−0.41)	(−0.55)	(−0.32)
ln(*Age of Home*)	−0.0683***	−0.0668***	−0.0650***	0.0066	−0.0111	−0.0110**
	(−36.51)	(−39.52)	(−48.49)	(0.87)	(−1.50)	(−2.39)
Acreage	0.0200***	0.0209***	0.0201***	0.0372***	0.0589***	0.0552***
	(17.12)	(20.28)	(24.52)	(9.82)	(12.25)	(23.18)
Sq. Ft.	0.0002***	0.0002***	0.0002***	0.0000**	0.0001***	0.0001***
	(14.20)	(13.45)	(14.30)	(1.96)	(4.91)	(7.83)
Bedrooms	0.0004	0.0038	0.0046	0.0356***	0.0148	0.0202***
	(0.08)	(0.71)	(1.12)	(3.56)	(1.34)	(2.81)
Bathrooms	0.0404***	0.0394***	0.0383***	−0.0495***	−0.0441***	−0.0463***
	(7.09)	(7.06)	(7.96)	(−5.08)	(−4.00)	(−5.91)
Foreclosure	−0.1546***	−0.1482***	−0.1401***	−0.4062***	−0.4258***	−0.4239***
	(−24.91)	(−27.52)	(−32.23)	(−19.06)	(−18.46)	(−21.16)
Number of Levels	−0.0032	−0.0012	0.0022	0.0202***	−0.0078	0.0010
	(−1.08)	(−0.46)	(0.96)	(2.65)	(−0.78)	(0.16)
Pool	0.0355***	0.0333***	0.0289***	0.0126	0.0159	0.0219
	(4.99)	(5.69)	(8.30)	(0.43)	(0.48)	(1.07)
Basement	0.0231***	0.0193***	0.0152***	0.0400***	0.1021***	0.0865***
	(3.52)	(3.89)	(4.88)	(2.77)	(6.03)	(8.86)
Short Sale	−0.0822***	−0.0818***	−0.0817***	0.3531***	0.3422***	0.3410***
	(−14.38)	(−14.82)	(−14.83)	(18.52)	(17.81)	(18.39)
Tenant	−0.0729***	−0.0721***	−0.0702***	0.2570***	0.2966***	0.2882***
	(−14.28)	(−16.27)	(−18.31)	(13.10)	(14.02)	(15.87)

Exhibit 3 | (continued)

Effect of a Nearby Rehab Center on a Home's Price and Liquidity with Different Location Controls

	Dependent Variable: *ln*(*Sale Price*)			Dependent Variable: *ln*(*Days on Market*)		
	(1)	(2)	(3)	(4)	(5)	(6)
Vacant	−0.0309***	−0.0326***	−0.0345***	0.1171***	0.1393***	0.1301***
	(−9.74)	(−12.22)	(−20.51)	(7.81)	(8.97)	(12.79)
Taxes ($)	0.0001***	0.0001***	0.0001***	−0.0001**	−0.0001***	−0.0001***
	(10.40)	(10.45)	(13.13)	(−2.17)	(−3.20)	(−6.69)
HOA Fees	0.0660***	0.0681***	0.0635***	−0.0847***	−0.1136***	−0.1100***
	(9.93)	(11.85)	(16.69)	(−4.25)	(−5.04)	(−8.49)
ln(*Time on Market*)	0.0014*	0.0016**	0.0015***			
	(1.67)	(2.40)	(2.79)			
ln(*List Price*)				0.5101***	0.2620***	0.2991***
				(11.71)	(5.67)	(11.74)
Constant	11.4958***	11.4429***	11.5281***	−4.1742***	−1.1906**	−1.6416***
	(156.44)	(260.80)	(259.87)	(−7.64)	(−2.12)	(−4.76)
Location Controls (Census Tracts)	√			√		
Location Controls (Blocks Groups)		√			√	
Location Controls (Blocks)			√			√
Year Fixed Effects	√	√	√	√	√	√

Notes: This table presents results of hedonic OLS models showing the effect of a nearby (i.e. within 0.125 mile) rehab facility on a property's sale price and time on market, while controlling for different spatial / area fixed effects. Errors are clustered by spatial area in each regression respectively. *T*-statistics are in parentheses. The number of observation in columns 1–3 is 116,663; the number of observation in columns 4–6 is 205,281.

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

Exhibit 4 | Effect of a Nearby Rehab and Methadone Treatment Center on a Home's Price and Liquidity

	Dependent Variable: *ln*(*Sale Price*) (1)	Dependent Variable: *ln*(*Days on Market*) (2)	Dependent Variable: *ln*(*Sale Price*) (3)	Dependent Variable: *ln*(*Days on Market*) (4)
Rehab Center ≤ *1/8 Mile*	−0.077**	−0.009		
	(−2.44)	(−0.04)		
Meth. Center ≤ *1/8 Mile*			−0.174**	0.192
			(−2.35)	(0.33)
ln(*Age of Home*)	−0.063***	0.125***	−0.063***	0.125***
	(−118.93)	(10.89)	(−118.92)	(10.86)
Acreage	0.019***	0.026***	0.019***	0.027***
	(42.37)	(5.22)	(42.38)	(5.24)
Sq. Ft.	0.000***	−0.000***	0.000***	−0.000***
	(232.99)	(−7.14)	(233.00)	(−7.10)
Bedrooms	−0.023***	0.093***	−0.023***	0.093***
	(−23.53)	(11.70)	(−23.52)	(11.69)
Bathrooms	0.024***	−0.054***	0.024***	−0.053***
	(22.80)	(−5.75)	(22.80)	(−5.73)
Foreclosure	−0.153***	−0.025	−0.153***	−0.026
	(−36.57)	(−0.62)	(−36.60)	(−0.64)
Number of Levels	−0.018***	0.077***	−0.018***	0.077***
	(−18.27)	(9.51)	(−18.27)	(9.51)
Pool	0.027***	−0.038**	0.027***	−0.038**
	(11.63)	(−2.04)	(11.62)	(−2.03)
Basement	0.039***	−0.062***	0.039***	−0.061***
	(24.13)	(−4.68)	(24.13)	(−4.67)
Short Sale	−0.115***	0.529***	−0.115***	0.528***
	(−20.08)	(11.42)	(−20.07)	(11.41)
Tenant	−0.080***	0.078**	−0.080***	0.078**
	(−21.18)	(2.46)	(−21.19)	(2.45)
Vacant	−0.041***	0.240***	−0.041***	0.240***
	(−34.67)	(22.44)	(−34.66)	(22.42)
Taxes ($)	0.000***	0.000*	0.000***	0.000*
	(91.96)	(1.82)	(91.95)	(1.86)
HOA Fees	0.059***	−0.076***	0.059***	−0.076***
	(41.51)	(−5.07)	(41.50)	(−5.05)
ln(*Time on Market*)	0.050***		0.050***	
	(45.52)		(45.45)	
ln(*Sale Price*)		1.254***		1.248***
		(7.48)		(7.44)

Exhibit 4 | (continued)

Effect of a Nearby Rehab and Methadone Treatment Center on a Home's Price and Liquidity

	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)
	(1)	(2)	(3)	(4)
Listing Density	0.000***		0.000***	
	(21.93)		(21.95)	
Competition		0.000***		0.000***
		(21.48)		(21.50)
Location Controls	√	√	√	√
Year Fixed Effects	√	√	√	√

Notes: This table presents the results of hedonic 3SLS models showing the effect of a nearby (i.e., within 0.125 mile) rehab facility, and a rehab facility that treats methadone addiction specifically, on a property's sale price and time on market; constant omitted here for brevity. *Z*-statistics are in parentheses. The number of observations in columns 1–4 is 110,361.

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

methadone clinics. Columns 3 and 4 in Exhibit 4 display the results of the same 3SLS estimations as columns 1 and 2, but confining the treatment variable to a dummy variable that equals one if the home is within 0.125 mile of a methadone clinic. The coefficient estimates in Exhibit 4 indicate that homes within 0.125 miles of a methadone clinic sell for approximately a 17% discount relative to homes that are located further away, holding other factors constant. There is little evidence, however, that these clinics affect nearby home liquidity. Overall, Exhibit 4 provides evidence that the market differentiates among risks generated by these potential externalities, and the treatment centers that may be perceived as having a higher risk to their neighbors have a much greater impact on the surrounding real estate market.

As a robustness check, in Exhibit 5 we explore the extent to which the control groups matter, finding results generally consistent with those in Exhibit 4. A critique of hedonic models for estimating any externality might be that the interpretation of the dummy variable essentially defines the control group as homes not located near (within 0.125 miles) the potential externality. Defining the control group in this way may present some unobserved spatial heterogeneity issues. To address this issue, in Exhibits 5 and 6 we estimate the same regressions as Exhibit 4, but confine the sample to homes that are located within 1.5 miles, 1 mile, and 0.6 miles of a rehab facility respectively. The results are consistent with the initial 3SLS estimates in Exhibit 4, and by extension, the initial OLS estimates in Exhibits 2 and 3. Both exhibits show that homes near substance abuse

Exhibit 5 | Effect of a Nearby Rehab Facility on a Home's Sale Price and Days on Market

	Dependent Variable: *ln(Sale Price)*	Dependent Variable: *ln(Days on Market)*	Dependent Variable: *ln(Sale Price)*	Dependent Variable: *ln(Days on Market)*	Dependent Variable: *ln(Sale Price)*	Dependent Variable: *ln(Days on Market)*
	Within 1.5 Miles of a Rehab Facility		Within 1 Mile of a Rehab Facility		Within 0.6 Miles of a Rehab Facility	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Rehab Center ≤ 1/8 Mile	−0.076**	−0.008	−0.077**	−0.083	−0.075**	−0.331
	(−2.34)	(−0.03)	(−2.42)	(−0.34)	(−2.27)	(−1.34)
ln(Age of Home)	−0.063***	0.133***	−0.059***	0.060	−0.063***	0.102
	(−30.75)	(3.60)	(−20.19)	(1.34)	(−12.40)	(1.60)
Acreage	0.022***	0.017	0.020***	0.045*	0.028***	0.015
	(12.14)	(0.91)	(7.61)	(1.85)	(5.83)	(0.35)
Sq. Ft.	0.000***	−0.000**	0.000***	−0.000	0.000***	−0.000
	(57.61)	(−2.31)	(42.39)	(−0.59)	(25.45)	(−1.08)
Bedrooms	−0.023***	0.123***	−0.025***	0.144***	−0.026***	0.211***
	(−5.92)	(4.30)	(−4.44)	(3.42)	(−2.96)	(3.21)
Bathrooms	0.028***	−0.018	0.018***	0.040	0.027***	−0.048
	(6.69)	(−0.51)	(2.88)	(0.81)	(2.58)	(−0.60)
Foreclosure	−0.147***	0.014	−0.171***	−0.195	−0.188***	−0.628**
	(−9.84)	(0.11)	(−7.62)	(−1.00)	(−4.93)	(−2.11)
Number of Levels	−0.025***	0.079***	−0.021***	0.046	−0.018**	0.110
	(−6.57)	(2.64)	(−3.81)	(1.05)	(−1.99)	(1.64)
Pool	0.021**	0.034	0.016	−0.103	0.027	−0.134
	(2.17)	(0.48)	(1.16)	(−0.97)	(1.12)	(−0.77)

Exhibit 5 | (continued)

Effect of a Nearby Rehab Facility on a Home's Sale Price and Days on Market

	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)
	Within 1.5 Miles of a Rehab Facility		Within 1 Mile of a Rehab Facility		Within 0.6 Miles of a Rehab Facility	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Basement	0.040***	0.004	0.034***	0.052	0.029*	−0.105
	(6.44)	(0.08)	(3.71)	(0.71)	(1.91)	(−0.89)
Short Sale	−0.122***	0.389**	−0.106***	0.315	−0.166***	0.006
	(−6.04)	(2.56)	(−3.23)	(1.25)	(−3.06)	(0.02)
Tenant	−0.099***	0.038	−0.114***	0.018	−0.140***	0.161
	(−6.82)	(0.32)	(−5.82)	(0.11)	(−4.47)	(0.65)
Vacant	−0.044***	0.218***	−0.046***	0.254***	−0.034***	0.304***
	(−9.59)	(5.59)	(−7.05)	(4.66)	(−2.97)	(3.68)
Taxes ($)	0.000***	0.000	0.000***	0.000***	0.000***	0.000**
	(23.21)	(1.13)	(15.54)	(3.58)	(11.40)	(2.22)
HOA Fees	0.068***	−0.104**	0.078***	−0.128*	0.079***	−0.151
	(11.98)	(−1.98)	(9.59)	(−1.72)	(5.73)	(−1.36)
ln(*Time on Market*)	0.043***		0.019***		0.010	
	(10.91)		(3.80)		(1.50)	
ln(*Sale Price*)		1.023**		0.071		0.295
		(1.98)		(0.12)		(0.39)
Listing Density	0.000***		0.000***		0.000**	
	(6.30)		(4.33)		(2.35)	

Exhibit 5 | (continued)

Effect of a Nearby Rehab Facility on a Home's Sale Price and Days on Market

	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)
	Within 1.5 Miles of a Rehab Facility		Within 1 Mile of a Rehab Facility		Within 0.6 Miles of a Rehab Facility	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Competition		0.000***		0.000***		0.000***
		(8.80)		(6.26)		(5.95)
Location Controls	√	√	√	√	√	√
Year Fixed Effects	√	√	√	√	√	√

Notes: This table presents the 3SLS results of simultaneous estimation of the effect of a nearby rehab facility on a home's selling price and liquidity (time on market), changing the sample to vary the control groups by smaller radii from a rehab center. *Z*-statistics are in parentheses. The number of observations in columns 1–2 is 7,711; the number of observations in columns 3–4 is 3,589; the number of observations in columns 5–6 is 1,324.

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

Exhibit 6 | Effect of a Nearby Rehab Facility that Treats Methadone Addiction

	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)
	Within 1.5 Miles of a Rehab Facility		Within 1 Mile of a Rehab Facility		Within 0.6 Miles of a Rehab Facility	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Meth. Center ≤ 1/8 Mile	−0.169**	−0.020	−0.179**	−0.086	−0.168**	−0.289
	(−2.21)	(−0.04)	(−2.37)	(−0.15)	(−2.17)	(−0.52)
ln(*Age of Home*)	−0.063***	0.129***	−0.059***	0.061	−0.063***	0.104
	(−30.70)	(3.49)	(−20.14)	(1.35)	(−12.30)	(1.64)
Acreage	0.022***	0.018	0.020***	0.045*	0.028***	0.014
	(12.17)	(0.99)	(7.62)	(1.84)	(5.83)	(0.33)
Sq. Ft.	0.000***	−0.000**	0.000***	−0.000	0.000***	−0.000
	(57.63)	(−2.17)	(42.43)	(−0.61)	(25.54)	(−1.10)
Bedrooms	−0.023***	0.122***	−0.024***	0.145***	−0.026***	0.216***
	(−5.88)	(4.26)	(−4.42)	(3.45)	(−2.91)	(3.29)
Bathrooms	0.028***	−0.016	0.018***	0.040	0.027***	−0.047
	(6.70)	(−0.45)	(2.89)	(0.81)	(2.59)	(−0.59)
Foreclosure	−0.148***	0.004	−0.173***	−0.196	−0.193***	−0.653**
	(−9.90)	(0.03)	(−7.71)	(−1.00)	(−5.06)	(−2.19)
Number of Levels	−0.025***	0.078***	−0.021***	0.047	−0.018**	0.109
	(−6.58)	(2.60)	(−3.84)	(1.05)	(−2.04)	(1.62)
Pool	0.021**	0.035	0.016	−0.103	0.026	−0.135
	(2.16)	(0.50)	(1.15)	(−0.97)	(1.10)	(−0.78)

Exhibit 6 | (continued)

Effect of a Nearby Rehab Facility that Treats Methadone Addiction

	Dependent Variable: *ln(Sale Price)*	Dependent Variable: *ln(Days on Market)*	Dependent Variable: *ln(Sale Price)*	Dependent Variable: *ln(Days on Market)*	Dependent Variable: *ln(Sale Price)*	Dependent Variable: *ln(Days on Market)*
	Within 1.5 Miles of a Rehab Facility		Within 1 Mile of a Rehab Facility		Within 0.6 Miles of a Rehab Facility	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Basement	0.040***	0.006	0.035***	0.051	0.030*	−0.104
	(6.44)	(0.13)	(3.72)	(0.70)	(1.94)	(−0.89)
Short Sale	−0.121***	0.383**	−0.106***	0.318	−0.165***	0.029
	(−6.02)	(2.52)	(−3.21)	(1.26)	(−3.03)	(0.07)
Tenant	−0.099***	0.031	−0.114***	0.019	−0.142***	0.158
	(−6.84)	(0.26)	(−5.84)	(0.12)	(−4.52)	(0.64)
Vacant	−0.044***	0.216***	−0.047***	0.254***	−0.034***	0.303***
	(−9.58)	(5.52)	(−7.08)	(4.67)	(−3.03)	(3.66)
Taxes ($)	0.000***	0.000	0.000***	0.000***	0.000***	0.000**
	(23.18)	(1.26)	(15.44)	(3.56)	(11.24)	(2.16)
HOA Fees	0.068***	−0.100*	0.077***	−0.130*	0.078***	−0.159
	(11.94)	(−1.90)	(9.53)	(−1.75)	(5.65)	(−1.43)
ln(Time on Market)	0.042***		0.020***		0.012*	
	(10.81)		(3.93)		(1.67)	
ln(Sale Price)		0.955*		0.082		0.322
		(1.85)		(0.14)		(0.43)
Listing Density	0.000***		0.000***		0.000**	
	(6.42)		(4.40)		(2.48)	

Exhibit 6 | (continued)

Effect of a Nearby Rehab Facility that Treats Methadone Addiction

	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)	Dependent Variable: *ln*(*Sale Price*)	Dependent Variable: *ln*(*Days on Market*)
	Within 1.5 Miles of a Rehab Facility		Within 1 Mile of a Rehab Facility		Within 0.6 Miles of a Rehab Facility	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Competition		0.000*** (8.86)		0.000*** (6.25)		0.000*** (5.89)
Location Controls	√	√	√	√	√	√
Year Fixed Effects	√	√	√	√	√	√

Notes: This table presents 3SLS results of simultaneous estimation of the effect of a nearby rehab facility that treats methadone addiction on a home's selling price and liquidity (time on market), changing the sample to vary the control groups by smaller radii from a rehab center. *Z*-statistics are in parentheses. The number of observations in column 1 is 7,711; the number of observations in column 2 is 3,589; the number of observations in column 3 is 1,324.

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

treatment centers are still negatively impacted, and by approximately the same magnitudes. Indeed, the last two columns are particularly striking. Given that this is already a "within neighborhood" estimation, by controlling for location, the fact that the substance abuse treatment center result is robust when the control group is reduced to 1 mile and 0.6 miles indicates that unobserved spatial heterogeneity is not likely driving the core results of this paper. More intuitively, this provides strong evidence that the substance abuse treatment center effect is not simply a "bad part of town effect," in that we are comparing "apples with apples" across the dimension of location; and, the principle characteristic distinguishing the variation in prices in these areas is the presence of a nearby substance abuse treatment center. Based on these results, we cannot conclude that there is a robust impact on property liquidity, but there appears to be a robust negative relationship between the presence of a substance abuse treatment center and nearby home values.

Conclusion

In this study, we find evidence that residential substance abuse treatment centers adversely impact the price of neighboring homes. We find that homes within 1/8 mile of a treatment center sell for approximately 8% less than otherwise comparable homes that are located further away. Furthermore, we find that the market differentiates between potential risks that nearby treatment centers may carry, as living near a methadone clinic that treats opiate addictions such as heroin or morphine may be associated with a reduction in home values by as much as 17%. We find little evidence that nearby treatment centers affect a home's time on market.

Examining this particular externality is important to the broader literature on neighborhood externalities and environmental factors, as well as the specific literature on the issue of residential treatment centers. The PPACA has expanded MH/SUD coverage and made intensive treatment options affordable, and as a result, demand for effective substance abuse treatment is increasing. Operating a treatment center is a growing industry and it is reasonable to assume that new centers will be built nationally, many of which will be sited near or within residential communities. Indeed, there is very little that individuals and localities can do to prohibit a substance abuse treatment center from locating in a residential area because alcohol and drug addiction is considered to be a handicap and thus alcoholic/addicts in recovery are members of a protected class under the federal anti-discrimination housing laws. Hence, as residential treatment centers become more common, it is important to understand all their effects, including the effects they may have on nearby real estate and how markets price the potential risk of nearby externalities.

Endnotes

1. For a more complete review on the impact of environmental externalities, see Boyle and Kiel (2001).

2 Consistent with other real estate studies, we culled outliers from our data set, confining our data to more ''typical'' range of homes listed at less than $1,000,000, fewer than 10 bedrooms, fewer than 16 acres (99% of observations), property taxes paid that were less $10,000 (99% of observations), and younger than 150 years old (99% of observations). For our other dependent variable of interest, time on market, we similarly trim the 1% extremes. Generally, the findings are not sensitive to dropping these observations. Further, important to disclose how our data has been trimmed for transparency and replicability. As an additional quality check, a sample of the MLS data was compared to county tax records, which contain data on price and housing characteristics.

3 There were approximately 153, 96, and 60 properties listed within 0.175 miles, 0.15 miles, and 0.125 miles of a rehab treatment facility respectively, over the time period of our study. Given the very recent and projected growth of rehab centers nationally, future research will be able to take advantage of additional homes (data points) being bought and sold near rehab facilities.

4 The choice of this radius does not fundamentally alter the qualitative conclusions of this study. The definition of one's ''backyard'' is somewhat ambiguous, and may differ depending on an individual's perception. Some externality studies use 0.1 mile, 0.2 mile, or 0.3 mile as a radius to examine a given externality. While similar results are obtained looking at bands slightly larger and slightly smaller, we follow Congdon-Hohman (2013) and use 1/8 mile in most of our tabulated regression results. An easy way to think of 0.125 miles, 0.15 miles, and 0.175 miles is that these are 2.5 minute, 3 minute, and 3.5 minute walks respectively (assuming a pace of 3 miles per hour).

5 For recent examples of amenity or disamenity studies of externality effects, see Asabere and Huffman (1991), Gibbons (2004), Linden and Rockoff (2008), Pope (2008), Rossi-Hansberg, Sarte, and Owens (2010), Campbell, Giglio, and Pathek (2011), Hoen, Wiser, Cappers, Thayer, and Sethi (2011), Daneshvary, Clauretie, and Kader (2011), Grout, Jaeger, and Plantinga (2011), Daneshvary and Clauretie (2012), Congdon-Hohman (2013), Guignet (2013), Linn (2013), Munneke, Sirmans, Slade, and Turnbull (2013), and Wentland, Waller, and Brastow (2014).

6 Recent examples include neighborhood foreclosure effects (Harding, Rosenblatt, and Yao, 2009; Lin, Rosenblatt, and Yao, 2009; Agarwal, Ambrose, Chomsisengphet, and Sanders, 2010).

7 Kuminoff, Parmeter, and Pope (2010) survey 69 hedonic studies and found that 80% rely on linear, semi-log, or log-log functional form. We have explored a number of non-linear functional forms and our results remain robust. Rather than repeat all of the above models with various non-linear explanatory variables, the authors will produce results of alternative specifications upon request.

8 For example, we use the following property specific variables: square footage, age, acreage, number of bedrooms, bathrooms, number of stories, new, vacant, HOA fees, whether it has a pool, a tenant, a basement, and whether it is a short sale or foreclosure. We also include year fixed effects to control for variation over time.

9 When we explore different location controls later, we will cluster by location (e.g., census tract, block group, or block).

10 For example, see Yavas and Yang (1995), Knight (2002), and Turnbull and Dombrow (2006).

11 Specifically, both our paper and Zahirovic-Herbert and Turnbull (2008) calculate C in the following way: ''The days-on-market or selling time is $s(i) - l(i) + 1$, where $l(i)$ and $s(i)$ are the listing date and sales date for house i. Denoting the listing date and

sales date for house j by $l(j)$ and $s(j)$, the overlapping time on the market for these two houses is $\min[s(i), s(j)] - \max[l(i), l(j)]$. The straight-line distance in miles between houses i and j is $D(i, j)$. The measured competition for house i is: $C(i) = \Sigma_j (1 - D(i, j))^2\{\min[s(i), s(j)] - \max[l(i), l(j)]\}$ where the summation is taken over all competing houses j, that is, houses for sale within one mile and 20% larger or smaller in living area of house i" (Zahirovic-Herbert and Turnbull, 2008).

[12] At the suggestion of a reviewer, we also identify the system by using different control variables. A simple way to do this is to use different location controls. We use ZIP Code fixed effects in the price equation, and census tract fixed effects in the time on market equation. Generally, the results are not very sensitive to which location controls are used in each equation. Further, the results are similar when we use the Turnbull and Dombrow (2006) method alone to identify the system.

[13] According to Belsley (1988), when there are strong interrelations among error terms, 3SLS is used instead of 2SLS in estimating systems of equations because it is more efficient. Specifically, one would expect unobservables that contribute to error in estimating price to be also correlated the error in liquidity.

[14] See www.census.gov for more detail, specifically: http://www.census.gov/geo/www/cob/tr_metadata.html#gad.

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The Effect of a Large Hog Barn Operation on Residential Sales Prices in Marshall County, KY

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Abstract In this paper, we examine the economic impact of a tightly clustered complex of hog barns, a type of concentrated animal feeding operation (CAFO) on residential property in a rural area near Benton, Kentucky. The operation creates noxious and offensive odors associated with swine-raising and waste disposal activities. Theory and practice indicate that buyers would avoid purchasing a property believed to be contaminated or subject to effects of unsustainable environmental disamenities. Using hedonic regression analysis, the results show price reductions of 23%–32% for residential properties sold within 1.25 miles of the facility, and much larger losses northeast (downwind) of the facility.

In this case study, we examine the economic impact of a hog barn, a type of concentrated animal feeding operation (CAFO) on residential property. The CAFO for this case study includes a tightly clustered complex of hog barns, with capacity for several thousand hogs, which was built and opened in a rural area near the town of Benton, Kentucky in 2007. After about a full year of operations that allows the waste pit to fill, the operation created noxious and offensive odors associated with swine-raising and waste disposal activities. Theory and practice indicates that, all else being equal, buyers would avoid purchasing a property subject to effects of an environmental disamenity because of unpleasant odors, possible health risks, reduced use, difficulty in reselling the property, uncertainty, and nuisance associated with these environmental issues. Therefore, properties suffering from proximity to a hog farm can be expected to sell less frequently and at a discounted price compared with properties not so situated. The amount of the discount can be equated to the sustainability adjustment to allow the properties to transact in the marketplace.

To determine potential reductions in sales prices, we reviewed the academic literature regarding the impact of CAFOs on property values; conducted a field trip to the project location and held interviews with affected parties living nearby; reviewed odor logs maintained by residents in the case area at various dates from 2007 through 2011, and also reviewed the environmental report of an expert in odor modeling. Next, we built a data set of approximately 270 residential sales and performed a hedonic regression analysis of sales in Marshall County, Kentucky from 2002 through 2012.[1]

Our main findings indicate statistically significant reduction of 23%–32% in residential sales prices due to the presence of the hog barn and its operations within a 1.25-mile radius from the hog barn complex. Higher losses are observed northeast of the facility, consistent with wind direction and a comprehensive compilation of the order logs.

Literature

Both economic theory and empirical evidence from peer-reviewed literature indicate that real property would be negatively affected by environmental disamenities, including the repeated presence of noxious or nuisance odors from nearby commercial activities such as CAFOs, where the existence of such a history of nuisance odors would need to be disclosed to potential buyers. In a rural area, the local knowledge of potential buyers is also expected to be relatively high, because of the lack of outside interest in living in this relatively isolated area. Identification and quantification of the negative impact of noxious odors can readily be determined through one or a combination of well-established, scientifically accepted real estate analytical techniques including hedonic regression, real estate sales trends analysis, contingent valuation analysis, and sale-resale analysis, although the preponderance of the literature cited below relies on regression analysis.

Hog farms are a type of CAFO. The other main types of CAFOs include cattle and chicken farms. Smaller operations handle several hundred or a few thousand animals at a time, and larger ones can grow to 10,000 animals or more. Sometimes the facilities have a cluster of animal barns. Activities at a CAFO typically include growing, but not slaughtering or butchering the animals. The work is relatively unpleasant, and much of the animal care is automated or handled by immigrant workers. CAFOs are typically located in relatively isolated areas because of potential negative amenities, including some noise, but especially odors. The bulk of the odors usually emanate from concentrated pits of animal by-products, such as urine, feed, body fluids, feces, medicine, and dead animal parts. These pits are rarely emptied, and a typical pit may be an acre in size and 20 feet deep: a large one could be three acres and 30 feet deep (Price, 2010). The liquids contained in a hog barn pit can lead to a strong odor, including chemicals such as ammonia and hydrogen sulfide. Because industrial-sized fans are often used to dissipate the odors locally, direction of fans and wind direction can be a large factor in where the odors go, and the impacts they have on nearby property.

In a seminal quantitative study of the impact of CAFOs on proximate property values, Palmquist, Roka, and Vukina (1997) used hedonic regression to analyze 237 arms-length transactions of rural, non-farm residences in nine North Carolina counties from January 1992 through July 1993. Their analysis, which evaluated impact based on the density of swine herds (equivalent to hog farms as we use it in this article) within concentric rings at one-half mile, one mile, and two-miles from each house, found a statistically significant reduction in house prices of up to 9% for each new hog operation opened, with the greatest losses occurring in areas of previously low hog farming density.

In an article outlining the scope of potential value diminution for properties located in the vicinity of CAFOs, Kilpatrick (2001) summarized a University of Missouri study that found losses to range from 6.6% for vacant land within three miles of the CAFO to 88% for a home within 0.1 mile of the facility. He also reported the results of single-property consulting studies, which found diminution of 50% for a fruit-and-vegetable family farm located one-quarter mile from a CAFO, 50% for a horse-breeding farm/residence 1,000 feet from a pork processing facility, and 60% for a residence 700 feet from another pork processing facility. In a recent conference paper, the authors also reported newer empirical studies consistently showing property losses, including some of the papers cited below (Kilpatrick, 2013).

Isakson and Ecker (2008) used hedonic regression to analyze 5,822 single-family homes that sold between January 2000 and November 2004 in Black Hawk County, Iowa, an area which included 39 swine (hog) CAFOs. The study incorporated a measure of the effects of prevailing winds, concentric circle analysis around the CAFOs, and spatial correlation factors. Within 2 miles of a CAFO, the authors found losses of 44% for houses directly downwind and 17% for houses at an average oblique wind angle, with wind angle the most powerful explanatory variable in their model.

Using hedonic regression, Herriges, Secchi, and Babcock (2005) evaluate 1,145 rural, owner-occupied home sales (arms-length transactions) from 1992 to 2002 in five Iowa counties with an aggregate of 349 livestock facilities (98% of which were swine facilities). The authors found statistically significant property value reductions of about 15% at one-quarter mile and 9% at one-half mile downwind of a CAFO.

Ready and Abdalla (2005) examined the impact of agricultural land use as both an amenity and disamenity. The hypothesis was that open space has a positive impact on residential property values, while local disamenities, including landfills, high-traffic roads, airport, and large-scale animal production and mushroom production, have a negative impact. The study area was Berks County, Pennsylvania. The findings indicated that animal production facilities have a significant negative impact on the property values of 6.4% within 500 meters and 4.1% within 800 meters. Large facilities (greater than 300 AEU[2] but less than 600 AEU) have less impact on residential property values than medium-sized facilities.

As summarized in Exhibit 1, these studies indicate that it is typical to find residential property value diminution of 10% to 45%, depending on location with respect to prevailing wind direction, within two miles of swine CAFOs. Losses can amount to 50% and more for individual properties located in close proximity to CAFOs. The adverse property value impacts are greatest where swine CAFOs are introduced into areas that did not previously contain high-density hog farming operations.

Exhibit 1 | Brief Summary of Literature

Author(s)	Year	Method	Findings
Palmquist, Roka, and Vukina	1997	Hedonic	9% loss
Kilpatrick	2001	Case Study	50–83% within 0.1 mile: 7% 3 miles away
Isakson and Ecker	2008	Hedonic	44% for houses downwind and 17% for those at an average
Herriges, Secchi, and Babcock	2005	Hedonic	9% at one-half mile downwind
Ready and Abdalla	2005	Hedonic	6.4% within 500 meters and 4.1% within 800 meters
Kim and Goldsmith	2009	Spatial Lag Model	10% loss

Study Area and Sales Data

The hog barns analyzed in this study are located in a rural area of Marshall County, Kentucky, and nearby Benton, Kentucky. The main complex includes a pair of large hog barns. The area's topography is dominated by level land and slightly rolling hills and a generally warm climate, with mild winters and hot humid summers. The case area (expected to represent the area most affected) where the affected residential properties are located is within a 1.25-mile radius of the main hog barn complex. All areas outside this radius are considered control (likely unaffected) property. However, since, the empirical evidence citied above suggests that the zone of affected property may be larger: in other words, part of the control area (outside the affected zone) may also suffer from diminished property values, we also tested an area between 1.25 and 2 miles from the hog farm complex. The case area and nearby control areas were all in Marshall County within about seven miles of the hog farm complex. They contain similar types and a similar range of housing stock, and were subject to similar local economic conditions, with the exception of their proximity to the subject hog barns, throughout the study period. Exhibit 2 identifies the general locale.

Study Area Particulars

In 2006, a hog farm complex capable of handling 5,000 hogs was proposed in the predominantly rural study area near Benton, Kentucky. The facility was opened in mid-2007, and within about a year the urine/catchment pool under the facility became full. Several large fans pointing generally west-northwest move odors and heat away from the facility. According to generally available data in the popular press, hog barns are associated with noxious chemicals including ammonia and hydrogen sulfide; when inhaled, these chemicals can lead to bronchitis, asthma, nosebleeds, brain damage, and seizures (Price, 2010). An expert report that documented environmental conditions (Winegar, 2013) confirmed the presence of these chemicals in proportions large enough to be noticed, and the wind direction, and attributed them to the hog farm. These nuisance odors are consistent with

Exhibit 2 | Study Area: Big Picture and Impacted Area

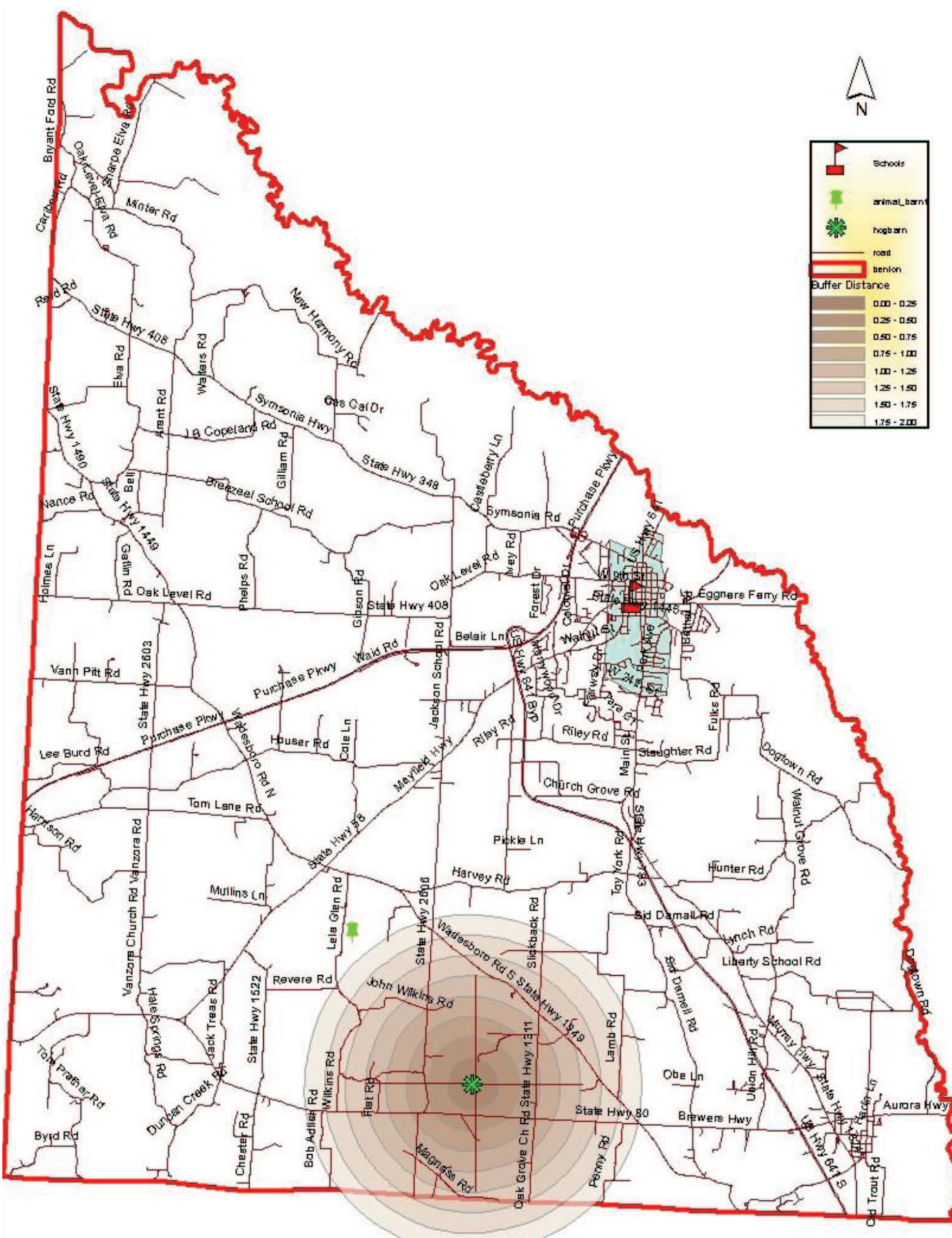
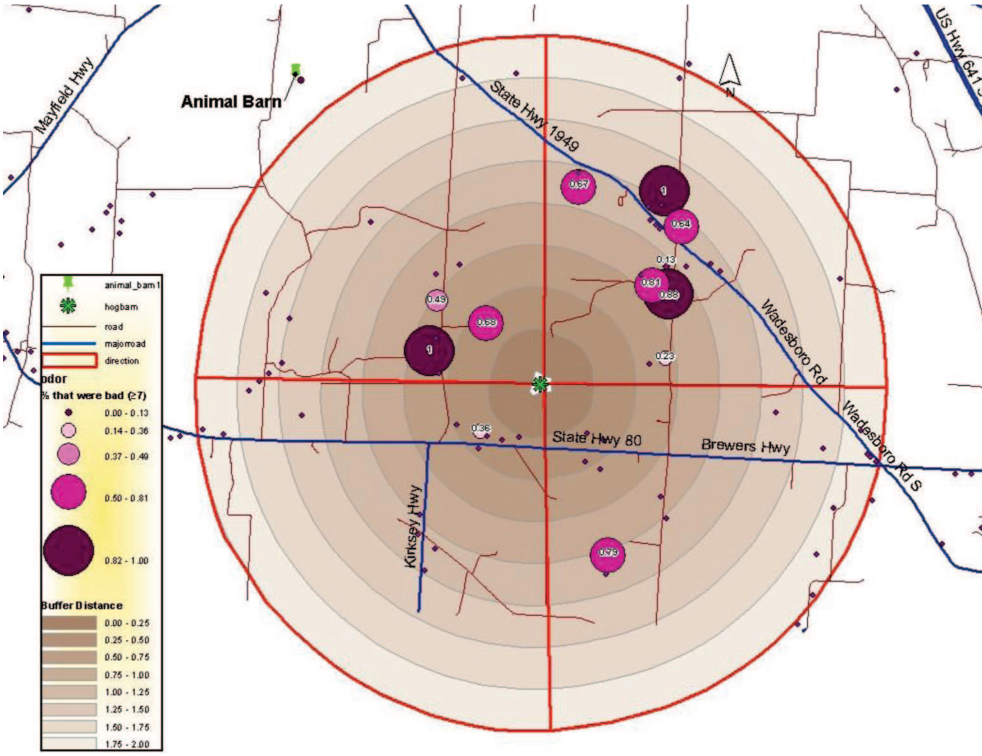


Exhibit 3 | Nearby Resident Odor Log Analysis: Severe Odor Percentages



Note: This is not a random sample of residents. Residents were involved in litigation against the hog farm operators.

those described in the peer-reviewed literature cited above. A slightly smaller hog farm operation, opened in about 2010 by the same owner, is located about 1.5 miles northwest of the main hog barns. There has also been a smaller chicken farm operation about 1/3 mile east of the main hog barns for over 15 years, and this is considered part of the baseline conditions with respect to odors. Both of these are shown in Exhibit 3. The case area includes about 300 residential properties, with about a third of the parcels being undeveloped land.

Personal interviews with a non-random sample of nearby residents confirmed that in about 2009 odors started emanating from the plant, and that they were intermittently bad to very bad in some directions from the facility (especially to the northwest), and sometimes noticeable in other directions. The odors persist until the present day.

Local Resident Odor Logs

Detailed logs of hog barn odor observations ("odor logs") were maintained by 14 nearby residents over varying periods of time from July 2007 through August

2011. The authors had no control over who provided these odor logs, and we do not assume this is a random sample. However, the logs do support that odors are strongest towards the northeast, and thus provide valuable information for model design.

We translated these observations into a common 10-point intensity scale,[3] and then calculated, for each location, an average ''odor intensity level'' and a ''severe-odor'' percentage (i.e., the percentage of all of the observations that were rated at 7 or higher on the 10-point intensity scale).

We employed a geographic information system to plot the severe odor percentages at the residents' homes on a map of the case area, which is shown in Exhibit 3, along with recent sales. The results of this process revealed that the largest cluster of severe odor percentage observations indeed occurred to the northeast of the hog barns. Other relatively high severe odor percentages were found to the northwest and southeast of the hog barn site, while the plaintiff odor logs showed less frequent severe odors to the southwest of the barns.

Residential Sales Data Set

The real estate market in this part of Kentucky has been resilient, and has largely avoided the economic downturn that has affected the rest of the United States. Although there is a mix of housing in the study area, from mobile homes on ¼-acre rural lots to newer mansions on 10+ acres, a typical house is a 2,000 sq. ft. ranch or bi-level, 15 years old, on 5–10 acres of land, and located along a rural road. Benton (population about 4,400) and Murray (home of Murray State University with a population of about 18,000) are the nearest towns, while Paducah, Kentucky and Nashville, Tennessee, TN would provide air links. Mineral Mounds State Park is about 45 minutes east of the area by car. In short, Benton is a rural area not convenient to urban life.

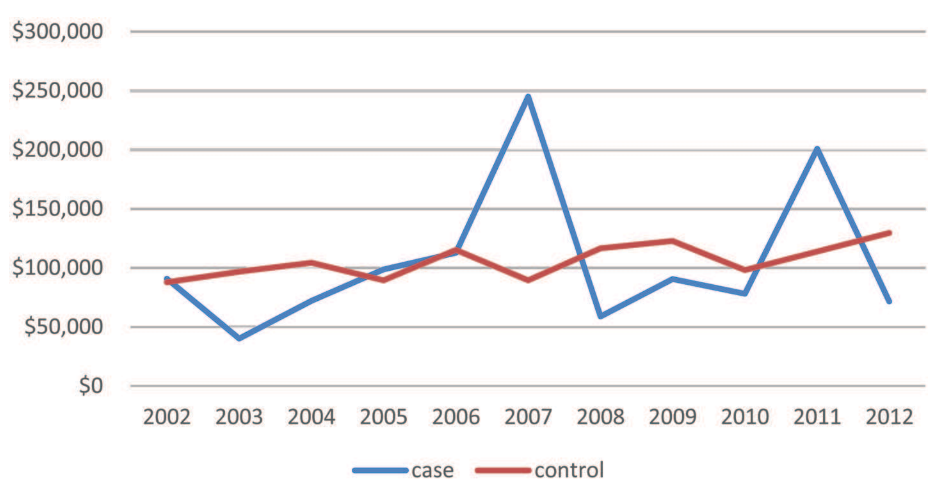
Exhibits 4a and 4b show local area housing sales price trends. While the balance of the U.S. was mired in the great recession due in large part to the foreclosure crisis, the study area was generally experiencing a continuation of steady growth in sales prices and transaction amounts (note in particular control area price trends in Exhibit 4b). Case area prices vary widely in some years, due to a small number of sales.

The initial database used to create the regression data set is a mix of local property valuation data (PVA) and the local multiple listing service (MLS), and included all (the population of) 305 single-family home sales from both the case and control areas, which transacted between 2002 and 2012. Based on information in the accompanying deeds and detailed MLS reports, 12 sales were deleted because they did not appear to be ''arm's length.'' We also deleted 15 sales that were not able to be properly geocoded, leaving 278 transactions. Because this is a rural area, this is a relatively small data set, but represents the vast majority of sales in the affected area and nearby. Hence, the case and nearby control areas are generally comparable, and subject to the same economic trends.

Exhibit 4a | Sales Activity and Average Prices for Case and Control Area: 2002–2012

	All Sales		Sales in Case Area		Sales in Control	
Sale Year	# of Sales	Average Price	# of Sales	Average Price	# of Sales	Average Price
2002	26	$88,265	4	$90,875	22	$87,791
2003	23	$89,443	3	$40,200	20	$96,830
2004	25	$96,524	6	$72,083	19	$104,242
2005	30	$90,600	4	$98,725	26	$89,350
2006	24	$115,075	2	$112,700	22	$115,291
2007	27	$100,870	2	$245,000	25	$89,340
2008	19	$110,407	2	$58,750	17	$116,485
2009	18	$119,106	2	$90,400	16	$122,694
2010	21	$93,405	5	$78,040	16	$98,206
2011	24	$132,028	5	$200,800	19	$113,930
2012	34	$115,990	8	$71,500	26	$129,679

Exhibit 4b | Average Sales Price Trends



The real estate public sales dataset was corroborated with MLS records where available, and contained virtually all of the variables required for a regression analysis. Continuous variables (unless otherwise noted) included property address (needed for geocoding distance and direction from the source of the odors), sale amount (the dependent variable) and year (a dummy variable), interior square footage of the building, porch size, garage/carport spaces, year built, bedrooms, number of barns and outbuildings, bathrooms, and lot size. Dummy variables were created for private swimming pool, home style (stick-built vs. mobile homes), topography, property and site conditions, special sale types (bank sales, land contracts, etc.), and a few other property characteristics. We deleted two non-arms-length properties owned by employees of the hog farm owner.

We retained all sales observations with complete data, and therefore deleted seven observations that were missing essential data. With this dataset, we also transformed certain variables to comply with functional form, consistent with theory and/or prior published regression research (e.g., Simons, Bowen, and Sementelli, 1997; Simons, Winson-Geideman, and Mikelbank, 2001). For technical reasons, we utilized year dummy variables for sales from 2002 to 2012, as well as seasonal variables. We used the logarithmic forms of the age and sales price variables.

All properties that were successfully geocoded enabled us to attach locational variables to each sale. The key variables were to place each sale in a distance band from the hog farm complex, and also to place it in one of four directional variables (NE, SE, SW, and NW) relative to the facility. We also added the ‘‘major road’’ variable in the model that is the dummy variable for sales within 0.1 mile (using a distance buffer ring) of a major road, as previous studies in the peer-reviewed literature have revealed that properties close to a major street tend to sell at lower prices due to traffic noise [Asabere, et al., reviewed in Simons (2006)]. Finally, we applied a dummy variable to sales outside 1.25 miles but inside 2 miles from the hog barn facility, to control for secondary proximity outside the designated case area.

We considered other location variables: schools, distance to downtown Benton, and other animal barns. As shown in Exhibit 2, there are two schools in the study area: Benton Elementary and Benton Middle School. These schools are located close to each other in downtown Benton. Models with these variables, schools, and distance to downtown Benton indicated that these variables are not statistically significant,[4] so they did not make the final models. We also had a variable for the newer hog barn facility that opened in 2010, but the result was not statistically significant. The chicken barns are explicitly modeled.

After cleaning the data to include only complete, arms-length transactions, 271 sale observations are available for the model. Descriptive characteristics of the data set used are presented in Exhibit 5. The typical house sale had a sales price of $104,400, on a 7.6-acre lot, with 2.9 bedrooms, and 1.7 full bathrooms. A total of 16% of the properties were sold within the case area (with 9% sold after 2008 in the case area); 10% of the transactions involved bank sales (i.e., sales of previously foreclosed properties back into the marketplace), and 9% involved properties with a mobile home as the residence. Sales prices ranged from $2,000 to $650,000 throughout the study period. Sales prices in the study area were stable, with a low average annual sales price of $88,300 in 2005 and a high of $132,000 in 2009.

Exhibit 5 | Descriptive Statistics

Variable	Label	Min.	Max.	Mean	Std. Dev.
ln_hp	Log of house price	7.601	13.385	11.315	0.733
Hp	House price	2,000	650,000	104,369	79,367
ln_acres	Log of acres	−0.952	5.150	1.054	1.224
Acres	Acres	0.386	172.441	7.643	18.333
ln_livtot	Log of living area	6.238	8.328	7.337	0.315
Bsmt__SF	Basement SF	0.000	1,620	115.82	356.86
ln_age	Log of age	−2.303	4.466	3.237	0.966
cond_good	Dummy for good condition	0.000	1.000	0.251	0.434
cond_avg	Dummy for average condition	0.000	1.000	0.734	0.443
cond_poor	Dummy for poor condition	0.000	1.000	0.011	0.105
site_good	Dummy for site good	0.000	1.000	0.059	0.236
BR	Bedrooms	1.000	5.000	2.856	0.619
BA	Bathrooms	1.000	4.000	1.683	0.605
Space_Equi	Garage space equivalent	0.000	5.000	1.321	1.046
Garage_SF	Garage size	0.000	2,808.000	447.620	492.880
No__of_Bar	Number of barns	0.000	5.000	0.173	0.512
topo_level	Dummy for topology (level)	0.000	1.000	0.731	0.445
topo_rolling	Dummy for topology (rolling)	0.000	1.000	0.240	0.428
topo_steep	Dummy for topology (steep)	0.000	1.000	0.030	0.170
Bank_Sale	Dummy for bank sales	0.000	1.000	0.100	0.300
Porch_SF	Porch SF	0.000	768.000	143.539	147.201
Road_Front	Road frontage	0.000	3,118	344.56	431.82
O_B_SF	Outbuilding SF	0.000	6,400	309.38	722.65
Out_Bldgs	Number of outbuildings	0.000	4.000	0.675	0.846
Mobile	Dummy for mobile homes	0.000	1.000	0.089	0.285
d_out_after	Sales 1.25–2 miles from hog barns after 2008	0.000	1.000	0.055	0.229
d_spring	Dummy for spring	0.000	1.000	0.310	0.463
d_summer	Dummy for summer	0.000	1.000	0.280	0.450
d_fall	Dummy for fall	0.000	1.000	0.203	0.403
d_winter	Dummy for winter	0.000	1.000	0.207	0.406
d_2002	Dummy for 2002	0.000	1.000	0.096	0.295
d_2003	Dummy for 2003	0.000	1.000	0.085	0.279
d_2004	Dummy for 2004	0.000	1.000	0.092	0.290
d_2005	Dummy for 2005	0.000	1.000	0.111	0.314
d_2006	Dummy for 2006	0.000	1.000	0.089	0.285
d_2007	Dummy for 2007	0.000	1.000	0.100	0.300

Exhibit 5 | (continued)

Descriptive Statistics

Variable	Label	Min.	Max.	Mean	Std. Dev.
d_2008	Dummy for 2008	0.000	1.000	0.070	0.256
d_2009	Dummy for 2009	0.000	1.000	0.066	0.250
d_2010	Dummy for 2010	0.000	1.000	0.078	0.268
d_2011	Dummy for 2011	0.000	1.000	0.089	0.285
d_2012	Dummy for 2012	0.000	1.000	0.126	0.332
Land_Contr	Dummy for land contract	0.000	1.000	0.037	0.189
buf_animal	Dummy for within 1.0 mile of pre-existing modest sized chicken feeding operation.	0.000	1.000	0.136	0.344
Case_before	Dummy for sale in case area prior to 2009	0.000	1.000	0.070	0.256
case_af	Dummy for sales after 2008 within case area	0.000	1.000	0.081	0.274
case_af09101112	Dummy for sales after 2009 within case area	0.000	1.000	0.074	0.262
case_af101112	Dummy for sales after 2010 within case area	0.000	1.000	0.066	0.250
case_af1112	Dummy for sales after 2011 within case area	0.000	1.000	0.048	0.214
case_af_nw	Dummy for sales after 2008 in northwest quadrant	0.000	1.000	0.007	0.086
case_af_ne	Dummy for sales after 2008 in northeast quadrant	0.000	1.000	0.037	0.189
case_af_sw	Dummy for sales after 2008 in southwest quadrant	0.000	1.000	0.022	0.147
case_af_se	Dummy for sales after 2008 in southeast quadrant	0.000	1.000	0.015	0.121
case1_af	Dummy for sales after 2009 in case 1 (0.75 miles from barns)	0.000	1.000	0.026	0.159
case2_af	Dummy for sales after 2009 in case 2 (0.75–1.25 mile radius)	0.000	1.000	0.048	0.214

Model and Results

General Form of the Models

Our analysis of residential property sales employed standard hedonic regression techniques (Rosen, 1974; Jackson, 2001; Colwell, Heller, and Trefzger, 2009;

Simons, Bowen, and Sementelli, 1997; Simons, Winson-Geideman, and Mikelbank, 2001; and Seo and Simons, 2012). The dependent variable is the log of housing sales prices. The independent variables include a number of control variables, plus one that isolates the effect odors (Eq. 1). We hypothesize that, after the opening of the hog barns, homes within a 1.25-mile radius of the facility have sold at lower prices than those in the control area.

To check for spatial autocorrelation in housing sales prices (Kim and Goldsmith, 2009), we used the Lagrange Multiplier (LM) test for lag, for error, RobustLag for lag, and RobustLM for error. None of the test results indicated spatial autocorrelation was a concern.[5]

Two models plus an examination of the effects of the hog farm over time are presented: a baseline model including all sales in the case area from 2009 onward; a space model focusing on wind direction; and a series of interactive models over time and space that allows us to identify variations in price impact over varying time periods, based on a case property's direction from the hog barn complex. All models are generally specified as follows:

$$Ln\_HP = \beta_0 + \beta_1 HC + \beta_2 LOC + \beta_3 TIME + \beta_4 CASE\_AF + \varepsilon, \quad (1)$$

where:

Ln_HP = The (log of the) sale price of each home that sold in our dataset;
β_0 = The model intercept;
HC = A matrix of physical housing characteristics;
LOC = A matrix of dummy variables for sales within 0.1 mile of a major road, outside the case area;
$TIME$ = A matrix of year and season dummy variables;
$CASE\_AF$ = The effect on sales price of location within the case area after the hog barns became fully operative, which can take different forms as discussed below; and
ε = The error term.

Results: Baseline Model

The results from our baseline model are presented in Exhibit 6. We checked for multicollinearity, and the VIF statistics shown in the far right-hand column are low, outside the concern of generally accepted cutoffs. We also tested for normality and heterogeneity using the Kolmogorov-Smirnov test, which indicated that there is no normality problem with the dataset. The value of K-S D is 0.07, which is statistically significant at the 99% confidence interval. Similarly, application of the Breusch-Pagan test found no heteroscedasticity.[6]

The model's adjusted R^2 value at 69.67 is satisfactory, indicating that the variables used in the model explain about 70% of the variation in sales price. Likewise the

Exhibit 6 | Baseline Model: Case Area from 2009 Onward

Variable	Estimate	Std. Dev.	*t*-Value	Pr > |*t*|	VIF
Intercept	10.6080	0.2052	51.69	<0.0001	0.00
Acres	0.0109	0.0015	7.34	<0.0001	1.22
Total_SF	0.0001	0.0001	2.63	0.0092	1.88
ln_age	−0.1239	0.0328	−3.77	0.0002	1.67
cond_good	0.0042	0.0672	0.06	0.9503	1.41
cond_poor	−1.1989	0.2455	−4.88	<0.0001	1.10
site_good	0.1324	0.1167	1.13	0.2577	1.26
BR	0.1125	0.0512	2.20	0.0290	1.66
BA	0.1233	0.0633	1.95	0.0528	2.43
Space_Equi	0.1157	0.0276	4.19	<0.0001	1.38
No__of_Bar	0.1696	0.0554	3.06	0.0025	1.34
topo_rolli	0.0231	0.0622	0.37	0.7104	1.17
topo_steep	−0.4038	0.1578	−2.56	0.0111	1.19
*Bank_Sale_*	−0.4758	0.0860	−5.53	<0.0001	1.10
Porch_SF	0.0002	0.0002	1.16	0.2469	1.39
O_B_SF	0.0002	0.0000	4.35	<0.0001	1.26
d_spring	0.1407	0.0753	1.87	0.0631	2.02
d_summer	0.0858	0.0752	1.14	0.2548	1.90
d_winter	0.1164	0.0806	1.44	0.1500	1.77
d_out_after	−0.1052	0.1208	−0.87	0.3844	1.27
mobile	−0.8050	0.1057	−7.62	<0.0001	1.50
d_2003	−0.0755	0.1214	−0.62	0.5345	1.90
d_2004	0.0701	0.1170	0.60	0.5496	1.91
d_2005	−0.0440	0.1168	−0.38	0.7064	2.23
d_2006	0.1102	0.1184	0.93	0.3530	1.88
d_2007	0.2184	0.1188	1.84	0.0671	2.10
d_2008	0.1179	0.1263	0.93	0.3518	1.73
d_2009	0.2301	0.1301	1.77	0.0781	1.74
d_2010	0.2449	0.1281	1.91	0.0570	1.95
d_2011	0.1729	0.1224	1.41	0.1591	2.01
d_2012	0.2371	0.1150	2.06	0.0404	2.41
case_before	0.0643	0.1058	0.61	0.5441	1.21
maj_road	−0.1481	0.0595	−2.49	0.0135	1.41
Land_Contr	0.0518	0.1376	0.38	0.7070	1.12
BUF_ANIMAL	0.0115	0.0764	0.15	0.8803	1.14
case_af09101112	−0.2662	0.1090	−2.44	0.0153	1.35

Notes: The number of observations is 271. The adjusted R^2 is 69.67. The *F*-statistic is 18.72.

F-statistic is 18.72, satisfactory but consistent with statistical analysis with a limited number of sales.

The coefficients on the housing characteristic control variables are generally as expected by theory, at over a 90% level of confidence. The variables for lot size, porch size, square footage of living area, number of bedrooms, and number of baths have the expected positive signs and possess significantly high *t*-values. Housing and site condition dummy variables are as expected and statistically significant. Bank sales (−0.48) show the expected negative and statistically significant effect on sales prices, as does the mobile home variable (−0.81). The locational variable (major road) shows the predicted negative effect and is statistically significant. We used the year 2002 as the base year; the coefficients for sales in the years 2003 and 2005 have negative signs but are not statistically significant; the coefficients for sales in the years 2007, 2009, 2010, and 2012 reflect statistically significant differences from the base year in the order of a 20% increase, stable since 2007, which is contrary to the national trend of a downward cycle, consistent with the figures in Exhibit 4.

We include the variable *case_before*, which covers the subject area prior to the CAFO beginning operations. The coefficient is insignificant from zero, showing that prior to the CAFO, the subject area prices moved similarly to the surrounding areas, ceteris paribus.

We initially employed the commonly-used distance-rings approach in the hedonic model to estimate the effect of location within the case area.[7] Using the 1.25-mile distance ring, we identified sales in the case area from 2009 onward; the coefficient for the corresponding variable (*case_af09101112*) shows a coefficient of −0.27, or an estimated loss of 23%[8] (Halvorsen and Palmquist, 1980) after performing log transformation, and this figure is statistically significant at a level of more than 95%. In other words, this baseline regression model reveals that the marginal effect of a home's location within the case area (i.e., within a 1.25-mile radius of the subject hog barns after December 31, 2008, there is a 23% reduction in sales price, holding all other factors constant).[9]

Space Model Results: Direction and Time within Case Area

As noted above, the analysis of odor observation logs kept by a non-random sample of nearby residents at varying times from 2007 through 2011 demonstrated that hog barn odors appeared to be somewhat stronger and more prevalent at locations to the north and northeast of the hog barns than in other portions of the case area. As per Winegar (2013), prevailing winds in southwestern Marshall County tend to blow more often and with greater intensity from south and southwest of the hog barn complex. Accordingly, in our space model we explored the marginal effect on sales price of a home's location within the four cardinal wind directions from the hog farm facility. The case area is split into four directions, with the reference category defined as outside in the case area. The sample sizes are limited, but there is particular interest in the northeast quadrant of the case area (i.e., at headings between 0° (north) and 90° (east) from the hog barns), during the period beginning January 1, 2009. The corresponding variable is *case_af0912_ne*. The results of the regression model are presented in Exhibit 7.

The adjusted R^2 value and F-statistic in the space model are slightly higher than those in the baseline model, at 71.54 (indicating that the space model explains about 72% of the variation in sales price among all sales in the dataset) and 18.86, respectively. The signs of the variable coefficients in this hedonic regression model are similar to those in the baseline model. The coefficient of the interactive variable (*case_af0912_ne*) is statistically significant (at a level greater than 99%) and negative, indicating that the marginal effect of a property's location within the northeast quadrant of the case area, after December 31, 2008, is a reduction in sales price of 49%,[10] holding all other factors constant. This clearly shows that for these data, properties located northeast of the hog barns have sustained larger-than-average losses.

However, due to the relatively small number of sales (the number of sales in this NE quadrant is 13), caution is advised in putting too much weight on the magnitude of the parameter estimate, which seems quite large. Also, the other wind quadrants had only a handful of sales or less, and none of their parameter estimates were statistically significant. Hence, prudence indicates that we can only say that wind direction matters.

Alternative Runs Over Time and Space

In this sensitivity analysis, we explored a number of additional variations, including varying start time of the effects, and splitting distance rings within the case area. For start time, we varied the starting year, going from 2008 when the stench pit was filling up, to 2009 and 2010, through 2012 in all cases. It's important to watch the number of sales dwindling: the strongest results are when the model contains at least 15 sales.

We also took a closer look at distance rings. We attempted three rings: within 0.75 miles of the hog barns, 0.75–1.25 miles, and 1.25–2.0 miles. We ran into sample size issues again: the 0.75–1.25 miles from hog barns (referred to as case2) had over 15 sales, enough to report, and the losses there were higher than average for the entire case area.[11] The close-in ring did not have enough sales to find significant results. Exhibits 6 and 7 do not show a statistically significant effect outside the 1.25-mile range. However, there were only 15 sales, which is a small number for statistical reliability in these models.

We also conducted several additional model runs with five outliers (high and low sales prices) removed. Results continued to show significant reductions on property sales prices after 2009, about 15% lower than the full model. The space model still had significant higher losses northeast of the hog farms, but at a magnitude 25%–30% lower than the baseline model. Thus the model appears to have potentially influential outliers, but caution is again advised because the number of sales is smaller still. It can be concluded that the magnitude of the main results vary somewhat but not their statistical significance.

Exhibit 7 | Space Model Case Area (Northeast Quadrant) from 2009 Onward

Variable	Estimate	Std. Dev.	*t*-Value	Pr > |*t*|	VIF
Intercept	10.5958	0.1989	53.28	<0.0001	0.00
Acres	0.0107	0.0014	7.43	<0.0001	1.23
Total_SF	0.0001	0.0000	2.22	0.0271	1.91
ln_age	−0.1249	0.0319	−3.92	0.0001	1.68
cond_good	0.0192	0.0654	0.29	0.7688	1.42
cond_poor	−1.1710	0.2379	−4.92	<0.0001	1.10
site_good	0.1375	0.1131	1.22	0.2252	1.26
BR	0.1179	0.0497	2.37	0.0185	1.67
BA	0.1382	0.0613	2.25	0.0252	2.43
Space_Equi	0.1127	0.0269	4.19	<0.0001	1.40
No__of_Bar	0.2103	0.0546	3.85	0.0002	1.38
topo_rolli	0.0392	0.0604	0.65	0.5168	1.18
topo_steep	−0.4251	0.1532	−2.78	0.0060	1.19
*Bank_Sale_*	−0.4764	0.0832	−5.73	<0.0001	1.10
Porch_SF	0.0002	0.0002	1.27	0.2046	1.39
O_B_SF	0.0002	0.0000	5.12	<0.0001	1.30
d_spring	0.1198	0.0732	1.64	0.1032	2.03
d_summer	0.0753	0.0731	1.03	0.3037	1.91
d_winter	0.1030	0.0784	1.31	0.1899	1.78
d_out_after	−0.1367	0.1172	−1.17	0.2446	1.27
mobile	−0.7621	0.1029	−7.40	<0.0001	1.52
d_2003	−0.0737	0.1176	−0.63	0.5315	1.90
d_2004	0.0722	0.1134	0.64	0.5247	1.91
d_2005	−0.0558	0.1132	−0.49	0.6224	2.24
d_2006	0.1033	0.1148	0.90	0.3691	1.89
d_2007	0.2098	0.1151	1.82	0.0696	2.11
d_2008	0.1362	0.1233	1.10	0.2704	1.76
d_2009	0.1860	0.1269	1.47	0.1441	1.77
d_2010	0.3172	0.1258	2.52	0.0123	2.00
d_2011	0.1001	0.1194	0.84	0.4028	2.04
d_2012	0.2247	0.1115	2.02	0.0450	2.42
case_before	0.0607	0.1026	0.59	0.5544	1.22
maj_road	−0.1317	0.0588	−2.24	0.0259	1.47
Land_Contr	0.1613	0.1353	1.19	0.2346	1.15
BUF_ANIMAL	0.0201	0.0746	0.27	0.7877	1.16

Exhibit 7 | (continued)

Space Model Case Area (Northeast Quadrant) from 2009 Onward

Variable	Estimate	Std. Dev.	*t*-Value	Pr > |*t*|	VIF
class_af_ne	−0.6782	0.1476	−4.60	<0.0001	1.37
class_af_nw	−0.1167	0.2919	−0.40	0.6898	1.11
class_af_se	0.1540	0.2103	0.73	0.4648	1.14
class_af_sw	0.2270	0.1722	1.32	0.1886	1.14

Notes: The number of observations is 271. The adjusted R^2 is 71.54. The *F*-statistic is 18.86.

Exhibit 8 | Compilation of Several Alternative Runs

Model	Case Area 2008–2012	Case Area 2009–2012	Case Area 2010–2012	Case Area 2009–2012 NE of Hogs	Case Area 2009–2012 NE of Hogs	Case 2 2009–2012 0.75–1.25 miles
Parameter Est.	−0.20	−0.27	−0.32	−0.68	−0.78	−0.56
T-stat.	−1.94	−2.47	−2.76	−4.60	−5.13	−4.09
Model Adj. R^2	69.52	69.81	70.00	71.54	72.11	71.04
# of Sales	22	20	18	10	9	17

Conclusion

Hog farms are generally associated with a reduction in nearby residential sales prices, and our results support this expectation. Our hedonic regression analysis found a statistically significant average reduction in property value averaging almost 23% across the subject area within 1.25 miles of the facility for sales transacting from 2009 through 2012, holding other factors constant. Results from our regression models indicate that this negative impact on affected area property values is increasing, as the regression analysis disclosed an average property value diminution of 27% for sales from 2010 onward. We also found a substantially higher diminution in value for properties located in the northeast quadrant of the subject area, which suffer from the most prominent prevailing winds in the area. The discount allows properties that otherwise would not sell to be transacted in the market place, and thus represents a ‘‘sustainability adjustment.’’

The peer-reviewed professional literature reports that it is not unusual to find property value losses of 10% to 45% within 2 miles of CAFOs, with the effects being largest and most pronounced downwind of the facilities and in areas that do not already have high densities of existing CAFOs. The subject area fits this latter category, as the subject hog barns and a smaller, related facility are the first swine CAFOs to be established in Marshall County. The peer-reviewed literature also contains examples of property value losses in the range of 50% to 60% for individual homes in close proximity to CAFOs, with higher-valued properties sustaining particularly large percentage losses in value. Our results match closely with Isakson and Ecker's (2008) findings concerning the magnitude of losses and importance of wind direction.

With respect to time effects, we found increased impacts over time, with limited effects in the transitional year when the swill pits on the hog farms were filling up and increasing over the next several years. We conclude that wind direction is more important than pure distance in determining the magnitude of the effects on residential property values, but qualify this with our limited number of sales.

Endnotes

1 The senior author was retained as an expert witness by the plaintiffs in a legal case related to this study in 2013.

2 AEU is animal equivalent unit.

3 Many of the residents' observations were recorded on such a 10-point scale of odor intensity, but others were in the form of verbal descriptions.

4 The *t*-value is −0.53 for the distance to downtown Benton variable, and R-squared is slightly lower than the model without this variable.

5 Spatial results were: 0.09 (0.764) for LM lag, 0.09 (0.760) for LM error, 0.43 (0.513) for Robustlag, and 0.43 (0.512) for Robust LM error, respectively. The numbers in parentheses are the *p*-values. All results are below threshold levels.

6 We also examined the dataset for heteroscedasticity by visual inspection of a scatterplot of sale price and model residuals, and no fanning pattern was evident.

7 Simons and Seo (2011) found a positive externality of a religious facility campus on neighboring housing sale prices. They used hedonic regression analysis using 2,500 sales in Ohio, and identified sales within quarter-mile distance buffers. A similar distance ring approach was taken by Smolen et al., Reichert, and Nelson in their analyses of the negative amenity from proximity to landfills [in Simons (2006, p. 96)].

8 Percentage log transformation of dummy variables, $[(e^{0.2662}) - 1] * 100 = 23\%$.

9 As additional interpretive context for this result, note that the coefficient for the variable *case before* is positive but not statistically significant. In other words, over the time period before the odors became apparent covered by the dataset (i.e., 2002–2007), the sales data do not allow us to conclude that the marginal effect on sales price of location within the "future" area that would be affected by odors was other than zero. Thus, the sales performance of homes within the case area did not significantly differ from homes throughout the entire study area. That is, the observed diminution in value of case area homes after 2009 represents a genuine and abrupt change in their sales performance relative to a multi-year pre-existing pattern in which such homes statistically matched the sales performance of homes in the surrounding areas of southwestern Marshall County.

10 Percentage log transformation of dummy variables, $[(e^{0.6782}) - 1] * 100 = 49\%$.

11 In the outlier-free models reported just below, case2 had significant losses equivalent to the entire case area: hence no model shows closer-in sales with higher losses.

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PART 2

A Study of LEED vs. Non-LEED Office Buildings Spatial & Mass Transit Proximity in Downtown Chicago

Author Sofia Dermisi

Abstract Although the number of Leadership in Energy and Environmental Design (LEED) certified office buildings continues to increase, research on their spatial distributions in comparison to non-LEED buildings and mass transit links need to be explored in depth. This paper focuses on these aspects using all the downtown Chicago Class A office buildings as the study area. The findings show that LEED buildings are 21% closer to each other, indicating possible proximity pressure. LEED-Gold buildings are also 18% closer to each other compared to Silver. Regarding mass transit, LEED compared to non-LEED buildings are on average 14% closer to a metro area commuter rail station (Metra) and 12% closer to a local commuter rail station (CTA). In addition, LEED and non-LEED buildings show some evidence of small group clustering in certain areas, while the econometric results indicate that buildings located along the most prominent office market street (Wacker Drive) achieved 12% higher LEED points compared to other LEED buildings. A similar result was experienced among buildings built after 1979 and those certified under LEED v.2009 (12% and 19%, respectively). Additionally, LEED-Silver buildings achieved a lower number of points compared to other certification levels by 20%.

One can argue that the inclusion of a building's sustainability status [Leadership in Energy and Environmental Design (LEED) and ENERGY STAR] in commercial property databases such as the CoStar Group may pressure building owners to pursue such standards, especially in markets with increased adoption of LEED certification (Dermisi, 2009). The elevation of a building's performance to a LEED standard usually requires a combination of strategies and measures in order to accomplish long-term energy cost efficiencies/decreases (e.g., energy-efficient lighting, efficient heating and cooling equipment, etc.), as well as improved emissions and an overall healthier work environment. The incurred costs by building owners may vary significantly as can their payback periods (Nils, Miller, and Morris, 2012). However, most owners are aware of the simple check-box on the CoStar Group's website, which if checked can exclude them from a perspective tenant's consideration if their building is not sustainable.

Researchers have compared the performance of LEED and non-LEED buildings based on their vacancies, rents, sale prices, and valuations (Miller, Spivey, and

Florance, 2008; Fuerst and McAllister, 2009, 2011; Miller and Pogue, 2009; Eichholtz, Kok, and Quigley, 2010a, 2010b, 2010c; Wiley, Benefield, and Johnson, 2010; Dermisi and McDonald, 2011; University of San Diego, CBRE, and McGraw Hill Construction, 2011). Others have focused on spatial regression modeling of real estate related issues, although LEED spatial patterns have not been analyzed. Specifically, Ayse (1998), Lipscomb (2004), Valente, Wu, Gelfand, and Sirmans (2005), Osland (2010), and Wallner (2012) focused on residential and mortgage spatial allocation patterns. Jennen and Brounen (2009) and Montero and Larraz (2011) focused on commercial property pricing patterns. Clapp and Rodriguez (1998) focused on travel distances calculations while Anselin (1998) and Thrall (1998) focused on the geographic information system (GIS) applications for real estate in a broad context.

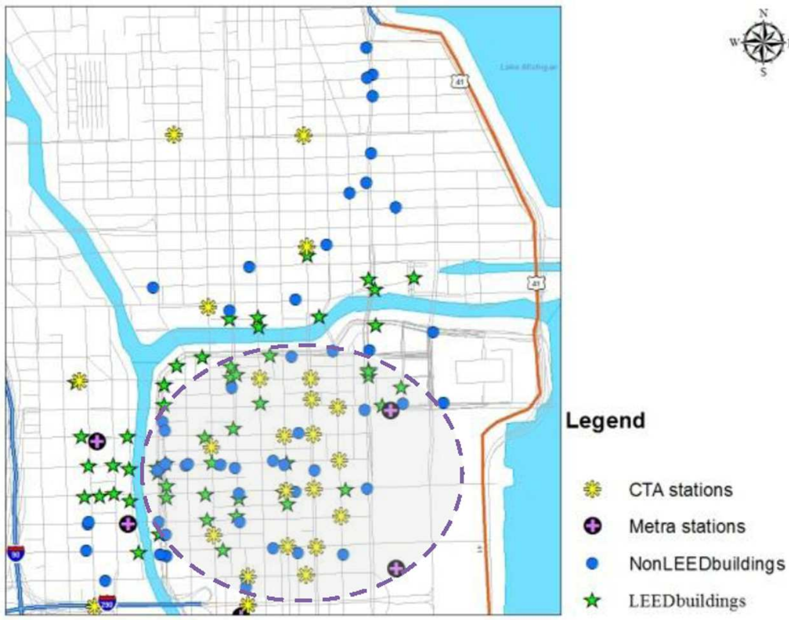
This paper tries to fill the void in the study of spatial distribution of LEED versus non-LEED buildings in dense urban environments, such as a downtown, and the lessons we can learn by studying their building characteristics. Focusing exclusively on all Class A office buildings (LEED and non-LEED with a limited exploration of ENERGY STAR labeled buildings) in downtown Chicago, the objective is to explore the underlying spatial patterns of these buildings in relation to each other as well as the mass transit rail system, their possible clustering, and the effect of building characteristics on LEED points a building can achieve.

Data

The study of LEED and non-LEED buildings requires the combination of two data sources: one for real estate (CoStar Group) and the other on sustainability [U.S. Green Building Council (USGBC)], allowing for the development of a full profile of a building. Due to the analysis of the spatial dynamics of both types of buildings in downtown Chicago in relation to mass transit stations, a third data source was introduced (City of Chicago database), which provided information on the location of all mass transit rail stations (Chicago metro area commuter: Metra and local commuter: CTA). The data extracted from the CoStar Group database included all Class A office buildings in downtown Chicago (LEED and non-LEED) with their specific characteristics, such as ENERGY STAR and LEED status, year built, rentable building area (RBA), number of stories, and submarket. This dataset was then complemented with more detailed information on the LEED building designation [rating (only buildings that achieved LEED: Existing Buildings Operations & Management (EBOM) or Core & Shell[1] were selected for the study), version, certification level and points] from the USGBC database. Finally, the mass transit rail station locations were extracted from the City of Chicago database, with an exclusive focus on downtown Chicago.

The overall dataset consists of 102 Class A office buildings with 71.6% (73 buildings) achieving ENERGY STAR label status at least once and 50.9% (52 buildings) of them being certified as LEED. Assessing the sustainability footprint of only the non-LEED buildings, 46% (23 buildings) have already achieved the ENERGY STAR label at least once. The area of study also includes five Chicago metropolitan area commuter stations, from which two are the main entry points

Exhibit 1 | Location of LEED and Non-LEED Buildings



with the largest volume of daily commuters (Union and Ogilvie stations–Metra) and 23 local commuter rail stations (CTA).

Methodology

Two aspects of the Class A office buildings in downtown Chicago were analyzed. The first is the spatial distribution of LEED versus non-LEED buildings and possible proximity pressure in achieving LEED in areas with significant LEED adoption. The spatial distribution of both groups of buildings is studied with the use of GIS, which allows the visualization of the locations of both groups of buildings (Exhibit 1) and the analysis of their spatial distributions. The availability of the ENERGY STAR status (Exhibit 2) allows a further evaluation of the first step towards sustainability managers of buildings take before pursuing LEED. The second aspect I analyze is the effect of building characteristics and location on the LEED scores achieved.

Four research questions were evaluated. The first question is: Are LEED and non-LEED buildings concentrated in the same areas? What is the average distance among buildings in each group and how is it affected by mass transit rail stations? These questions require the spatial analysis of these buildings. Directional distribution (Exhibits 3 and 4) is a first step in answering the first part of the question and determined the dispersion of the buildings within each of the two groups. Utilizing ArcGIS a standard deviation ellipse[2] polygon was generated

Exhibit 2 | ENERGY STAR and Non-ENERGY STAR Buildings

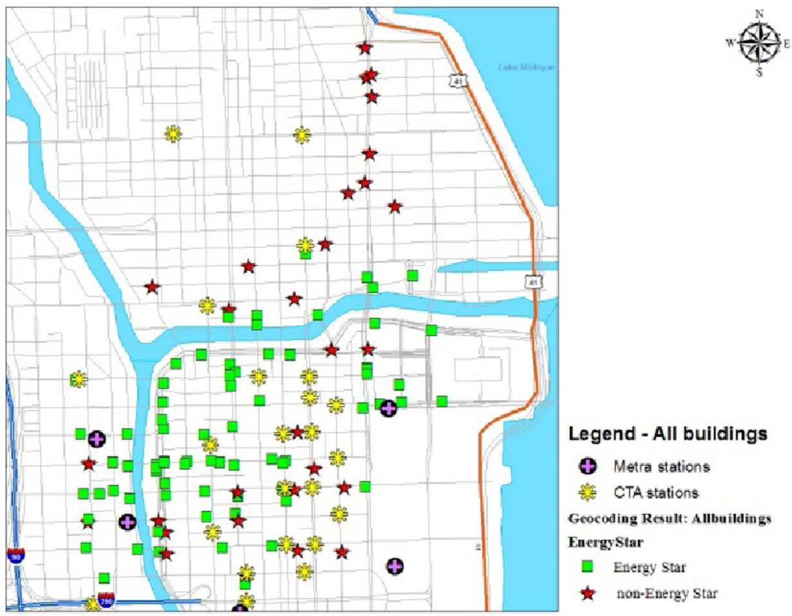


Exhibit 3 | Directional Distribution and Central Features of LEED Buildings

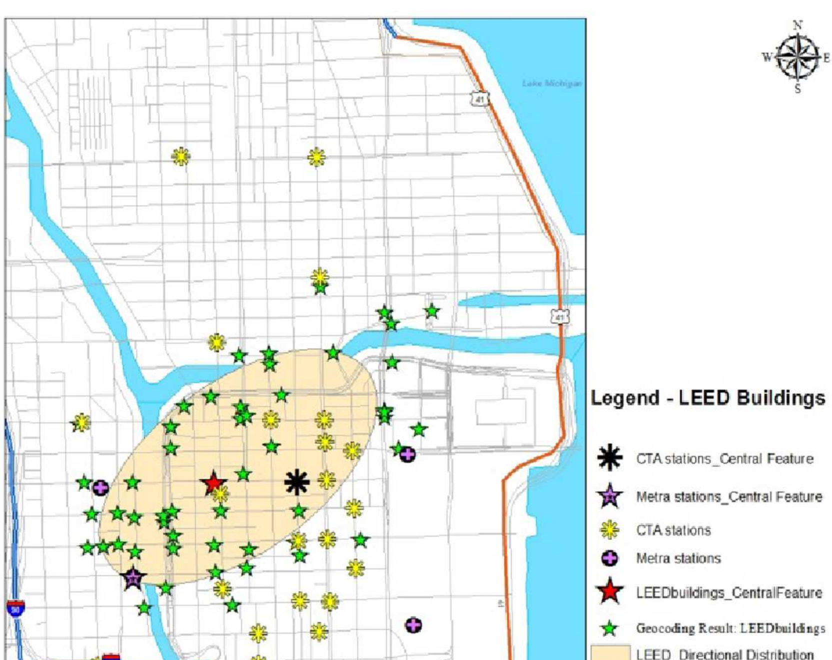
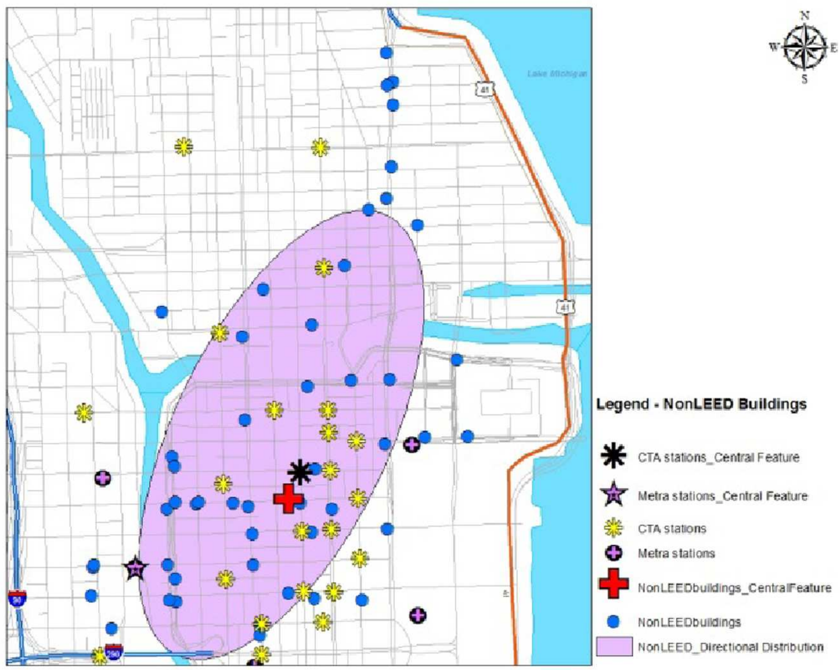


Exhibit 4 | Directional Distribution and Central Features of Non-LEED Buildings



based on the buildings' coordinates. The denser patterns of the LEED buildings led to the decision to define the directional distribution ellipse to encompass 68% of the data (1-standard deviation polygon), (Exhibit 3). For consistency purposes, a 1-standard deviation polygon was also used for the non-LEED buildings (Exhibit 4).

The identification of the most central point of the spatial distributions (Exhibit 5) of both building groups (LEED and non-LEED) allowed the quantification of any difference between them with the use of ArcGIS. The central feature was also determined for each of the two mass transit rail modes (METRA and CTA) to effectively estimate their overall proximities to the central features of LEED and non-LEED buildings.

Identifying the distances between neighboring buildings for each of the two groups (LEED and non-LEED) provided insights on the concentration or dispersion pattern in a quantitative beyond a visual representation (Exhibit 6). Distances were estimated based on clusters of three neighboring buildings. LEED-Silver and LEED-Gold buildings were the most popular certification levels (17 and 25 buildings, respectively) and distances were estimated using the same three-neighbor logic.

A one-on-one distance analysis between each of the mass transit stations (Metra and CTA) and each of the LEED and non-LEED buildings was performed to

Exhibit 5 | Central Feature Comparison of LEED and Non-LEED Buildings

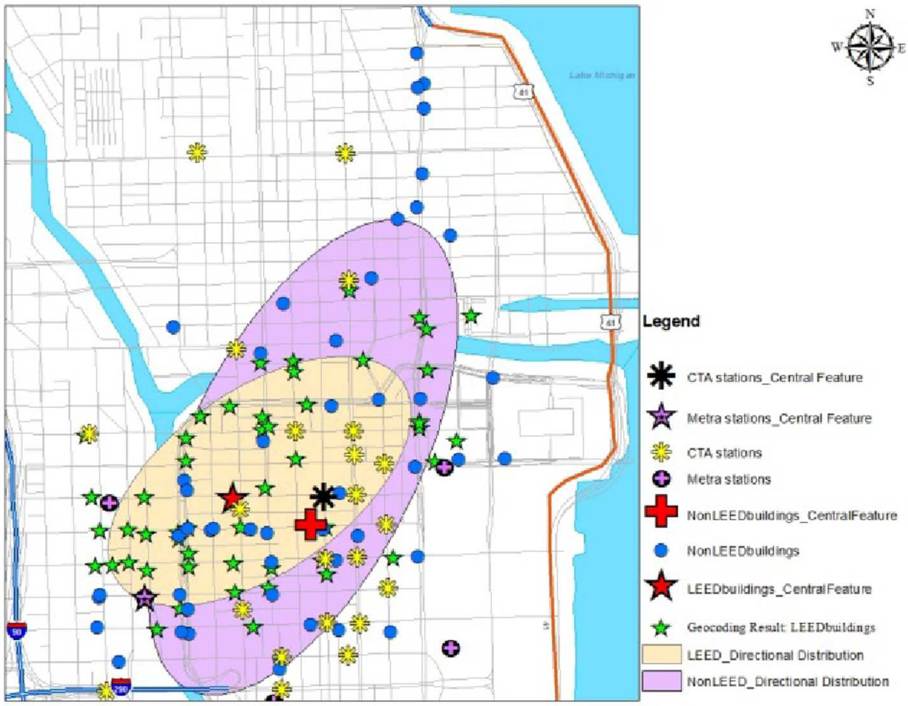


Exhibit 6 | Distance between Neighbors

	Mean	Min.	Max.
All LEED	0.127	0.100	0.261
Non-LEED	0.161	0.067	0.397
Silver	0.218	0.141	0.320
Gold	0.178	0.107	0.390

determine the existing distances and the evolving patterns. Exhibits 7 and 8 present some basic statistics from this comparison by station and type of building.

The second research question is: Are LEED and non-LEED buildings randomly located throughout the Chicago downtown area? This question is answered using both a quantitative and a visual approach.

Utilizing the average nearest neighbor equations[3] from ArcGIS, an assessment was made regarding the randomness of the distributions (Exhibits 9 and 10). The

Exhibit 7 | Distances between Mass Transit METRA Rail Stations and Buildings

	LEED			Non-LEED		
METRA Station	Average	Min.	Max.	Average	Min.	Max.
Ogilvie	0.48	0.05	1.11	0.68	0.21	1.48
Union	0.50	0.07	1.17	0.66	0.10	1.66
Randolph	0.58	0.03	0.98	0.61	0.05	1.13
LaSalle	0.67	0.21	1.19	0.74	0.09	1.81
Van Buren	0.77	0.29	1.15	0.79	0.17	1.63

Note: All values in miles.

spatial autocorrelation was then assessed with ArcGIS's Global Moran's I,[4] which evaluated autocorrelation based on the buildings' proximity to others and the assessed characteristic [e.g., year built, rentable building area (RBA), LEED levels, and points achieved]. Under the null hypothesis, various characteristics are randomly distributed among the buildings in the area of study.

With the help of ArcGIS, a surface was generated throughout the study area based on the location of each building compared to the others, a building characteristic (e.g., year built, RBA, LEED levels, and points achieved), and the number of cells sharing the building's characteristic within a defined neighborhood (Exhibits 11–17). The maps generated calculated a magnitude effect per foot,[5] based on the building's characteristics, which fall within a neighborhood generated around each cell. Due to the close proximity, a torus neighborhood was defined among LEED buildings with an inner radius of 0.0036 miles and outer of 0.011 miles. In contrast, due to the distribution patterns of non-LEED buildings, the inner radius decreased slightly to 0.004 but the outer increased to 0.013 miles. Another set of density maps was generated utilizing the proximity of each building to each of the mass transit stations (Metra and CTA). Each building was assigned a ranking from 1 to 3 based on the overall average proximity across all of the Metra or CTA stations. Buildings that achieved an overall average distance of less than 0.5 miles across all transit stations were assigned to group 1, those that were between 0.51 and 0.7 miles were assigned to group 2, and those with more than 0.7 miles from a station were assigned to group 3. This grouping was then used to develop the density map based on this feature.

A final approach in identifying the statistical significance of clustering (hot spots, cold spots, and outliers) was explored using Anselin's Local Moran's I.[6] Each building of both groups (LEED and non-LEED) was assessed for their possibility of clustering based on their characteristics and location, including mass transit (Exhibits 14–17). Four spatial significance groups were generated, which determined the underlying patterns: High-High Clusters (HH), High-Low Outlier (HL), Low-High Outlier (LH), Low-Low Cluster (LL), and for the lack of

Exhibit 8 | Distances between Mass Transit CTA Rail Stops and Buildings

	LEED			Non-LEED		
CTA Station	Average	Min.	Max.	Average	Min.	Max.
Adams / Wabash	0.56	0.09	0.92	0.61	0.12	1.46
Chicago / Franklin	0.97	0.56	1.30	1.00	0.47	1.43
Chicago / State	0.96	0.37	1.39	0.92	0.22	1.52
Clark / Lake	0.38	0.07	0.66	0.50	0.09	1.08
Clinton / Congress	0.74	0.22	1.43	0.87	0.09	1.94
Clinton / Lake	0.56	0.01	1.09	0.75	0.29	1.37
Grand / State	0.66	0.03	1.08	0.68	0.06	1.21
Jackson / Dearborn	0.54	0.13	0.93	0.60	0.04	1.57
Jackson / State	0.58	0.16	0.91	0.62	0.06	1.56
Lake / State	0.43	0.16	0.76	0.51	0.11	1.11
LaSalle	0.65	0.19	1.14	0.72	0.06	1.77
LaSalle / VanBuren	0.57	0.11	1.07	0.64	0.01	1.69
Library	0.62	0.23	0.99	0.67	0.07	1.65
Madison / Wabash	0.49	0.45	0.85	0.55	0.08	1.29
Merchandise Mart	0.49	0.07	0.79	0.61	0.07	0.95
Monroe / Dearborn	0.44	0.01	0.77	0.51	0.03	1.40
Monroe / State	0.48	0.09	0.81	0.54	0.06	1.39
Quincy / Wells	0.46	0.05	1.02	0.57	0.09	1.59
Randolph / Wabash	0.47	0.14	0.83	0.53	0.08	1.12
State / Lake	0.44	0.14	0.79	0.52	0.09	1.05
Washington / Dearborn	0.39	0.08	0.67	0.48	0.05	1.24
Washington / State	0.43	0.12	0.75	0.50	0.04	1.22
Washington / Wells	0.35	0.04	0.82	0.49	0.06	1.33

Note: All values in miles.

Exhibit 9 | Quantifying Patterns: Average Nearest Neighbor

	Observed Mean Distance (miles)	Expected Mean Distance (miles)	Nearest Neighbor Ratio	z-score	*p*-value	Pattern Distribution
All LEED	0.069	0.064	1.085	1.170	0.242	Random
Non-LEED	0.084	0.093	0.898	−1.381	0.167	Random

Exhibit 10 | Quantifying Patterns: Moran's I

All LEED	Moran's I	z-score	*p*-value	Pattern Distribution
YB	0.030	0.422	0.673	Random
RBA	0.130	1.242	0.214	Random
Certification level	−0.007	0.107	0.914	Random
Certification points	−0.099	−0.670	0.503	Random
Non-LEED				
YB	0.068	0.675	0.499	Random
RBA	0.078	0.803	0.422	Random

significance. The existence of HH and LL clusters are indicative of the existence of statistically significant similar values in the surrounding buildings. In contrast, the existence of HL and LH represents statistically significant spatial outliers.

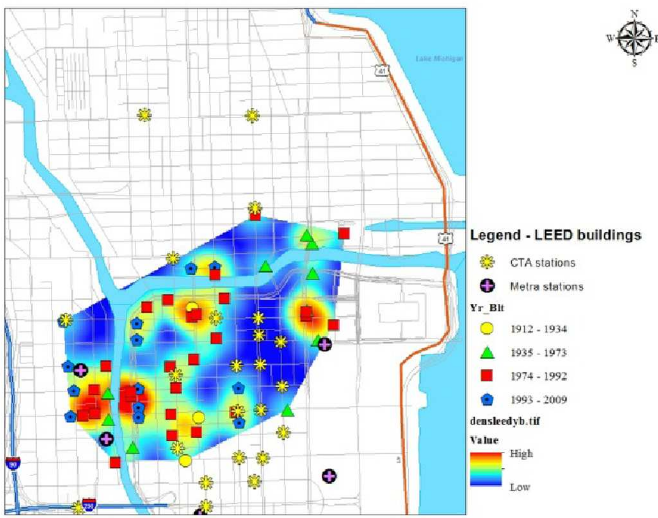
The third research question is: What is the level of differentiation among characteristics of LEED versus non-LEED buildings? Initially, building characteristics such as RBA, year built, and number of stories were assessed for their average and standard deviation trends between the two building groups. These same characteristics were also assessed within each of the four different types of LEED certification (Certified, Silver, Gold and Platinum) and between buildings with and without an ENERGY STAR label. Exploring the characteristics of buildings with and without an ENERGY STAR label provides additional insight on each of the two types Exhibits 18 and 19. These ENERGY STAR buildings are potentially more likely to pursue LEED because achieving the ENERGY STAR label indicates an embracing of the sustainability mentality [an ENERGY STAR score of 69 is a prerequisite for LEED under version 2009, but an ENERGY STAR label (75 score) is a prerequisite under version 4].

Three hypotheses are examined between LEED and non-LEED buildings, as well as those with and without an ENERGY STAR label. Hypothesis 1: Larger RBA buildings are on average sustainable (either LEED and/or ENERGY STAR label). The argument behind this assumption is that larger RBA buildings can attain significant operating expense reductions by adopting sustainable practices that reduce energy and water use significantly because of the building volume, allowing it to remain competitive. Hypothesis 2: Newer buildings are on average more sustainable (either LEED and/or ENERGY STAR label) because of the advanced building systems they benefit that allow for a lower retrofit cost. Hypothesis 3: The average number of stories is not differentiated between sustainable (LEED and/or ENERGY STAR label designations) and non-sustainable buildings.

The fourth research question is: How do building characteristics affect the LEED points achieved? The two types of econometric models applied were a weighted fixed effects and a weighted least squares regression. The two different approaches

Exhibit 11 | Density Analysis Based on Year Built

Panel A: LEED Buildings



Panel B: Non-LEED Buildings

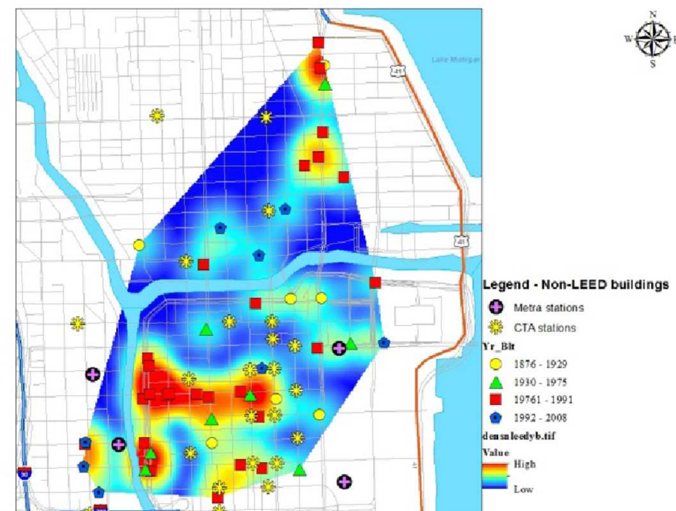
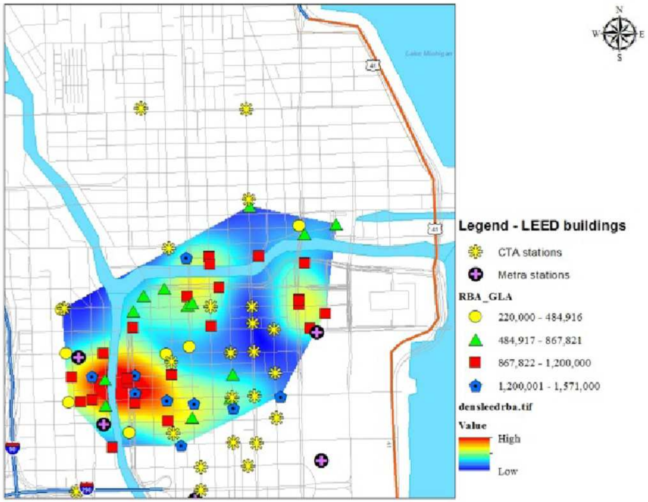


Exhibit 12 | Density Analysis Based on RBA

Panel A: LEED Buildings



Panel B: Non-LEED Buildings

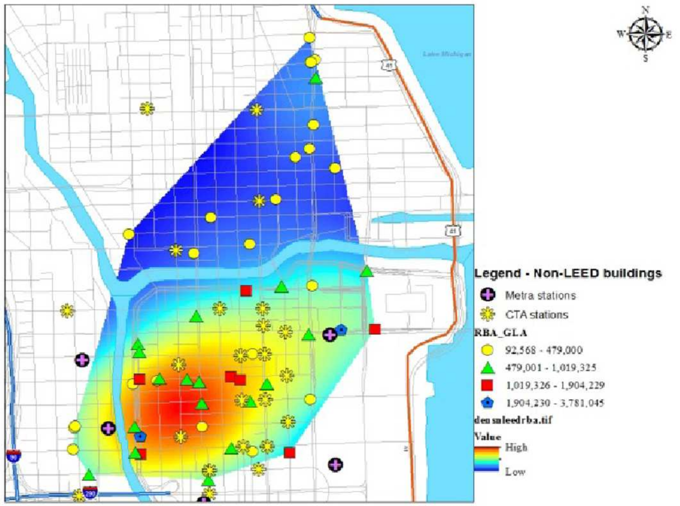
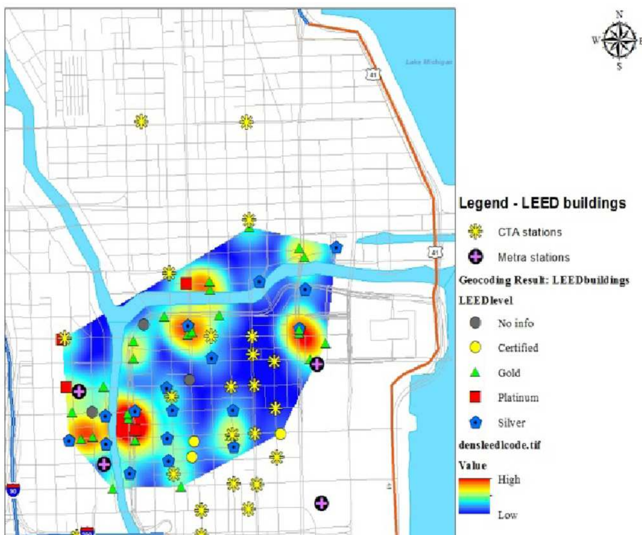


Exhibit 13 | Density Analysis of LEED Level

Panel A: LEED Certification Levels Achieved



Panel B: LEED Points Achieved

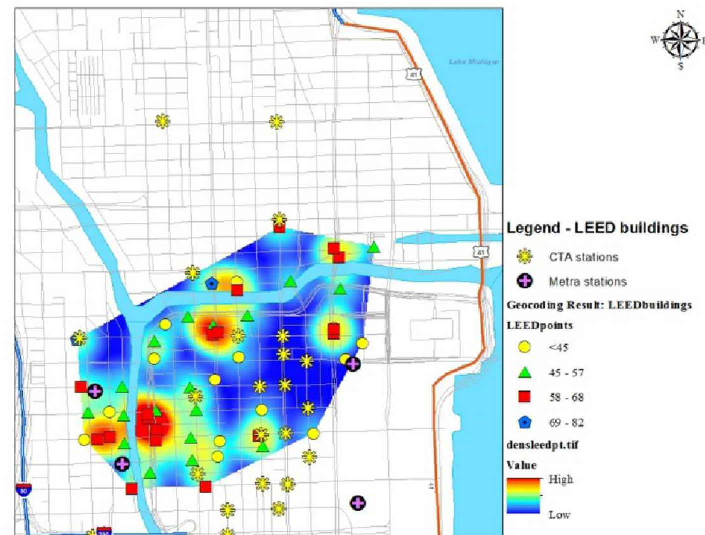
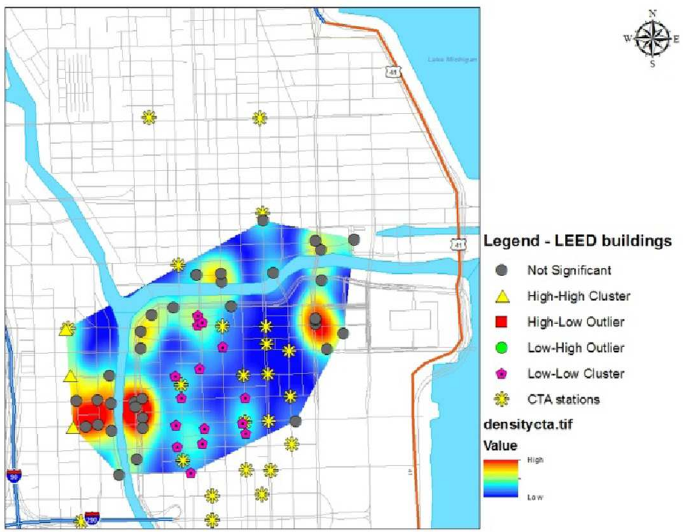


Exhibit 14 | Density and Cluster Analysis Based on CTA Station

Panel A: LEED Buildings



Panel B: Non-LEED Buildings

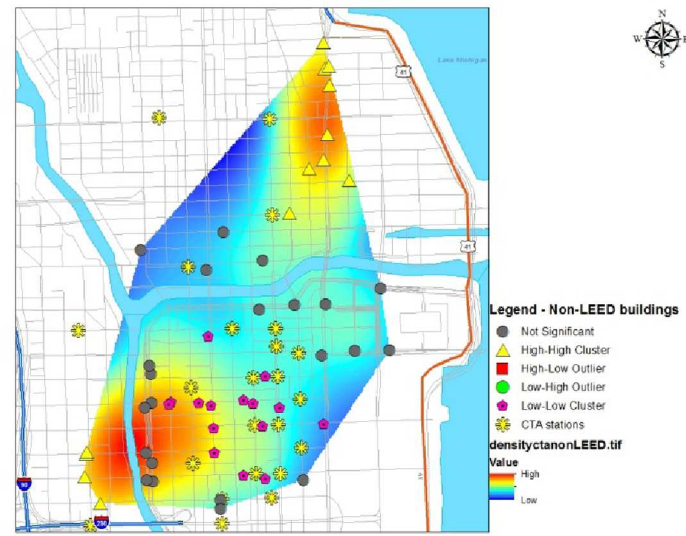
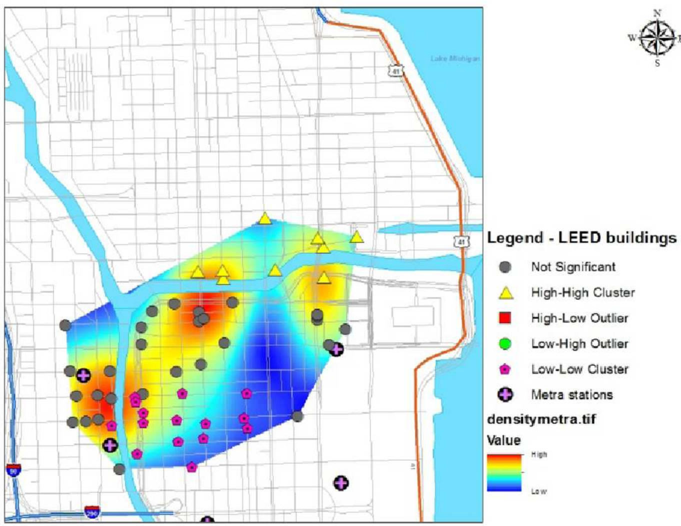


Exhibit 15 | Density and Cluster Analysis Based on Metra Stations

Panel A: LEED Buildings



Panel B: Non-LEED Buildings

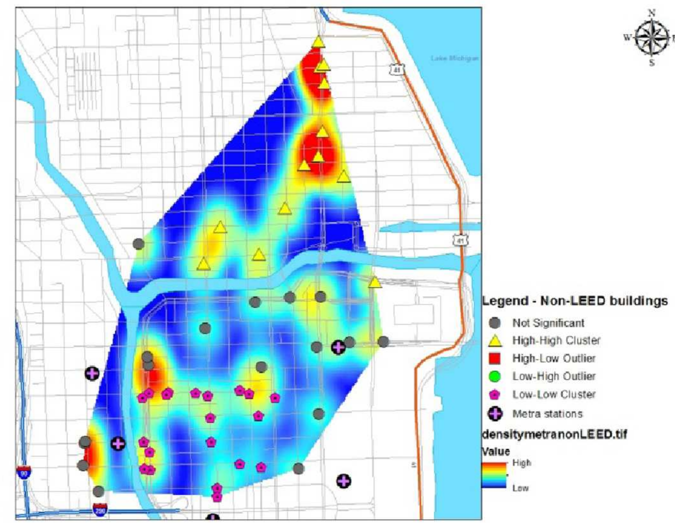
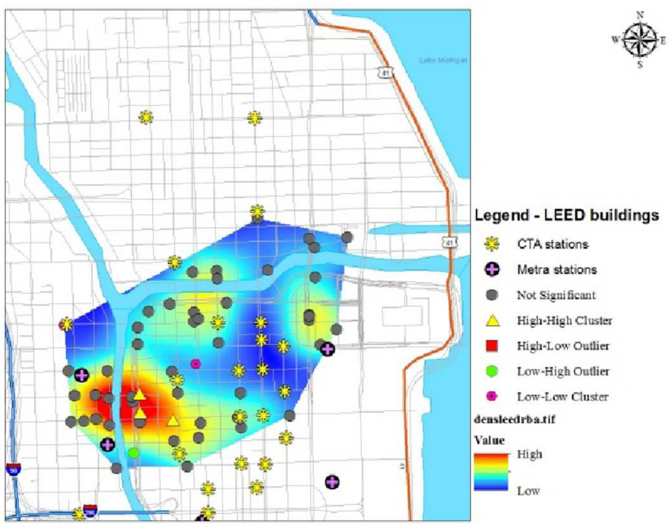


Exhibit 16 | Cluster Analysis Based on RBA

Panel A: LEED Buildings



Panel B: Non-LEED Buildings

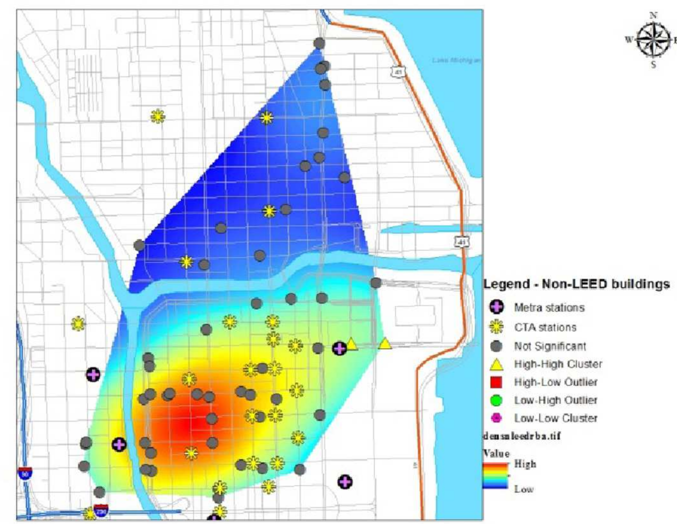


Exhibit 17 | Cluster Analysis of LEED Certification Levels Achieved

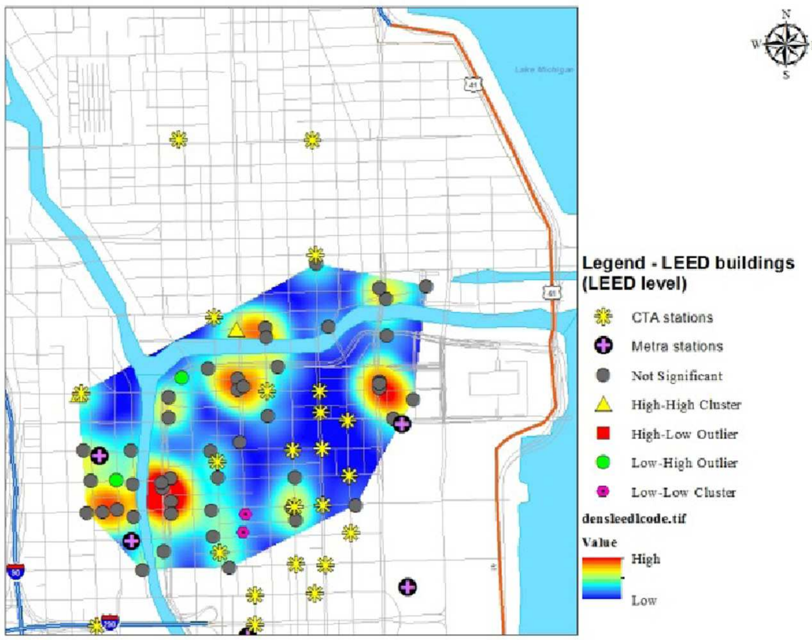


Exhibit 18 | Descriptive Statistics of LEED and Non-LEED Buildings

		Mean			Std. Dev.		
	N	RBA	Year Built	Stories	RBA	Year Built	Stories
All buildings	102	836,441	1979	36	539,351	26	18
All LEED	52	939,456	1983	36	333,741	20	12
Non-LEED	50	729,305	1974	35	678,753	31	23
LEED Certified	3	1,136,288	1964	44	296,018	27	5
LEED Silver	17	927,775	1980	35	359,731	20	13
LEED Gold	25	935,760	1984	36	265,375	20	11
LEED Platinum	4	892,932	2005	34	587,090	4	24
LEED in progress	3	901,645	1987	39	537,929	5	2

were used to analyze the effect of submarkets overall, as well as on an individual basis. The weighted fixed effects model assessed the effect of submarkets (overall dataset), as well as clusters generated with the use of ArcGIS for the most popular LEED certification levels: Silver and Gold (partial dataset). All regression models were weighted by RBA for consistency purposes.

Exhibit 19 | Descriptive Statistics of ENERGY STAR Label and Non-ENERGY STAR Buildings

		Mean			Std. Dev.		
	N	RBA	Year Built	Stories	RBA	Year Built	Stories
All ENERGY STAR	73	914,657	1983	36	433,612	20	14
All Non-ENERGY STAR	29	639,552	1969	35	713,958	37	27
ENERGY STAR & Non-LEED	23	886,175	1982	36	604,390	18	18
ENERGY STAR & LEED	50	927,758	1983	36	334,232	20	12
Non-ENERGY STAR & Non-LEED	27	595,674	1967	35	720,312	37	28
Non-ENERGY STAR & LEED	2	1,231,902	1988	40	169,672	21	13

Exhibit 20 | T-test Results

	N	Mean	Std. Dev.	*t*-Test
Panel A: RBA				
Non-LEED	50	729,305	678,753	−1.996
LEED	52	939,456	333,741	
Non-ENERGY STAR	29	639,552	713,958	−2.377
ENERGY STAR	73	914,657	433,612	
Panel B: Year built				
Non-LEED	50	1974	31	−1.799
LEED	52	1983	20	
Non-ENERGY STAR	29	1969	37	−2.557
ENERGY STAR	73	1983	20	
Panel C: Number of stories				
Non-LEED	50	35	23	−0.275
LEED	52	36	12	
Non-ENERGY STAR	29	35	27	−0.309
ENERGY STAR	73	36	14	

The fixed effects models control for two distinct groups. The first group contains the allocation of buildings within one of the five downtown submarkets as defined by the CoStar Group [Exhibit 21, column 1, Equation 1; Exhibit 22 identifies the submarkets]. The submarkets were used to explore differences between them, which are rumored among the real estate professionals to exist. The second group is buildings based on their geocoding and spatial distribution by LEED Gold and Silver certification (Exhibit 21, columns 3 and 4, respectively, and Equation 2). Exhibits 23 and 24 show the spatial distribution of the groups. The groups

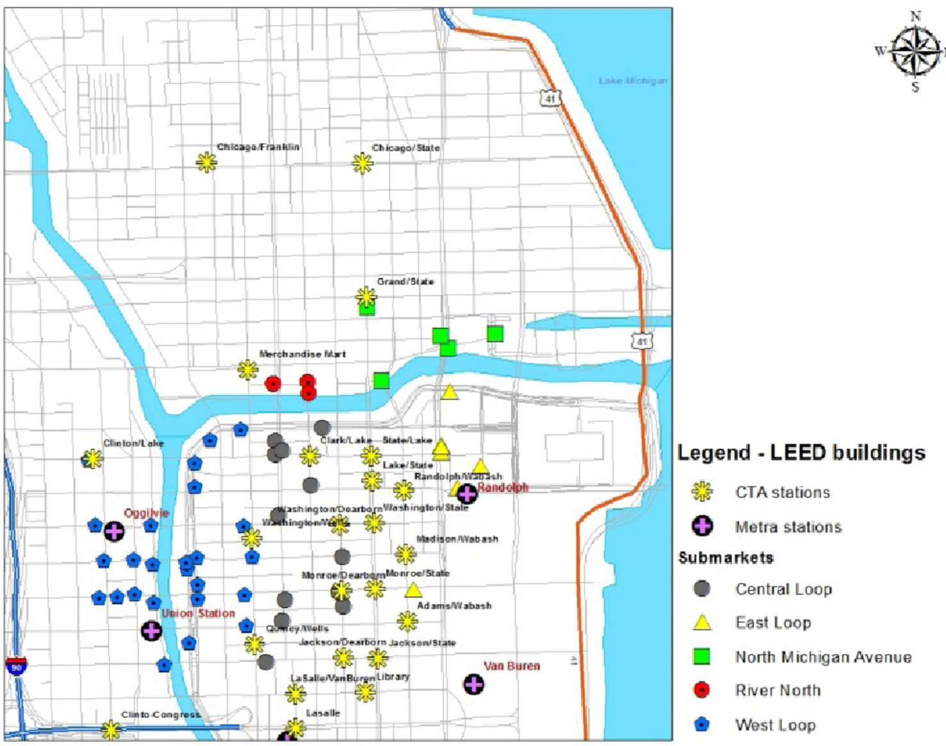
Exhibit 21 | Regression Models

	Submarket		Spatial Group	
	(1)	(2)	(3)	(4)
Land size	0.01 (0.2)	0.00 (0.11)	−0.02 (−0.46)	0.15 (2.66)*
Number of stories	−0.005 (−1.99)*	−0.005 (−2.41)*	−0.001 (−0.16)	−0.004 (−2.35)*
Dummy Variables				
Wacker Address	0.12 (1.82)**	0.12 (1.71)**	−0.01 (−0.13)	−0.07 (−0.64)
Year built from 1980 and after	0.18 (1.73)**	0.18 (1.87)**	0.04 (0.19)	0.15 (1.89)**
Renovated	0.10 (0.99)	0.10 (1.10)	0.02 (0.11)	0.02 (0.41)
LEED 2009 version	0.29 (5.75)*	0.30 (5.30)*	0.29 (3.93)*	0.32 (5.86)*
LEED Silver Certification	−0.19 (−2.53)*	−0.19 (−1.84)**		
LEED Gold Certification	−0.10 (−1.39)	−0.11 (−0.91)		
Submarket Dummies				
Central Loop		−0.13 (−1.87)**	0.13 (1.08)	Dropped
East Loop		−0.22 (−1.98)*	Dropped	0.17 (1.38)
West Loop		−0.08 (−1.23)	0.14 (0.78)	0.22 (3.71)*
Constant	3.884	3.983	3.765	3.402
N	46	46	23	16
R^2	62.02%	61.81%	74.66%	96.50%
VIF (multicolinearity test)	5.02	2.40	0.21	6.43
F-statistic	1.435		5.91	8.63

Note: *t*-statistics are in parentheses.
*Statistically significant at the 5% level.
**Statistically significant at the 10% level.

for the two LEED certification levels were determined using ArcGIS based on the coordinates of each building, assuming the existence of at least one natural neighbor in common with another group of buildings (Delaunay triangulation); five groups were generated for Gold buildings and four for Silver buildings.

Exhibit 22 | Submarkets and Major Road Names



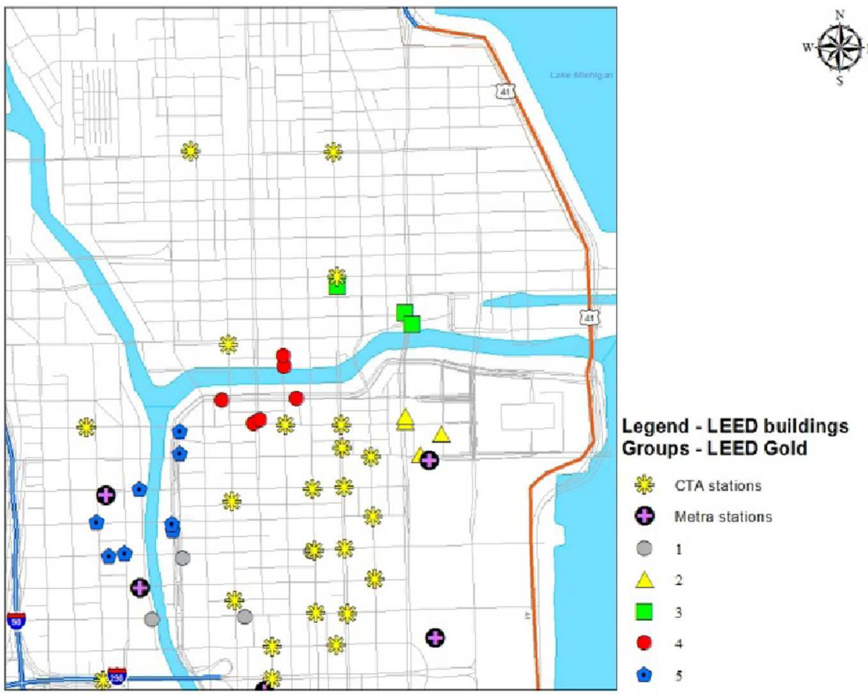
$$
\begin{aligned}
\ln(LEED\ points) = {} & \alpha + \beta_1 LS_i + \beta_2 NS_i + \beta_3 WA_i \\
& + \beta_4 YB80_i + \beta_5 R_i + \beta_6 L09_i + \beta_7 LS_i \\
& + \beta_8 LG_i + \eta_i + \varepsilon_i. \qquad (1)
\end{aligned}
$$

$$
\begin{aligned}
\ln(LEED\ points) = {} & \alpha + \beta_1 LS_i + \beta_2 NS_i + \beta_3 WA_i \\
& + \beta_4 YB80_i + \beta_5 R_i + \beta_6 L09_i + \beta_7 CL_i \\
& + \beta_8 EL_i + \beta_9 WL_i + k_i + \varepsilon_i. \qquad (2)
\end{aligned}
$$

Where:

- LS = Lot size;
- NS = Number of stories;
- WA = A dummy variable that takes the value 1 if the building has a Wacker Drive address and zero otherwise;

Exhibit 23 | Groups of LEED Gold Buildings in Fixed Effects Regression



YB80 = A dummy variable that takes the value 1 if the building was built more recently than 1979 and zero otherwise. This cutoff year was determined based on the age distribution of the buildings and the data mean, which was 1979.

R = A dummy variable that takes the value 1 if the building has been renovated and zero otherwise;

L09 = A dummy variable that takes the value 1 if the building received its LEED certification under the current LEED v.2009, and zero otherwise;

LS = A dummy variable that takes the value 1 if the building is certified at the Silver level and zero otherwise;

LG = A dummy variable that takes the value 1 if the building is certified at the Gold level and zero otherwise;

CL = A dummy variable that takes the value 1 if the building is located in the Central Loop submarket and zero otherwise;

EL = A dummy variable that takes the value 1 if the building is located in the East Loop submarket and zero otherwise;

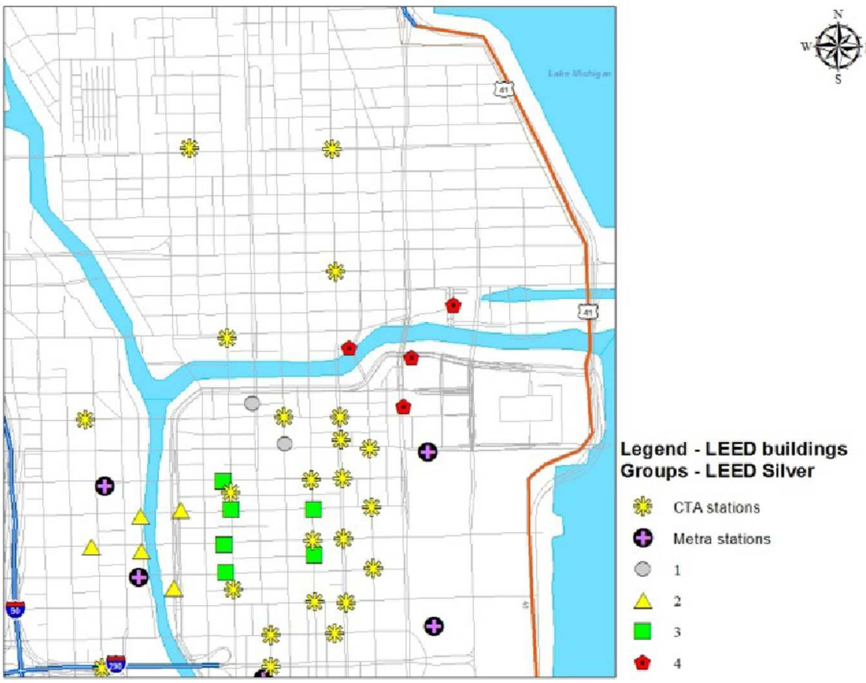
WL = A dummy variable that takes the value 1 if the building is located in the West Loop submarket and zero otherwise;

η = The submarket specific characteristics;

k = The spatial groupings specific characteristics; and

ε = The error term.

Exhibit 24 | Groups of LEED Silver Buildings in Fixed Effects Regression



The weighted least square (WLS) model in column 2 of Exhibit 21 assessed the effect of the same variables from equation (1) on LEED points with the only difference being the exclusion of the submarket grouping and the inclusion of dummy variables representing the three submarkets (Central, East, and West Loop) where LEED buildings are mostly present. The inclusion of these variables allows the evaluation of the individual effect experienced by each of these submarkets:

$$\begin{aligned}\ln(LEED\ points) = {} & \alpha + \beta_1 LS_i + \beta_2 NS_i + \beta_3 WA_i \\ & + \beta_4 YB80_i + \beta_5 R_i + \beta_6 L09_i + \beta_7 CL_i \\ & + \beta_8 EL_i + \beta_9 WL_i + \varepsilon_i, \qquad (3)\end{aligned}$$

where all the variables are as defined under equations (1) and (2).

Results

A first step in assessing the spatial dynamics of LEED and non-LEED buildings was the visual representation of their locations. Exhibit 1 shows a mixed concentration of both building groups in the Loop area of downtown Chicago (highlighted in a semi-transparent circle). In contrast, the area west of the Loop, where newly constructed office buildings are located, as well as the two main commuter stations (Union and Ogilvie stations), shows a more pronounced concentration of LEED buildings. The presence of non-LEED buildings is more evident north of the river, especially along North Michigan Avenue above Ohio Street. The comparison of LEED (Exhibit 1) with ENERGY STAR label buildings (Exhibit 2) indicates that throughout the Loop area a significant number of non-LEED buildings have achieved the ENERGY STAR label, which is not the case for buildings north of the river. Achieving an ENERGY STAR label is important because it is a first step in energy conservation with long-term cost benefits for owners and tenants. The ENERGY STAR label can possibly be indicative of a future pursuit of LEED, due to the new requirement under LEED version 4.

The first question focused on the spatial distribution of LEED versus non-LEED buildings, their distances and the links with mass transit rail stations. The three approaches applied provide both visual and quantitative evidence of different concentration patterns within each of the two groups, as well as differences in the proximity of buildings in each group (Exhibits 3–8). LEED buildings are mainly agglomerated in the Loop area, with an overspill to the West due to the proximity to the main commuter stations (Union and Ogilvie) and the new office construction activity along Wacker Drive during the last decade. This construction activity prompted a number of building managers to pursue LEED certification to remain competitive to the new stock, leading to this northeast-to-southwest directional distribution (Exhibit 3). In addition, Exhibit 3 includes the mass transit system stations (Metra and CTA) and their central features, allowing the comparison between mass transit and buildings spatial distribution, which is also shown in Exhibits 4 and 5. The Exhibit 3 ellipse characteristics are x-axis standard distance of 0.246 miles and y-axis standard distance 0.473 miles, with a rotation of 54.8°. On the other hand, the significant number of non-LEED buildings inside and north of the Loop creates a north-to-south trend, with a slight shift to the west (Exhibit 4). In Exhibit 4's case, the x-axis standard distance is 0.314 miles and the y-axis standard distance is 0.704 miles, the rotation is 26.3°. Additional proof of the difference between the spatial concentrations of the two building groups is evident by the 0.226 mile difference between the two central points of each building group (Exhibit 5). The comparison between central feature of LEED buildings and Metra stations suggests a distance differentiation of 0.361 miles, while the distance to the central feature of CTA stations is 0.247 miles. The values for non-LEED buildings show some variation, with the central feature distances reaching 0.492 miles for Metra while the distance to CTA stations is only at 0.085 miles.

The spatial dispersion between the two building groups is studied with a third approach, which determines the distance among neighboring buildings within the same group. The results indicate that LEED buildings are on average 20.9% closer to each other compared to non-LEED buildings. The similar result is evident with the maximum distance, indicating a tighter concentration for LEED buildings by 34.16% compared to non-LEED buildings (Exhibit 6). An analogous comparison, among the most popular certifications (LEED Gold and Silver), indicates that Gold buildings are located on average 18.05% closer to each other compared to Silver buildings (Exhibit 6). The comparison among the five Metra station distance results indicates that LEED buildings are on average 13.8% closer to Metra stations compared to non-LEED buildings (Exhibit 7). The overall average distance across all buildings and the five Metra stations is 0.599 miles (Exhibit 7), in contrast to non-LEED buildings, which is 0.696 miles (Exhibit 7). Both LEED and non-LEED buildings achieve the same level of minimum distances of 0.05 miles (LEED buildings to Ogilvie station and non-LEED to Randolph station). Another significant observation is the significantly smaller maximum distances from any of the five Metra stations achieved by LEED versus non-LEED buildings (Exhibit 7). Shifting the focus on the local mass transit rail stations (CTA), the results are similar, with LEED buildings being located 12.02% closer to a CTA station compared to non-LEED buildings (Exhibit 8). The overall average distance across all buildings and the 23 CTA stations is 0.550 miles (Exhibit 8), in contrast to non-LEED buildings, which is 0.625 miles (Exhibit 8). Although in 65.22% of the cases the minimum distances of LEED buildings to CTA stations is larger compared to non-LEED buildings, in 100% of maximum distances LEED buildings are closer compared to non-LEED buildings (Exhibit 8).

The second research question, which focuses on the clustering or randomness of the LEED and non-LEED buildings, was also explored through three different methods. Although the overall assessment of both groups of buildings suggests random patterns, the visual representation with density and cluster analysis hints towards potential clustering in some areas (Exhibits 9–17). Comparing the spatial distribution of both building groups with a random one, the results indicate that the patterns among both are random (Exhibit 9). The positive[7] z-score among LEED buildings is indicative of a dispersed pattern, but the score is not sufficiently high to designate the pattern as dispersed when compared to a random distribution (Exhibit 9). In contrast, the negative[8] z-score among the non-LEED buildings indicates possible clustering, but the score is not sufficiently high to designate the pattern as clustered when compared to a random distribution (Exhibit 9). Evaluating the spatial distributions of both building groups, while considering one of the building characteristics (RBA, year built, etc.), further reinforces the initial randomness result (Exhibit 10). The negative Moran's I in two of the Exhibit 10 results indicates the existence of outliers among both the LEED certification levels and points achieved.

Exhibits 11–17 provide a visual representation of the densities experienced throughout the study area, by generating surfaces showing the predicted distribution of a building's characteristic (e.g., year built, RBA, LEED certification level, and points achieved), based on the value present at each location, as well as those in close proximity. Panels A and B in Exhibit 11 show the spatial distribution patterns of LEED and non-LEED buildings based on their construction completion. The results show the existence of aggregate patterns in close proximity to the two main Metra stations (Ogilvie and Union), although transportation is not taken into account in this case, and certain parts of the Loop area for LEED buildings (Exhibit 11, Panel A). The patterns tend to be very different for non-LEED buildings, indicating increased density of similar buildings in the middle of the Loop, as well as north of the river (Exhibit 11, Panel B). The existence of such densities in both cases (Exhibit 11, Panels A and B) shows that buildings of a similar age group in certain areas are aligned with each other in their decisions to pursue or not LEED certification.

Shifting the focus to RBA (Exhibit 12, Panels A and B), the densities show the existence of aggregation patterns towards the Metra stations to the west and east for LEED buildings. In contrast, the non-LEED buildings seem to be denser in the Loop. The density analysis of the LEED certification level as well as the points (Exhibit 13, Panels A and B) provides evidence of similarities across certain areas as well (e.g., close to the two main mass transit stations to the west and a third one in the Loop). The existence of such density patterns, along with those seen in Exhibits 11–13, show that in certain areas evidence of peer building pressure may be a reality in order to remain competitive. A further examination of both density patterns and potential clustering helps explore the underlying trends in the dense downtown area. The results in Exhibits 14 and 15, which take into account mass transit, provide clear evidence of clustering when only the location of the buildings is taken into account regardless of their other characteristics. Some evidence of clustering is also seen based on the building's RBA and the LEED certification achieved (Exhibit 16, Panel A, and Exhibit 17).

The last two research questions focus on statistical trends and modeling of the dataset rather than spatial representation. The third question examines the level of differentiation among the characteristics of LEED versus non-LEED buildings. Exhibits 18 and 19 provide an assessment of the average and standard deviation trends experienced by LEED and non-LEED buildings, as well as buildings with and without the ENERGY STAR label. The comparison of average RBA, year built, and number of stories between the two building groups indicates that newer LEED buildings are larger in size, while the number of stories does not seem to differentiate between the two groups (Exhibit 18). The evaluation of building characteristics among LEED certification levels shows that the most frequent certification levels are Silver and Gold. LEED-Gold buildings are also larger on average and newer than Silver, while there was no difference based on the number of stories (Exhibit 18). The comparison of buildings with and without the ENERGY STAR label indicates that ENERGY STAR buildings are on average larger in size and newer compared to the non-ENERGY STAR buildings (Exhibit 19). The comparison of ENERGY STAR buildings which are non-LEED to those that are shows that those with both sustainability designations (LEED and ENERGY STAR) are larger in RBA; however, the average year built and number of stories do not show differentiation between the two (Exhibit 19). The *t*-test results on the RBA indicate that we can accept the hypothesis that LEED buildings are on average larger (RBA) than non-LEED buildings, with the same result being true for ENERGY STAR label buildings (Exhibit 20). Factors contributing to such an outcome can be the significant long-term operating cost reduction, based on the size of the footprint, and the continuation of the competitiveness of these buildings compared to the newer ones, which are usually smaller in size.

The results of the second *t*-test support the second hypothesis regarding the construction timing of LEED versus non-LEED buildings, due to the newer building systems which require less investment to achieve the sustainability standards (Exhibit 20). The same is true for ENERGY STAR label buildings. The results of the third *t*-test are also in agreement with the original hypothesis, indicating that the average number of stories does not show any differentiation between sustainable (either LEED and/or ENERGY STAR label designations) or non-sustainable buildings.

The final research question assesses the effect of building characteristics on the points a LEED building can achieve. Columns 1 and 2 of Exhibit 21 explore the effect of building and other characteristics on the LEED points achieved with the difference being that column 1 is using a weighted fixed effects model and column 2 a weighted least squares model. The latter model (column 2) also assesses the effect on an individual submarket basis (Exhibit 22). The absence of any statistically significant difference between columns 1 and 2 underscores the stability of the models and their highlighted effects. Specifically, taller buildings achieve lower LEED points, with the results showing that a one-story increase is associated with a 0.5% decrease in the LEED points achieved (Exhibit 21, columns 1 & 2). In contrast, LEED points are higher for buildings with a Wacker Drive address by 12.6%,[9] compared to all other LEED buildings (Exhibit 21, columns 1 & 2). This variable was included because Wacker Drive has seen an office building construction boom the last decades and buildings with this address represent the most prominent office stock in downtown Chicago. Buildings built from 1980 and beyond achieved 19.7% higher points compared to all other buildings, while those built under the current LEED version (v. 2009) experienced a 34.2% increase compared to the previous version of LEED (Exhibit 21, columns 1 & 2). The results in both columns also show that LEED Silver buildings achieve 20.5% less points compared to the other certification levels (Exhibit 21, columns 1 & 2). The F-statistic reported in column 1 shows that the generated submarket dummies were not statistically significant. Focusing on the submarket performance, the results in column 2 show that LEED buildings in the Central and East Loop experience a fewer number of points compared to the other submarkets by 14.3% and 24.4%, respectively.

Shifting the focus exclusively on the points achieved among LEED Gold buildings (Exhibit 21, column 3; Exhibit 23 map) and LEED Silver buildings (Exhibit 21, column 4; Exhibit 24 map), the only common effect is the point increases both experienced under the current version of LEED compared to the previous. In both cases, buildings certified under LEED v. 2009 achieved a 34.2% increase in points for Gold buildings and 38.1% for Silver buildings. The F-statistic reported in both columns shows that the generated cluster dummies were statistically significant (Exhibit 21, columns 3 & 4). Other results of column 4 show that taller buildings achieved lower LEED points among LEED Silver buildings. Specifically, a one-story increase is associated with a 0.3% decrease in the LEED points achieved. Newer buildings, as well as buildings located in the West Loop submarket, achieve higher points under the Silver certification level by 16.6% and 25.1%, respectively (Exhibit 21, column 4).

Conclusion

Exploring downtown Chicago's Class A office building sustainability (LEED certification and ENERGY STAR label) adoption patterns, there is evidence of possible proximity pressures in the pursuit of LEED certification and a key link between mass transit rail stations and LEED versus non-LEED buildings. Benefiting from the use of geospatial and econometric modeling, evidence is provided for a number of trends, including the more concentrated pattern of LEED versus non-LEED buildings, especially in the most prominent areas. The proximity experienced among LEED buildings reached 21% compared to non-LEED buildings, while LEED Gold buildings were located 18% closer than Silver buildings.

LEED buildings in the study are located 14% closer to metropolitan area commuter rail (Metra) and 12% closer to local commuter rail stations (CTA). Exploring the possible clustering of LEED buildings, the results show a random overall pattern, although small clusters are evident among groups of buildings. The comparison between average size (RBA) and year built for LEED and non-LEED buildings indicates that LEED buildings are larger and constructed more recently. The same is true for ENERGY STAR versus non-ENERGY STAR buildings. Finally, exploring the effect of buildings and other area characteristics on the LEED points achieved, the results show that taller buildings, those with Silver certification, and those in certain submarkets achieve lower points compared to other LEED buildings. In contrast, buildings with a prominent street address, as well as those constructed after 1979 and under the current LEED v. 2009, achieved higher LEED points than other LEED buildings. This trend is also maintained for LEED Silver buildings, with the exception of the prominent address, although one of the prominent submarkets shares the same effect.

Endnotes

[1] The dataset includes three LEED Core & Shell buildings with one of them already in the process of receiving LEED: Existing Buildings Operations & Management (EBOM).

[2] The standard deviation ellipse surface given in ArcGIS is applied in this study as follows: $SDE_x = \sqrt{\Sigma_{i=1}^{n}(x_i - \overline{X})^2/n}$; $SDE_y = \sqrt{\Sigma_{i=1}^{n}(y_i - \overline{Y})^2/n}$, where x_i and y_i are coordinates for building i, $\{\overline{X}, \overline{Y}\}$ represent the mean center within each of the two buildings groups, and n equals 52 for the LEED buildings and 50 for the non-LEED buildings. The angle rotation is calculated as: $\theta = (A + B)/C$; where $A = (\Sigma_{i=1}^{n} \tilde{x}_i^2 - \Sigma_{i=1}^{n} \tilde{y}_i^2)$; $B = \sqrt{(\Sigma_{i=1}^{n}\tilde{x}_i^2 - \Sigma_{i=1}^{n} \tilde{y}_i^2)^2 + 4(\Sigma_{i=1}^{n} \tilde{x}_l\tilde{y}_l)^2}$; and $C = 2\,\Sigma_{i=1}^{n} \tilde{x}_i^2\tilde{y}_i^2$, where $\tilde{x}_l$ and $\tilde{y}_l$ are the deviations of the xy − coordinates from the mean center. Source: http://resources.arcgis.com/en/help/main/10.2/index.html#/How_Directional_Distribution_Standard_Deviational_Ellipse_works/005p0000001q000000/.

[3] The average nearest neighbor ratio given in ArcGIS is applied in this study as follows: $ANN = \overline{D}_o/\overline{D}_E$, where $\overline{D}_o$ is the mean distance between each building and its nearest neighbor: $\overline{D}_o = \sum_{i=1}^{n} d_i/n$ and $\overline{D}_E$ is the expected mean distance for the features given in a random pattern $\overline{D}_E = 0.5/\sqrt{n/A}$, where d_i is the distance between building i and its

nearest neighbor, n equals 52 for the LEED buildings and 50 for the non-LEED buildings, and A is the area of a min enclosing rectangle around each of the two building groups. The z-score is calculated as $z = (\overline{D}_o - \overline{\overline{D}}_E)/SE$, where $SE = 0.21636/\sqrt{(n^2/A)}$. Source: http://resources.arcgis.com/en/help/main/10.2/index.html#/How_Average_Nearest_Neighbor_works/005p0000000p000000/.

4 The Global Moran's I given in ArcGIS is applied in this study as follows: $I = n/S_o (\Sigma_{i=1}^{n} \Sigma_{j=1}^{n} w_{i,j} z_i z_j)/\Sigma_{i=1}^{n} z_i^2$, where z_i is the deviation of an attribute (e.g., year built, RBA, LEED levels, and points achieved) for building i from its mean $(x_i - \overline{X})$, w_{ij} is the spatial weight between building i and j, w does not take a value, n equals 52 for the LEED buildings and 50 for the non-LEED buildings, S_o is the aggregate of all the spatial weights $S_o = \Sigma_{i=1}^{n} \Sigma_{j=1}^{n}$. The z_I-score is then computed as $z_I = (I - (-1/(n - 1)))/\sqrt{E[I^2] - E[I]^2}$. Source: http://resources.arcgis.com/en/help/main/10.2/index.html#/How_Spatial_Autocorrelation_Global_Moran_s_I_works/005p0000000t000000/.

5 The map units are based on feet due to the very close proximity of buildings.

6 The Local Moran's I given in ArcGIS is applied in this study as follows: $I = (x_i - \overline{X})/S_i^2 \{\Sigma_{j=1, j=i}^{n} w_{i,j}(x_j - \overline{X})\}$, where x_i is an attribute (e.g., year built, RBA, LEED levels, and points achieved) for building i, $\overline{X}$ is the mean of the attribute x_i, w_{ij} is the mean of the attribute, $w_{i,j}$ did not take any values, and $S_i^2 = [\Sigma_{j=1, j\neq i}^{n} w_{i,j}(x_j - \overline{X})^2]/(n - 1) - \overline{X}^2$ with n equal to 52 for the LEED buildings and 50 for the non-LEED buildings, the $z_{I_i} = (I_i - E[I_i])/\sqrt{V[I_i]}$, where $E[I_i] = -(\Sigma_{j=1, j\neq i}^{n} w_{i,j})/n - 1$ and $V[I_i] = E[I_i^2] - E[I]^2$. Source: http://resources.arcgis.com/en/help/main/10.2/index.html#/How_Cluster_and_Outlier_Analysis_Anselin_Local_Moran_s_I_works/005p00000012000000/.

7 A positive z-score is obtained when the observed mean distance is greater than the excepted mean distance.

8 A negative z-score is obtained when the observed mean distance is less than the excepted mean distance.

9 Due to the log regression models used in Exhibit 24, all the dummy variables require an adjustment to [exp(coefficient)-1]% in their explanation.

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Monte Carlo Cash Flows and Sustainability: How to Decide on Going Green

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Abstract Green, sustainable or energy-efficient buildings apparently outperform other buildings with respect to rental level, value, and/or occupancy rates according to empirical findings. Most studies focus on commonly accepted databases to analyze the value or rent differences from a top-down perspective, that is, investigating value or rent differences between subject and control groups. But the decision-making problem at hand is mainly omitted from detailed discussions. We propose a framework using cash flow simulations in order to mirror the decision-making problem that owners face. By enabling both costs and benefits in different ways as inputs to a simulation model, we set up a large variety of realistic scenarios. We also consider findings and indications from previous decision modeling research. Our approach may be employed at all levels of detail that is needed and assists in economic-based decisions for sustainable investing.

Recent years saw a tremendous increase in market activity and discussions in the area of sustainable real estate, although, for example, DeLisle, Grissom, and Högberg (2013) note that there still is no consensus on what it actually means. This is in contrast to the needs of an information-based world with fast-moving economies. Transparent and quickly adoptable definitions and standards that were developed in the years before were apparently not removing much of the definitional confusion. Irrespective of definitions, we now have several certification systems detailing green features, designs or systems that might be utilized in a commercial property. But how does one decide how green to be and whether there is a payoff?

In the United States, the ENERGY STAR program of the U.S. Environmental Protection Agency (EPA) and the Leadership in Energy and Environmental Design (LEED) Green Building Rating System of the U.S. Green Building Council (USGBC) have become the accepted standards. The Building Research Establishment Environmental Assessment Method (BREEAM) of BRE Global is widely accepted in the United Kingdom, although other European green building councils operate the method as well. Further examples are Haute Qualité Environnementale (HQE; High Quality Environmental standard) of Association HQE in France, Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Japan, the Green Building Assessment System of the

China Green Building Network (CGBN) or the certification system of the German Society for Sustainable Building (DGNB; Deutsche Gesellschaft für Nachhaltiges Bauen). All systems aim at providing a framework that enables the classification of property with respect to ''sustainability,'' ''greenness,'' ''environmental impact'' or similarly termed attributes.

Clearly, the variety of systems and programs brings with itself considerable variation among the approaches, level of investment, and differences about how narrow or wide sustainability is defined. Not only are green or ecological characteristics included in the different systems and programs, accessibility, process quality or even the location enter some certification schemes. Depending on the respective system at hand, decision makers may face very different settings that form what ultimately is labelled sustainable or not.

Despite these issues that have yet to be resolved, considerable effort was spent on estimating whether and how sustainable or green buildings perform better in economic terms, given availability of classified data. Studies for the U.S. are provided by Miller, Spivey, and Florance (2008), Fuerst and McAllister (2009, 2011a, 2011b), Eichholtz, Kok, and Quigley (2010), Pivo and Fischer (2010), Wiley, Benefield, and Johnson (2010), Dastrup, Graff, Costa, and Kahn (2012), Eichholtz, Kok, and Yonder (2012), and Reichardt, Fuerst, Rottke, and Zietz (2012) among others. Brounen and Kok (2010), Fuerst and McAllister (2011c), Kok and Jennen (2012), and Cajias and Piazolo (2013) provide insight on the value and return effects in the European area, while Yoshida and Sugiura (2010) and Deng, Li, and Quigley (2012) study sustainable properties' performance differences in an Asian context. With minor exceptions, the studies provide initial evidence on economic gains from certification, as can be seen in Exhibit 1 where we list several exemplary studies. Naturally, the studies differ not only with respect to country or sector focus but also in terms of methodology. The results summarized in Exhibit 1 thus provide merely a rough overview in order to have an orientation about the scale of differences in values/and/or returns between certified and non-certified groups. An example where effects are indeed disentangled is provided by Chegut, Eichholtz, and Kok (2014), who find that while areas that are rich with green buildings are experiencing a positive impact, the additional supply limits the positive effect for green buildings. Their finding provides deeper insight into the supply-side effects studied in Eichholtz, Kok, and Quigley (2013), who report robust premia for green buildings.

Naturally, the identification of benefits in terms of higher values/rents/returns or reduced vacancy risk and vacancy times for sustainable real estate is of major interest not only to decision makers that aim at profitable business, but to certification providers, councils, governments, and other policymakers as well. Only if the (economic) value added by (certified) sustainability is significant and highly probable, certification methods and schemes will in the long-run be successful and thus may serve as accepted tools that finally help inducing a ''sustainable'' or at least ''green'' industry. Moreover, the conceptual differences mentioned above and the differences in what is expected by market participants is crucial, which is discussed by Bügl, Leimgruber, Hüni, and Scholz (2009) and DeLisle, Grissom, and Högberg (2013), among others. Even if one abstains from

Exhibit 1 | Findings of Studies on Certification

Source	Estimated Variable	Finding	Certification / Characteristic	Location	Sector
Miller et al. (2008)	Value	+5.3%	ENERGY STAR	U.S.	Office
	Value	+9.9%	LEED	U.S.	Office
	Occupancy	+3.7%	ENERGY STAR	U.S.	Office
	Occupancy	+4.2%	LEED	U.S.	Office
	Rental Level	+9%	ENERGY STAR	U.S.	Office
	Rental Level	+50.5%	LEED	U.S.	Office
Wiley et al. (2008)	Rental Level	+7% to +17%	ENERGY STAR or LEED	U.S.	Office
	Occupancy	+10% to +18%	ENERGY STAR or LEED	U.S.	Office
Fuerst and McAllister (2009)	Occupancy	+3%	ENERGY STAR	U.S.	Office
	Occupancy	+8%	LEED	U.S.	Office
Brounen and Kok (2010)	Value	+2.8%	Energy Certificates	Netherlands	Residential
Eichholtz et al. (2010)	Rental Level	+3%	ENERGY STAR or LEED	U.S.	Office
	Rental Level	+7%	ENERGY STAR or LEED	U.S.	Office
Pivo and Fischer (2010)	Rental Level	+5.2%	ENERGY STAR	U.S.	Office
	Rental Level	+4.8%	CBD regeneration properties	U.S.	Office
	Occupancy	+1.3%	ENERGY STAR	U.S.	Office
	Occupancy	+0.2%	LEED	U.S.	Office
	Value	+8.5%	ENERGY STAR	U.S.	Office
	Value	+6.7%	CBD regeneration properties	U.S.	Office

Exhibit 1 | (continued)
Findings of Studies on Certification

Source	Estimated Variable	Finding	Certification / Characteristic	Location	Sector
Yoshida and Sugiura (2010)	Value	−6% to −11%	Green labeled	Japan	Condos
Fuerst and McAllister (2011a)	Rental Level	+3% to +5%	ENERGY STAR or LEED	U.S.	Office
	Rental Level	+9%	ENERGY STAR and LEED	U.S.	Office
	Value	+18%	ENERGY STAR	U.S.	Office
	Value	+25%	LEED	U.S.	Office
	Value	+28% to +29%	ENERGY STAR and LEED	U.S.	Office
	Occupancy	none	LEED	U.S.	Office
	Occupancy	small positive	ENERGY STAR	U.S.	Office
Fuerst et al. (2011b)	Rental Level	+4% to +5%	ENERGY STAR or LEED	U.S.	Commercial
	Value	+25% to +26%	ENERGY STAR or LEED	U.S.	Commercial
Dastrup et al. (2012)	Value	+16%	ENERGY STAR or LEED	U.S.	Office
	Value	+3.5%	Solar Panels	California	Housing
Deng et al. (2012)	Value	+6% Green Mark	Green Mark	Singapore	Housing
	Value	+14% Platinum	Green Mark	Singapore	Housing
	Value	+2.3% Gold Plus	Green Mark	Singapore	Housing
	Value	+14% Platinum	Green Mark	Singapore	Housing
Cajias and Piazolo (2013)	Rental Level	+0.76% Euro / sqm	Energy-efficient vs other	Germany	Residential
	Value	+3.15%	Energy-efficient vs other	Germany	Residential

Note: This table provides an overview on the some of the most indicative previous regarding the benefits of certification.

narrowing the focus to economic or non-economic considerations, the focus may be differing: Kimmet (2009) discusses the differences between social responsibility and sustainability, finding that the criteria do not always lead to results where both are achieved.

However, apart from those that focus on market participants' views on sustainability, the studies discussed above aim at resolving the question about the beneficially of ''going green'' with a top-down or aggregate view on what one on average may expect given the respective certification scheme or classification. While these studies provide answers with respect to the average benefits of certification based on different systems, the inside view, or bottom-up perspective of valuation under consideration of sustainability is a different one. This special area of sustainability and valuation is examined by Lützkendorf and Lorenz (2007, 2011), Lorenz and Lützkendorf (2011), and Warren-Myers (2013), among others. While our approach is merely embedded in the valuation area, we do not approach the topic of valuation standards, but rather focus on the inside view of decision making as it is of paramount importance for investors to make decisions on their own economic surrounding and the structures they face. Thus, we focus on the purely economic considerations for now, with the underlying decision-making problem on whether or not to aim for certification being considered a complex trade-off system: As investors or owners face the problem of choice whether to construct property that can be certified or not, or to retrofit in order to get certification, they need to handle the trade-off between increased construction costs and possibly higher future income. If corporate social responsibility or other non-economic factors for now are excluded, decisions are based on this trade-off. So decision makers would either calculate the needed minimum additional profit from certification and property characteristics (and their aggregated effects) or calculate what the maximum additional cost may be, based on the (expected) value added from characteristics.

Accordingly, depending on the structure each decision maker faces and the information she has about possible benefits, she will have to make her optimal decision. We explain our systematic approach on how this may be accomplished on a detailed basis in the next section. We do so by laying out a concept that serves as a blueprint for calculations needed in the decision-making process. Adding to the literature in the growing field of studies related to sustainable real estate, to the authors' knowledge this is the first bottom-up and simulation approach that highlights the ''green/sustainable decision-making problem,'' while a study by Jackson (2009) employs Monte Carlo simulations in a risk and return context based on findings of several studies mentioned above. In the third section, we describe the parameters and indications we use, followed by the result section. We provide an extension in the fifth section, followed by conclusions and a future outlook in the last section.

Real Estate Cash Flow Model for Decision Making

General Model Setup

In general, we use a cash flow model that is based on several inputs for which stochastic processes are defined, and where the random outcomes define the resulting cash flows. With our simulation approach, we are in line with many studies that apply Monte Carlo methods for cash flows in the real estate area (e.g., Pyhrr, 1973; Atherton, French, and Gabrielli, 2008; and Loizou and French, 2012), which mainly focus on risks. The application of Monte Carlo methods both in static and dynamic approaches is discussed by Pfnür and Armonat (2013). They employ stochastic processes, where the focus is on operational flows in a risk environment. They argue that the findings of Pfnür and Armonat (2004) and Farragher and Savage (2008) identify that the majority of Monte Carlo approaches in real estate valuation are static and reflect linear trends. Pfnür and Armonat (2013) provide a detailed overview on previous applications of simulations in the real estate domain and find that most of the applications center on modeling income, credit default probabilities, and capital costs. In our approach, we aim at a full-scale model where all elements that are causal to cash flows are modeled on simulated basis.

We employ an example building consisting of N identical rental units for which the most relevant drivers of cash flows are modeled. In our model, we enable a discounted cash flow model for valuation and define the property value V_t at each point over time t as follows: $V_{t,\tau} = \Sigma_{\tau}^{\Theta}\ CF_{t+\tau}/(1 + r_{t+\tau})^{t+\tau}$ with $CF_{t+\tau}$ being the cash flow in future period $t + \tau$. Summing up all discounted cash flows for future periods $\tau = 1$, ... therefore results in the current value of the property.

The cash flow of the building in each period t is the result of both the amount of rental units with an existing lease contract $0 \leqq n_t \leqq N$ and the level of the rent R_t, resulting in $CF_t(R_t, n_t) = R_t * n_t$. The rental level is determined by an exemplary rental index that is inflation-adjusted. Notably, this is a simplification where the assumption is that on average the rental level increases along with general inflation, which could be replaced with rental level projections, cyclical methods or applicants' views. Evolving inflation over time is modeled as a geometric Brownian motion:

$$I_t = I_0 * e^{X_t}, \text{ with } dX_t = \left(a - \frac{1}{2}b^2\right) dt + b * dW_t.$$

W_t is a Wiener process with $a = 0.0194$ and $b = 0.01$. This specification is a special case of the model by Jarrow and Yildirim (2003), with the parameters set according to typical long-term German inflation rate behavior.

As the focus of our study is on the certification in a decision-making process, we model the interest rate curve with a reasonable example value and apply a constant rate of 4%. Having a very general example necessitates that we model the building in the pre-letting phase, and therefore assume that there are no contracts existing at the valuation start, i.e., $n_t = 0$ for $= 1$.

With no loss of generality, the simple modeling of the interest rate curve or the rental level may be replaced with more complex systems. This however is not needed for our task at the moment as we want to isolate the certification decision problem most clearly.

In our simple case, we assume that there are 10 identical rental units of 1,000 square meters each. In line with the assumptions for the rental increase, we assume that the total costs TC_t (where we do not focus on allocable or non-allocable costs) rise in parallel with the inflation rate. From the income and cost side explained above, we arrive at the final definition for the cash flow in each period t:

$$CF_t(R_t, AC_t, NAC_t, N, n_t) = R_t * n_t - TC_t.$$

While this definition is more or less clear-cut given the modeling with inflation indexing, we also need a proper setup for the vacancy or occupancy status, as in each period the number n_t of occupied rental units must be known. In accordance with many other applications that employ stochastic waiting times in economic settings, we use an exponential distribution to model the vacancy duration. The parameter λ parameterizes the exponential distribution for a random variable x that is defined as the time that has to pass until the first realization of a certain outcome is observed. The following density function is denoting the exponential distribution:

$$f_\lambda(x) = \begin{cases} \lambda e^{-\lambda x} & x \geqq 0 \\ 0 & x < 0 \end{cases}$$

Accordingly, the random variable x has a mean of $1/\lambda$ and a variance of $1/\lambda^2$.

Following the definition of the vacancy duration, we have defined all necessary equations to model the cash flow process in a simple stochastic way. This means that we can now set the remaining parameters and make assumptions for simulations in the basis scenario: (1) time intervals are defined on monthly frequency; (2) initial contracts and all possible rental extensions are based on five year contracts; (3) a probability of 50% for a rental start or extension after contract expiry is assigned; and (4) when extensions are not immediately reached, the average vacancy duration is six months ($\lambda = 1/6$).

Notably, one may define all sorts of different parameters and assumptions, depending on the respective economic surrounding of the property under consideration. For example, one might set the vacancy rate or the inflation rate as constant over time, define sinusoids, or even model future rental growth with specific models. In addition, the amount and sizes of differing rental units, contracts, special characteristic cost, and other parameters may enter the calculation whenever needed. Complexity in this setup accordingly is only the result of the model assumptions and the respective property and market structures, so the needed flexibility regarding a realistic decision-making process may be transparently accomplished.

Given the parameterization, the calculation of cash flows and therefore values is done by using Monte Carlo simulations for all stochastic elements. A large set of simulations needs to be done in order to capture a reasonable number of different paths over time, where we use monthly calculations. In our setup, we simulate with 50,000 random paths. Exhibit 2 depicts how economic influences like the inflation rate factor into the calculations and how the distribution of cash flows emerges. Of course the distribution type in the graphic is just exemplary, and in the simulations depends on the specific stochastic processes that were defined.

Examples and Parameter Variations

Using the specification of the model from above, we report the example calculations in this section. We report both the statistics of simulated outcomes of the baseline specification and variations to the parameters.

We consider it straightforward to adjust the model parameters in order to see whether the model is responsive to changes and how sensitive it behaves. This necessitates a grid for combinations of parameter variations. Simulations with 50,000 Monte Carlo paths for each combination scenario to obtain the respective cash flows over time were done using the following parameter ranges: (1) contract lengths between three and fifteen years in three-year steps are used: 3-6-9-12-15; (2) probabilities for a rental start or extension after contract expiry are used in 20%-steps between 0% and 100%: 0-20-40-60-80-100; (3) average vacancy is varied between one and twelve months in steps of about three months: 1-3-6-9-12; and (4) rental level of 24.5 €/sqm (a reasonable example value for a Frankfurt/Germany office building) is increased up to approximately 15% (3.67 €/sqm) above that level in the following steps: 0-0.75-1.5-2.25-3-3.75.

For the cost level at the beginning, a market-conform value of 8.5 €/sqm is used. Above combinations lead to 900 scenarios for the grid. By defining the grid, one can see various combinations of outcomes that can be put in relation to empirical findings regarding the effect of certification. We need to take into account here that due to the general model setup, we do not set vacancy or occupancy rates directly; they are a result of the parameters of the rental structure. Thus, one calculates the vacancy rate as an average over time and over simulations. Exhibit 3 presents 10 examples from the 900 scenario grid and Exhibit 4 depicts the change in the average vacancy rate compared to the base scenario and the change in the rental level compared to the base scenario, along with their influence on the property value.

Of course, the approach to use all combinations of parameters yields scenarios that one would consider more likely, as well as others that one would consider less likely. It is still straightforward to consider all scenarios however, in order to capture the full range of possible outcomes.

From Exhibits 3 and 4, one can see, for example, that a reduction in the average vacancy rate of 2% and an accompanying increase in the rental level of 2% would lead to an increase in property values of about 5%. This is one of the points where the interpolated result surface indicates a 5% value increase against the shaded

Exhibit 2 | The Monte Carlo Setup for Cash Flow Generation

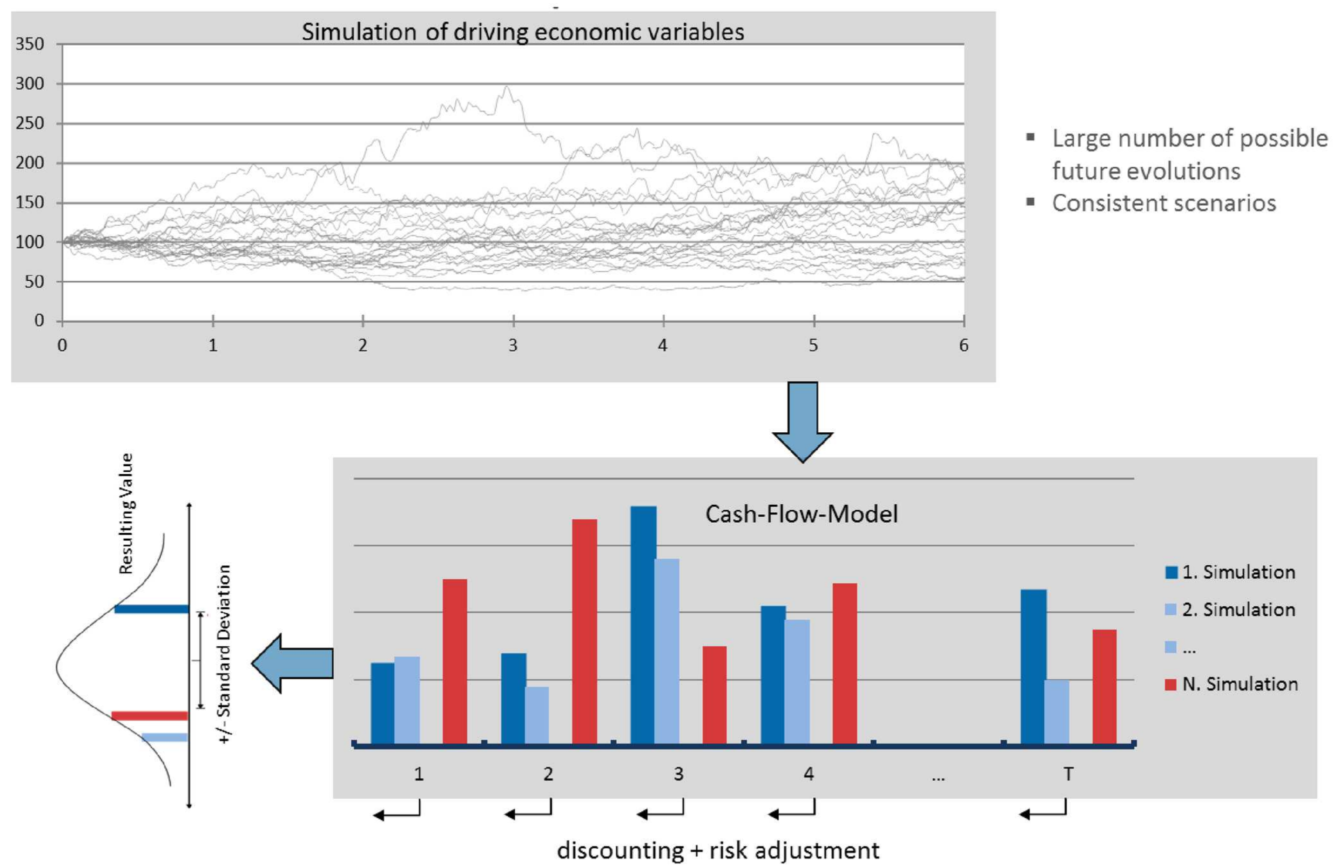


Exhibit 3 | Examples from 900 Scenarios of the Grid

Rental Level (€)	Extension Probability	Average Vacancy Duration	Contract Length	Resulting Value	Std. Dev. of Resulting Value	Average Vacancy Rate
24.5	0.5	0.1667	5	67.2925	2.8839	0.0538
26	0	0.0833	3	72.8199	2.8172	0.0425
28.25	0.4	0.0833	9	83.6918	3.0112	0.0103
24.5	1.0	0.25	3	73.3101	2.9802	0
27.5	0.6	1.0	9	76.6951	3.1196	0.0517
26	0.8	1.0	15	76.2883	3.0894	0.0139
26.75	0.2	0.75	3	58.8596	2.7397	0.1806
27.5	0.4	0.5	12	79.1485	3.0408	0.0325

Note: This table shows the base scenario and some examples from the 900 scenarios that were used.

surface indicating the baseline scenario. All results appear to be reasonable on economic grounds, given the respective input's difference to the baseline. Furthermore, while exact judgment on the correctness of magnitudes of the changes is difficult, the changes are sub-additive. This is good news regarding the plausibility of the chosen approach of Monte Carlo simulations for each component of the model.

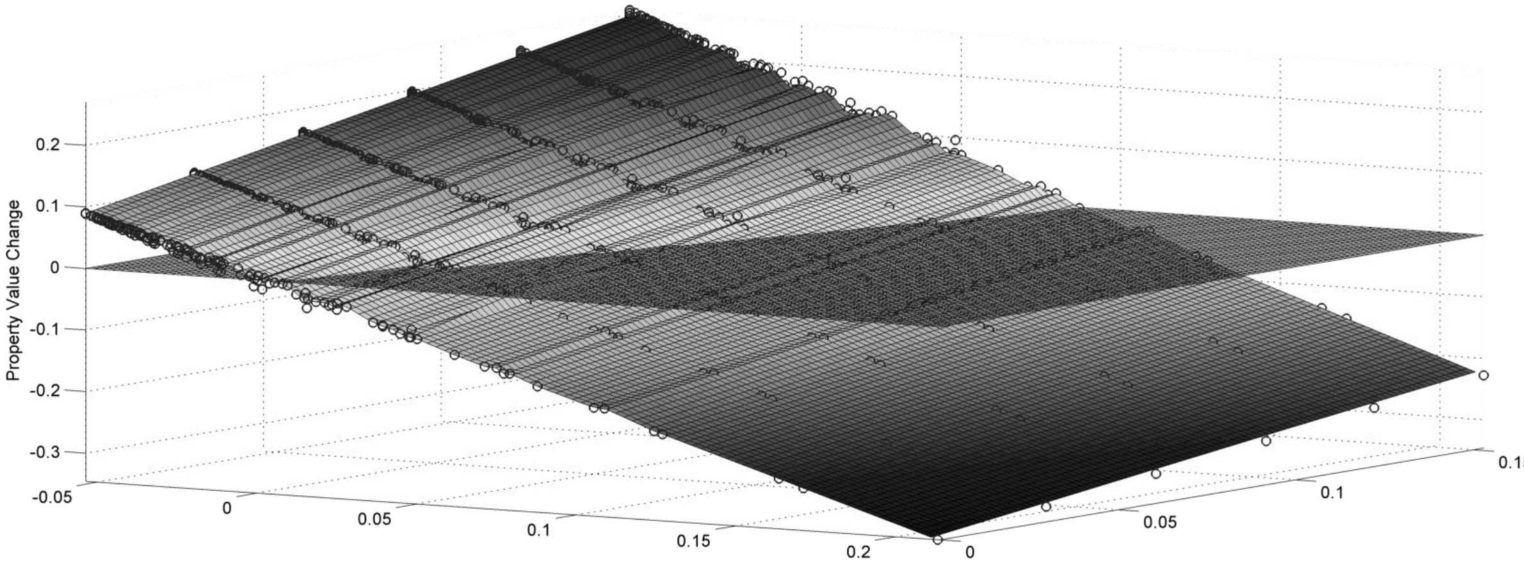
How the prevailing structure for each building factor into the resulting surface of changes in values depends on the parameterization itself of course, and accordingly enables full flexibility. In the next step, decision making is simulated in light of the benefits and costs of "going green," with indications as to what can be expected.

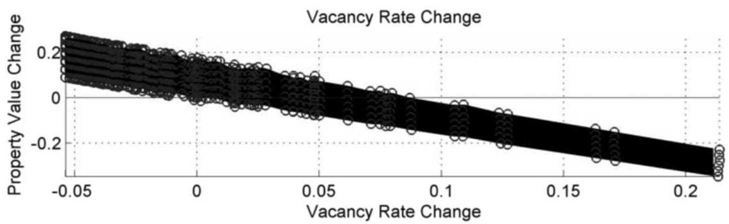
Investing in Sustainability? Available Benefit and Cost Indications

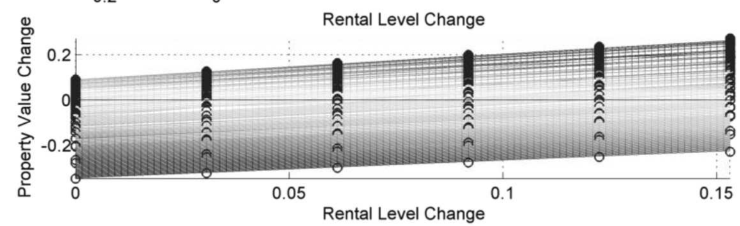
Indications for Certification Benefits

As mentioned in the introductory section, there has been increased activity regarding the estimation of economic benefits of certification. To have an orientation of possible ranges of outcomes, we reviewed the findings in the related studies. An overview on some of the most important results of the recent past is reported in Exhibit 1. Most studies focus on property in databases where they are classified on being certified by ENERGY STAR or LEED. Office is the most actively researched sector followed by housing, which is understandable based on data availability and market size.

Exhibit 4 | The Vacancy Rate–Rental Level–Value Change Surface







The graphs show the interplay of the percentage vacancy rate change (as a result of the three parameters contract length, continuation probability, and average vacancy duration), the rental level change, and the change in property value against the base scenario. The surface is interpolated with the dots representing the 900 scenario outcomes. The two-dimensional plots show the same result surface, but from the respective side view.

Naturally, results differ in magnitude, but apart from the exception of the Yoshida and Sugiura (2010) analysis, all studies find (mostly significant) positive effects from certification. Researchers analyzed rental levels and values, as well as occupancy rates. Incorporating these effects in a general granular setup is easy, as the rental level may be used directly and the occupancy rate as the opposite of the vacancy rate is indirectly obtained (the vacancy rate in our model is determined by the interplay of extension probability, contract length, and vacancy duration as described above).

In the description of the Monte Carlo model we already mentioned that the complexity of the general model depends only on the details the decision makers may want to focus on. This holds true not only for the very structure, but for the inclusion of certification effects as well.

As reduced pollution and energy-efficiency are crucial for receiving certification, one may want to consider the savings from reduced energy consumption. Thus, there are benefits from reduced costs that add to the positive side of certification effects. According to Miller, Spivey, and Florance (2008), operating expenses from energy costs are lowered by about 30% ($1.27/sf per year vs. $1.81) for ENERGY STAR-rated buildings compared to others. For the general model this means that we might include these effects in the total effects from certification or by adjusting the cost equation. We expect that gains from lower costs on energy translate into higher demandable rents, so it reasonable to do the former and continue with our general model specification.

Indications for Certification Costs

Having a considerably good basis for possible economic benefits, we now focus on costs. Evidence on costs arising for certification is scarce and is due to several problems arising when aiming at defining viable ranges for costs. One crucial problem is that certificates are handed out by the respective authorities based on considerably differing criteria or frameworks. In addition, within the different programs, there are always degrees of certification. For example, different degrees of fulfilment in one area may be binding, while other criteria are less crucial. Thus, judging on what characteristics or structures candidate buildings need to have is by no means easy and depends both on the respective certificate's requirements and the structure of a (planned) building.

In addition, not only do requirements and the different levels and thresholds that may be applicable harden the task of defining cost ranges, the costs themselves are highly heterogeneous among buildings, countries, markets, and construction companies. Deciding to have everything set up in order to get the desired (level of) certification may result in numerous different cost projections or offers. Miller, Spivey, and Florance (2008) note that most available surveys on the costs for going green are from the USGBC and caution against potential downward bias. In addition, they state: "Developers point out the direct cost of certification and the high indirect costs of dealing with inflexible, uninformed, and uncooperative local building code regulators or the lack of local experts and resources. Clearly the costs of going green vary by local market, the number of vendors and experience in the local market, developer/owner experience, and project or portfolio scale."

The above citation points in the same direction as our perception of a highly unclear cost side when it comes to certificates in the green or sustainable area. Despite the problems regarding cost indications however, we aim at finding a range that might be used in the simulations or to use as a comparative counterpart for calculated benefits.

Additional building/construction costs are different from certificate to certificate and between levels as the programs naturally demand different characteristics. Miller, Spivey, and Florance (2008) discuss the results of a 2007 study by Greg Kats of Capital E Analytics [Kats (2003) in the following], where direct LEED certification costs are reported as follows: 0.6% (Certified), 1.9% (Silver), 2.2% (Gold), and 6.8% (Platinum). They argue that this is roughly in line with numbers from the USGBC and show that there is variation across regions as well. Apparently, the estimated ranges for costs for Silver are 1.0%–3.7%, for Gold they are 2.7%–6.3%, and a platinum certificate would increase construction costs by 7.8%–10.3%. Interestingly, they report that developer surveys indicate a 3% base cost for minimum certification, which increases the USGBC numbers somewhat.

Fuerst and McAllister (2011b) by citing Kats (2003), Hershfield (2005), and Berry (2007) conclude that green construction cost premia are around 2% on average only, which would be in line with the 3% reported by developers according to Miller, Spivey, and Florance (2008). Like the latter, Fuerst and McAllister (2011b) report results of market participants' studies too, with reference to Davis Langdon, a global construction consultancy. Langdon (2009) finds interesting evidence of no significant difference in the construction costs of green and non-green commercial buildings in New York City. One noteworthy point is that if the construction costs depend strongly on relatively new technology, then the costs may be expected to decrease over time. This would imply that there is an added value from the option to wait. We do not consider this case of expectation building in the following, but it would be easily added to the setup by setting the calculation point to a future period, then with the lower construction costs being relevant.

With regards to maintenance costs, the picture is even less clear cut: While Yoshida and Sugiura (2010) attribute part of the found discount at which energy-efficient condos are valued to the risk of increased maintenance costs of cost-saving technology, Kats (2003) takes the notion that green buildings in general should have lower maintenance costs.

Decision Making Implications

Having defined reasonable spans of parameter variations and having discussed additional benefits and costs from certification based on the literature, we can get a grasp on the decision-making problem. For example, when expecting higher construction costs of 7.8%–10.3%, we may use the surface obtained from the grid simulations to identify what is needed to at least offset the additional costs. Put another way, one can identify combinations of changes on rental level and vacancy rate that lead to expected cash flows of the property whose present values are at least as high as the additional costs.

With respect to the spans used for simulations, we can back-out those scenarios for which the expected gains are at least offsetting the additional costs from investing in sustainability. Exhibit 5 presents the overview for the four inputs used (i.e., contract length, probability of continuation, average vacancy duration, and initial rental level). It is possible to see the variations that were included in the various scenarios and whether that scenario was one that resulted in a higher present value of at least 7.8%. From this it is possible to see what fraction of scenarios with a single fixed parameter value led to an increase in property value of the needed magnitude.

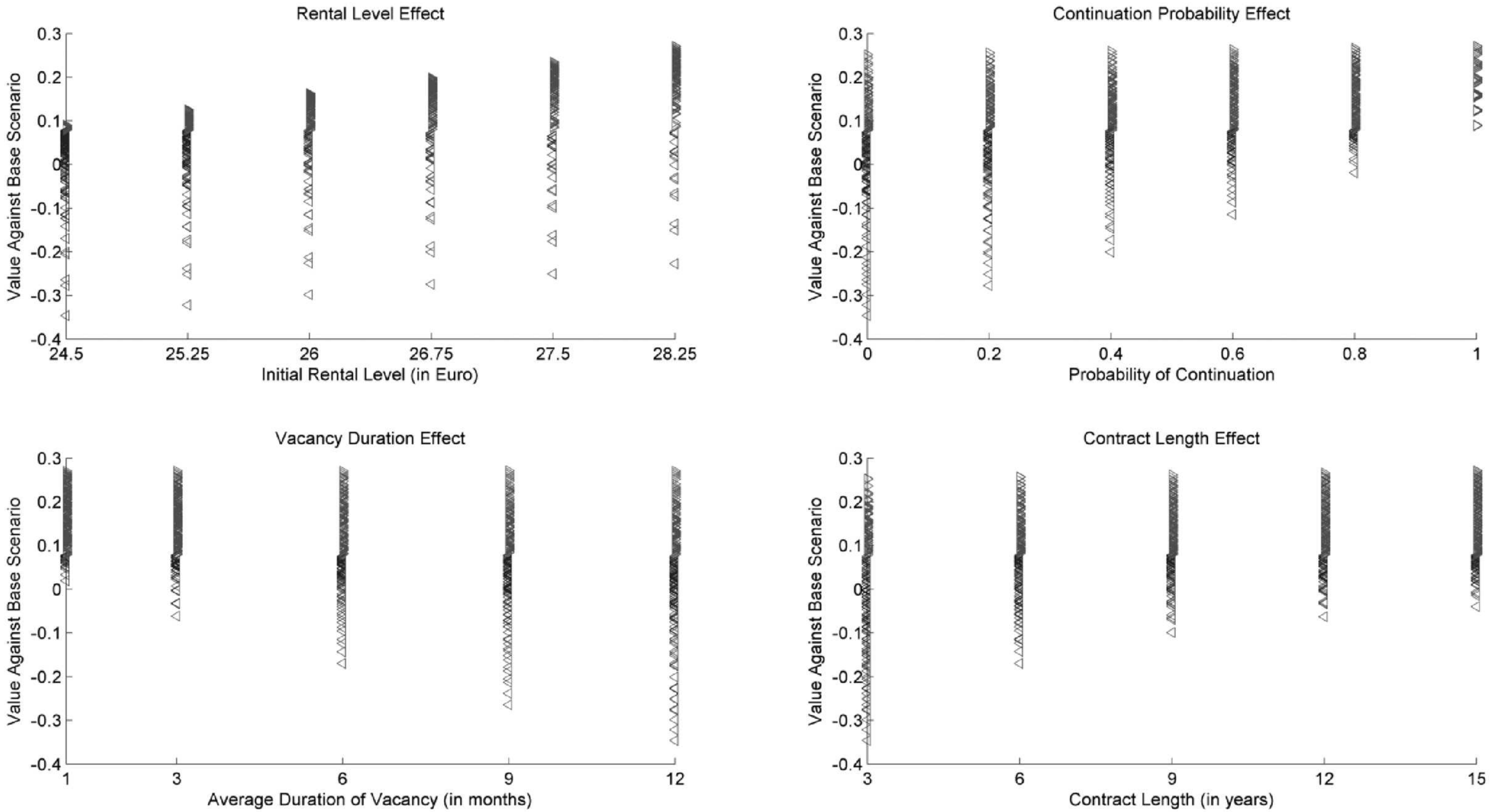
So the decision-making process can be done by facilitating either a change analysis, as in Exhibit 4 where the most crucial effects of rent, vacancy, and value are related to each other, or a parameter analysis like in Exhibit 5. The respective probabilities for likely scenarios and parameters thereby are at the discretion of the decision maker applying the approach.

Extending the Model: Developments and Partial Rental Losses

While the focus so far has been on the decision of whether to develop a sustainable building in the first step and to calculate possible paths that follow, we need to focus on an aspect that has strong relevance for decision makers in practice, namely the decision on developments of standing assets. If buildings are candidates for refurbishments and retrofitting, decision makers need to explicitly model the loss of rental income if parts of the buildings are uninhabitable during the process. In the framework proposed above, we can easily introduce modifications that take into account a reasonable span of development times during which rental income is reduced in full or partially.

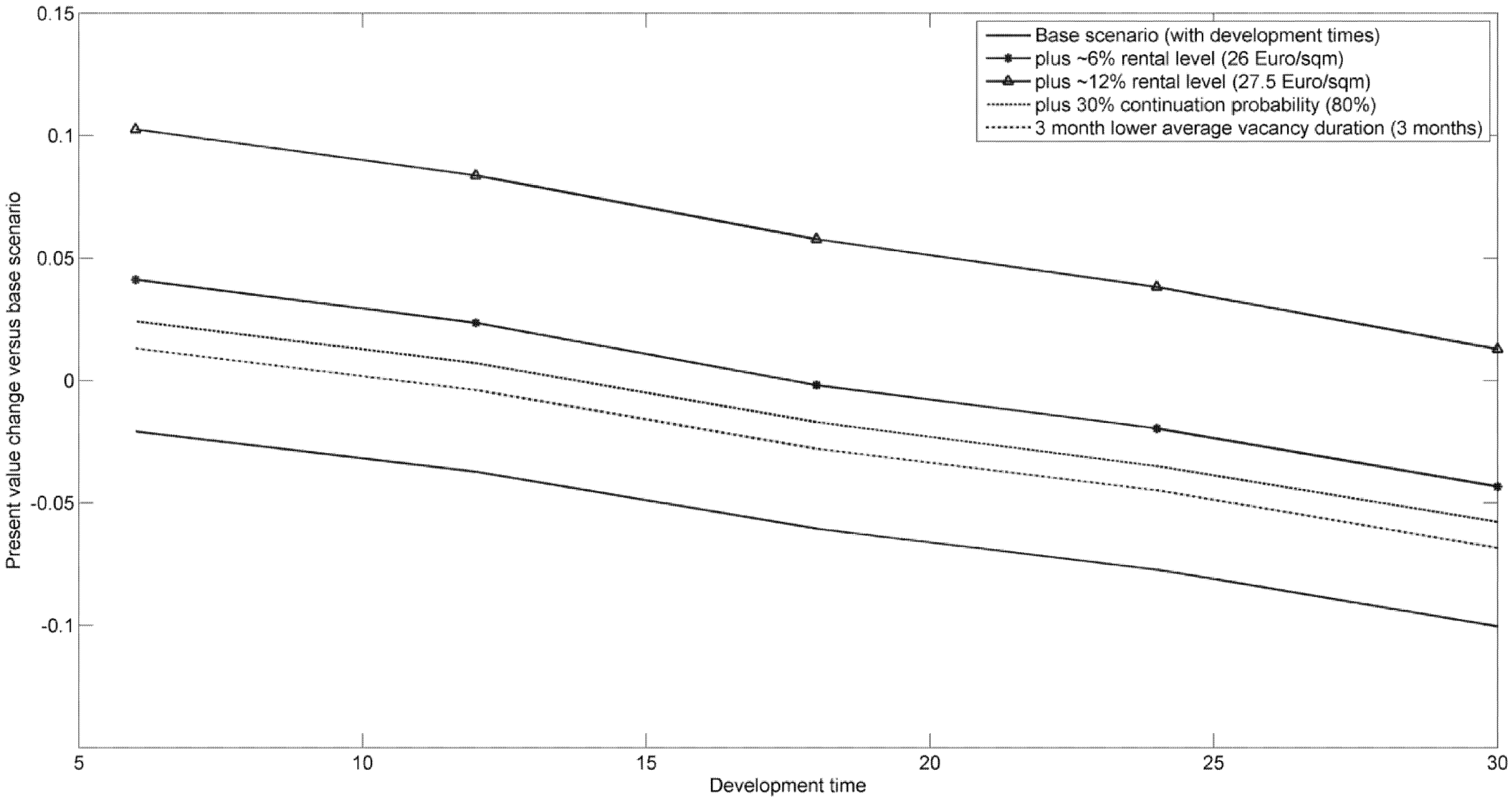
Exhibit 6 depicts the effect of development times (measured in months) on the present value for the base scenario and for possible more beneficial scenarios after going green (i.e., higher rental level, higher probability of continuation or a lower vacancy duration). Naturally, for the base scenario with development time, the line is always below the base scenario without development time. As for the analysis before, it depends on the economic benefits of sustainability as to whether this outweighs the costs that have to be incurred. For the sake of brevity, we do not plot the combinations of benefits and we do not calculate the construction costs in this example. As the construction costs are due more or less at the beginning of the decision making problem, one can simply add those to the needed benefit of the project, and one might use the reported 7.8% from above. In the simulation results shown here, we assumed that all rental income is lost for the respective development time spans. Separate calculations revealed that when only partial rental losses are incurred due to only partially uninhabitable buildings, those

Exhibit 5 | Four Model Parameters and Their Effects in Simulation Outcomes



The graphs show the interplay of the respective parameters and the change in value of the exemplary building compared to the base scenario. Outcomes that are at or above 7.8% value change are indicated by > arrows and outcomes that fail to produce an increase of at least 7.8% are indicated by < arrows.

Exhibit 6 | Development Times and Their Effects



The graphs show the interplay of the development time where all rental income is lost and the present value against the base scenario without development time.

results are fairly linear to the full loss model. Notably, when assuming construction costs of 7.8%, not much of the benefit-adjusted curves would be resulting in an economic gain, so only strong rental income increases or combinations of benefits would lift the projection over the break-even line. For example, an increase of about 6% in the demandable rent only leads to the demanded increase in the current value when coupled with a reduced average vacancy (3 to 6 months) or increase in continuation probability (50%–80%). Then, the current value increases by 7.62% and 8.69% respectively, when for example six months of rental loss is assumed.

Conclusion

We approach the decision making problem in the area of sustainability or going green by using a cash flow model that may be employed based on each decision maker's property and its structure. Defining a reasonably large parameter span served us well when it comes to defining scenarios for Monte Carlo cash flow modeling and evaluation of how probable certain outcomes are. Naturally, the parameter span should reflect both property-specific parameter possibilities and empirically found indications.

It is of utmost importance to specify the components of cash flows directly, and compose the resulting projections using the simulations from the processes. Only a detailed modeling in this way enables decision making based on the respective characteristics of property and the related economic surrounding. While we have abstained from coupling processes and thus have assumed all outcomes from the grid to be equally probable, scenario analysis and stress testing may be easily facilitated when imposing dependence structures on the stochastic processes.

The outcomes of the modeling can be put in direct relation to empirical findings and market information to assess the probability of a possibly benefiting effort to go green/sustainable. With the detail degree of the approach being in the hands of the decision maker, we consider the proposed model useful in bottom-up decision making what is analyzed in detail by academics and practitioners. Therefore, the cash flow based analysis is adding to the field of sustainability research by being the natural counterpart to top-down analyses that are needed to derive indications on possible average costs and benefits when deciding on whether or not to go green.

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The Effect of Sustainability on Retail Values, Rents, and Investment Performance: European Evidence

Authors Hans Op 't Veld and Martijn Vlasveld

Abstract This paper is the first to focus on the effects of sustainability on the investment performance of a European retail portfolio comprising 128 properties in the Netherlands and extends the existing range of studies on the office and residential sectors in the United States. As the data sample is an existing fund portfolio, all attributes of the properties are known. Environmental sustainability is measured by the Dutch energy label, which compares with ENERGY STAR in the U.S. Through OLS regressions, we examine whether a sustainability premium exists. We find that green retail properties have a significantly higher income return of 0.52%, while, counterintuitively, non-green retail properties appear to have significantly higher rents and values. After controlling for various factors, however, the sustainability effects become insignificant. This contradicts some of the findings in the office and residential sectors. We attribute this to the importance of traditional retail location theory factors, which continue to dominate returns.

The attention institutional investors pay to the environmental performance of real estate investment portfolios is increasing. This is understandable in view of estimations that buildings are responsible for approximately 30% of the CO_2 emissions worldwide and 40% of global energy consumption (UNEP, 2009). This makes the sector vulnerable to increases in the prices of energy, and could impact future investment returns negatively. Consequently, the built environment also has substantial potential to contribute to a decrease in CO_2 emissions (Enkvist, Naucler, and Rosander, 2007). Therefore, it is essential for governments to include the real estate sector in plans to decrease global CO_2 emissions and diminish the use of natural resources. The United Nations has already suggested an active tax policy to their member states, making energy-efficient properties more attractive and energy-inefficient properties less attractive (UNEP, 2009).

Further to this notion, the impact of sustainability on investment returns has been the topic of a stream of literature. Several researchers find that sustainable office and residential properties have higher rents and values (e.g., Eichholtz, Kok, and Quigley, 2010; Kahn and Kok, 2012). However, there is very limited research available on the effect of sustainability on the total shareholder returns of properties. The absence of this evidence makes it hard for investors to justify (large) investments to make their properties more sustainable (INREV, 2010). The issue is compounded by the fact that studies are on office and residential properties, typically based on U.S. data.

In this paper, we explore the effect of sustainability on the investment performance of retail properties. Furthermore, we extend the range of papers with European evidence. We focus on the effects of sustainability on the investment performance of a portfolio of 128 retail properties in the Netherlands, covering the performance of the properties between 2007 and 2011. As the data sample is taken from an existing fund portfolio, all attributes of the properties are known, allowing us to analyze performance differential to a very high degree. The properties in the sample are diverse in age and type. The oldest asset in the study was built in 1820 and the study covers high street retail, neighborhood centers, and shopping malls.

The paper is structured as follows: the next section covers the literature review about the effect of sustainability on investment performance. The main sustainability labels are covered in the second section. In the third section, the data and methodology of this study are explained. The fourth section covers the study findings and the fifth section is the conclusion.

Literature Review

Finance literature on the impact of sustainability on real estate can be divided into a stream on the performance of individual properties and another on the performance of portfolios and/or funds. The literature provides insight on useful control variables we implement in our model.

Property Level Performance Literature

Several studies have been done on the effects of sustainability and the performance of individual properties, generally offices. Most studies focus on the effects of sustainability on the rent of the properties analyzed. Some studies have also examined the occupancy rates and the value of offices, although less evidence is available and fewer transactions take place. Exhibit 1 shows the results from these studies.

All studies on the American office sector find a premium on the rents, values, and/or occupancy rate for sustainable buildings in comparison to buildings without a sustainable certification like ENERGY STAR or LEED. All studies share the CoStar database as their principal datasource. Variations in the results can be attributed to data selection (i.e., the size of the sample, the control variables, and the timespan of the data). Some of the earlier studies find relatively large differences in sales prices (e.g., Fuerst and McAllister, 2009); however, the groups of green and non-green properties show large differences in age, size, and/or vacancy level.

Eichholtz, Kok, and Quigley (2010) look at performance and take into account a large number of control variables. The authors control for factors such as age,

Exhibit 1 | Overview of Source Data

Study	Database	Country	Period	Control Buildings	Sample	Rent Premium	Sales Premium	Occupancy Premium
Office Sector								
Miller, Spivey, and Florence (2008)	CoStar	U.S.	2003–2007	>2,000	643 ENERGY STAR	8%	6%	2%–4%
					LEED		10%	2%–4%
Fuerst and McAllister (2009)	CoStar	U.S.		10,000	1291 ENERGY STAR	6%	31%	3%
		U.S.			292 LEED	6%	35%	8%
Fuerst and McAllister (2011)	CoStar	U.S.		15,000	834 ENERGY STAR	4%	26%	3%
		U.S.			197 LEED	5%	25%	8%
Miller (2010)	CoStar	U.S.	2008–2010	378	12 ENERGY STAR	—	—	(4%–5%)
		U.S.			5 LEED	12%	15%	
Wiley, Benefield, and Johnson (2010)	CoStar	U.S.	2008	7,308	ENERGY STAR	7%–9%		
		U.S.		1,151	LEED	16%–18%		
Eichholtz, Kok, and Quigley (2010)	CoStar	U.S.	2007	8,105	ENERGY STAR	3%	16%–17%	
		U.S.			LEED	5%	16%–17%	
Eichholtz, Kok, and Quigley (2011)	CoStar	U.S.	2009			2%–7%	13%	3%
		U.S.				6%	11%	3%
Reichardt, Fuerst, Rottke, and Zietz (2012)	CoStar	U.S.	2000–2010	7,140	ENERGY STAR	3%–7%		
					LEED	3%–4%		
Chegut, Eichholtz, and Kok (2011)	CoStar	U.K.	2000–2009	1,104	67 BREEAM	21%		
				1,953	70 BREEAM		26%	
Kok and Jennen (2011)		NL		1,100	Energy Labels	7%		
Residential Sector								
Brounen and Kok (2011)				145,325	31,993 energy labels		4%	
Aroul and Hansz (2012)				14,922	7,180 green buildings		2%–4%	
Kok and Kahn (2012)				1,600,000	4,321 green labels		9%	
Property Investment Funds					Outperformance on	Fund	Asset	Level
Eichholtz, Kok, and Yonder (2011)		U.S.		128 funds	ENERGY STAR	0%	1%	
					LEED	0%	2%	

Note: This table provides an overview of the studies on the impact of sustainability on performance studies published to date with their key findings.

building size, and building quality. The distinguishing feature in their paper is their control for location: not in a city or submarket, but within a range of 0.2 square miles. In addition, they control for the service sector employment increase in the area and for the amenities near the offices. This research shows that even after implementation of thorough controls, the sustainability premium for offices still remains and is statistically highly significant.

In Europe, the first study about the connection between property performance and BREEAM rated buildings in the United Kingdom was done by Chegut, Eichholtz, and Kok (2011). They find a relatively high premium (a 21% higher rent and 26% higher value) for sustainable offices in the U.K. This premium exists after extensive controlling for location (on ZIP Code level and by distance to a public transportation station), rental unit size, age, storage, amenities, and renovation. The sample is relatively small though, introducing a sample bias, as the best buildings typically are the ones that are labeled first.

Kok and Jennen (2011) compared 1,100 rent transactions of Dutch office properties with the Energy Performance Certificates. Energy Performance Certificates comparable to the ENERGY STAR ratings, but with labels ranging from G (energy inefficient) to A++ (very energy efficient), calculated based on an underlying energy index. They controlled for location (based on the ZIP Code, distance to the nearest train station and the nearest highway ramp), age, size, and the ‘‘walk score,’’ being the distance to a varied set of neighborhood amenities. The sustainability premium varied per year: the highest rent premium of 6.5% for green properties was in 2010, in which year the rentals for ‘‘non-green’’ declined fast and the rentals for ‘‘green’’ buildings rose fast.

Although the studies consistently find a premium for sustainable offices, Eichholtz, Kok, and Quigley (2011) note that the building quality of green buildings is higher than for non-green buildings. For instance, the sample of rated buildings comprises 75% of Class A buildings, while the sample of control buildings only has 26% Class A buildings. Furthermore, green buildings are generally younger, larger in size, and have more favorable characteristics regarding location, transport, and amenities.

In the residential sector, the results of the three studies indicate that there is also a price premium for green residential properties. The premium can be found in different continents, is highly significant in a large sample (1.6 million transactions), and holds in regression analysis (Kahn and Kok, 2012).

Fund Level Performance Literature

None of the prior studies focus on the investment returns of the properties. For investment funds as a broader sector, studies of the relation between their financial performance and sustainability level have been done for a long time. The 30 years of research shows mixed results, which is also found in large review studies. Griffin and Mahon (1997) and Margolis and Walsh (2001) conclude that there is no clear direction in the evidence, while Orlitzky, Schmidt, and Rynes (2003) conclude from a meta-analysis of 52 paper that there is a (small) positive relation between the sustainability level and the financial performance of a fund.

To date, only one study has examined the relation between sustainability and the returns of property companies. Eichholtz, Kok, and Yonder (2011) examined 128 real estate investment trusts (REITs) for the relation between the total return performance of real estate securities and the percentage of green assets in their portfolio. They do not find a higher fund return for funds with a greener portfolio, but on a property portfolio level, they do find that portfolios with a 1% higher percentage of green properties have an increased asset return of 0.5% for ENERGY STAR and 2% for LEED properties. Furthermore, the portfolio beta decreases 0.7%–1.0% when there are 1% more ENERGY STAR buildings in the portfolio and the portfolio beta decreases by 6%–7% if the share of LEED buildings in the portfolio increases by 1%.

In conclusion, all studies on property level collectively find a premium in valuation for sustainable real estate, although there is a long running discussion as to whether sustainability leads to a better investment performance. Findings also suggest that sustainable properties in general have a better location and a higher building quality than properties without a high sustainability level. However, some elements of a better location and a higher property quality could still be visible in the financial characteristics of the building, since the quality of a location and building is determined by many elements, and it is very difficult to controls for all these elements.

Data and Methodology

In general, the methods to assess the sustainability level of properties can be divided in two categories: the first category focuses on solely on energy, such as the ENERGY STAR label in the U.S. and the Energy Performance Certificate (EPC) or energy label in Europe. The second category of sustainability assessment methods focuses on aspects such as water, waste, materials, pollution, and management, next to energy usage. LEED and BREEAM are well-known labels in this category.

In the U.S., ENERGY STAR and LEED are most prevalent. In the U.S., almost 32,000 buildings have been rated with the LEED sustainability assessment method as of April 2012 (USGBC, 2012). In Europe, BREEAM is very prevalent in the U.K. and has been used for the sustainability assessments of almost 200,000 buildings. Outside the U.K., only around 300 buildings have been certified with BREEAM (BRE, 2013).

The European Performance on Buildings Directive (EPBD) has led to the proliferation of Energy Performance Certificates in Europe. The 2003 directive is aimed at the reduction of energy consumption of buildings, in view of the reduction of CO_2 emissions and the dependence on fossil fuels. Over time, energy certificates will become mandatory whenever a property is transacted, and will therefore over time become a large source of data.

Since the EPBD obliges European countries to generate Energy Performance Certificates (also called energy labels) for all properties, energy labels are the

Exhibit 2 | Energy Label Categories and the Corresponding Energy Indices

Energy Label	A++	A+	A	B	C	D	E	F	G
Energy Index	0.00–0.51	0.51–0.70	0.71–1.05	1.06–1.15	1.16–1.30	1.31–1.45	1.46–1.60	1.61–1.75	>1.76

most common measure of sustainability in Europe outside the U.K. For instance, almost 2,000,000 energy labels have been issued in the Netherlands. Although most of these labels have been issued for residential dwellings, approximately 10,000 energy labels have been issued for commercial buildings, of which roughly 1,900 are for retail properties (AgentschapNL, 2011). Therefore, the energy label is the most widely available sustainability label currently in use in the Netherlands.

The energy label consists of several categories, ranging from A++ to G in which A++ is very energy efficient and G is very energy inefficient. Every energy label category corresponds with an interval range of Energy Index scores. These interval ranges are not constant, as Exhibit 2 shows; therefore, the relationship between the energy index and energy labels is not linear. Therefore, the Energy Index has been used in the calculations and the energy label categories only to make a distinction between the "green" and "non-green" categories. The Energy Index score is calculated by a formula that takes several energy efficiency measures of the property into account, such as the thickness of the isolation, the type of material used in the walls, the total surface of the glass, etc. The *higher* the Energy Index, the more energy *in*efficient a property is (Exhibit 2).

For the energy label, the green categories are defined as the A++ to C categories with an Energy Index below 1.30 and the non-green categories are the D to G labels, with an Energy Index >1.30. The U.S. ENERGY STAR label is given to properties that belong to top 25% on energy efficiency and is roughly comparable with properties with an A++ to A label.

We draw data from a dataset of retail properties managed by CBRE Global Investors in the Netherlands for the period 2007–2011. The dataset consists of 128 retail properties, which entails the entire portfolio of retail properties managed by CBRE in the Netherlands. The properties are held in four funds, with a strategy to hold the assets for a long term (greater than five years). Properties that have been acquired, sold or redeveloped in the study period have not been included in this study, as full period information is not available.

As the data sample consists of an existing fund portfolio, all attributes of the properties are available. The properties are diverse in age and type. The oldest property was built in 1820, whereas the youngest was developed in 2007; the study covers retail properties in the main streets of city centers, as well as neighborhood centers and shopping malls. General information of the 128 properties (address, property type, type of center, age, size, number of leases) is drawn from the property characteristics database of CBRE Global Investors. The rents are extracted from the CBRE Global Investors database and are the actual gross rents. In this way, the data are more accurate than the frequently used market rent data, since negotiation results and incentives have been included.

Property values have been derived from valuations made by external national and international appraisers. Every property is valued quarterly by two independent appraisers, who jointly appraise the property, in accordance with the Royal Institute of Chartered Surveyors (RICS) standards.[1] Rental and market values of all properties are as per year-end 2011. A transaction price database providing energy labels is not available.

Total return, income return, operating costs, and vacancy rates for 116 properties are all annualized figures and have been extracted from the Investment Property Databank (IPD) database. IPD uses a consistent method to calculate the performance characteristics for all properties. The returns on 12 properties not in the IPD benchmark have been calculated using the same method.

As the first large investor in the Netherlands, CBRE Global Investors has certified all of its retail properties with an energy label. The energy labels of the properties in the research sample have been matched with their performance characteristics during the study period between 2007 and 2011. Some properties have multiple parts and a separate label for each part has been made. For these properties, a consolidated label has been calculated, based on the sizes of the specific parts of the property. In total, 195 energy labels have been designated to the properties in the research sample and the consolidation of the 195 labels has led to 128 labels at the property level.

Innax and Search are the market leaders in issuing energy labels in the Netherlands and made the energy labels for these properties. Both companies are certified to issue energy labels as independent certifiers, under supervision by the Dutch government.

In establishing the labels, actual information regarding the building structure is used. Data on tenant installations and lighting is standardized, ensuring comparability. Of each labeled property, several attributes are used as controls. The size of each property has been corrected for the amount of space on the several floors of a property, since the rent and value of a property is significantly different on each floor. The control factors per floor are averages. In accordance with various sources regarding the Dutch situation, standard percentages have been applied (see Bolt, 1995, 2003; Mols, 2006; SCN, 2012). The percentages are provided in Exhibit 3.

Information about the number of inhabitants living in the area near the retail property (the catchment area) and the size of the overall center is extracted from the Locatus database. Locatus is a Dutch research firm that has a database of all the retail properties in the Netherlands and contains information about the location, size, tenant, retail type, and the catchment area of each property. The size of the total center is defined as the sum of the sales area of all retail properties in a specific center. The catchment area of a retail property has been calculated by combining the type of center the property lies within and the number of inhabitants with a range of 2, 5 or 10 kilometers, as indicated by Locatus. For properties in

Exhibit 3 | Value Correction Percentages for Retail Space by Floor

Floor	−2	−1	0	1	2	3	5	6
Percentage	10%	25%	100%	30%	15%	10%	10%	10%

Notes: The table provides the correction percentages that have been used to standardize the surface area of each property depending on its structure. The correction factors applied are standard percentages that stem from literature.

large and medium city centers, the number of inhabitants within a range of 10 kilometers is used. For properties in urban district centers and small city centers, the inhabitants within a range of 5 kilometers is used. For neighborhood centers, the number of inhabitants within a range of 2 kilometers is used. To determine whether a retail property falls in a large, medium or small center, the categorization as used by the IPD is followed.

These data are analyzed in two steps. First, to see whether there are statistical differences between "green" properties and "non-green" properties, the groups have been compared using a *t*-test for the normally distributed variables and a Mann-Whitney test for the not-normally distributed variables. Second, the differences between the green and non-green properties have been examined with a multiple OLS regression analysis.

The general formula of the regression analysis is of the following form:

$$\begin{aligned} R_i = {} & \alpha + \beta_1 \, ln\,(EI_{t0}) + \beta_2 \, CENTERTYPE_{t0} \\ & + \beta_3 \, ln\,(CENTERSIZE_{t0}) + \beta_4 \, ln\,(CATCHMENT_{t0}) \\ & + \beta_5 \, ln\,(PROPERTY\ SITE) + \beta_6 \, ln\,(LEASE\ SIZE_{t0}) \\ & + \beta_7 \, ln\,(AGE_{t0}) + \varepsilon. \end{aligned}$$

In which:

R_i = Total annualized period return on property *i*;
α = Constant;
$\beta_1 \ldots \beta_7$ = Regression coefficients;
EI_{t0} = The energy index value of property *i*;
$CENTERTYPE_{t0}$ = The type of center of property *i*;
$CENTERSIZE_{t0}$ = The size of the total center where property *i* is located, in square meters retail space;
$CATCHMENT_{t0}$ = The number of inhabitants in the catchment area of property *i*;
PROPERTY SIZE = The size of the center in square meters;
LEASE SIZE = The average amount of square meters per lease;

AGE = The age of the property in years; and
ε = Error term

The control variables are based on the general retail and land rent theories of Reilly (1931), Christaller (1933), Myrdal (1957), Nelson (1958), and Alonso (1964), combined with empirical evidence on the variables that influence retail sales, rents, and values, such as described in among others in the review article of Mejia and Benjamin (2002). Control variables were tested for normality through a Kolmogorov-Smirnov test. On those variables that were not normally distributed, a natural log transformation was applied. The regression model progressively introduces the control variables. The order of the variables is based on the highest expected influence based on the literature review. Control variables that did not have a significant effect on the performance driver were removed from the model. The data were checked for multicollinearity, heteroscedasticity, dependent errors, non-linear relationships, not normally distributed residuals, and outliers that strongly influence the gradient of the regression line.

Empirical Results

In this section we look at the performance of green and non-green properties and relate these to various explanatory variables. This allows us to verify the extent to which the findings arise from difference in energy labels, or whether they can be attributed to other factors. The differences between the green and non-green properties are shown in Exhibit 4.

We find an insignificant total return difference of green properties of 0.60% versus the total return of non-green properties. The income return difference is highly significant and amounts to 0.52%. Counterintuitively, the rents and values of green properties are *lower* than the rents and values of non-green properties (both significant at the 99% confidence level). Another surprising finding is that green properties have a *higher* vacancy than non-green properties, at a 95% confidence level. For operating costs, there is no significant difference. The characteristics of green and non-green properties also differ. The non-green properties in the portfolio are on average 25 years older than the green properties. Furthermore, the green properties are on average three times larger than the non-green properties and there is also a size difference in the average unit size of green properties, although to a lesser extent. Furthermore, non-green properties are located in larger cities than green properties.

To see whether these differences are interconnected, the partial correlation between the characteristics is calculated. Exhibit 5 presents the results. The results indicate that only the age of the property and the size of the total center have a partial correlation with the Energy Index.

The fact that green properties are younger can be explained due to the evolution in building codes, in which energy efficiency requirements have become more stringent and new materials have been introduced (e.g., for insulation). The fact that non-green properties are more prevalent in larger centers is quite remarkable,

Exhibit 4 | Descriptive Statistics

		N	Mean	Median	Std. Dev.	Sign. Diff.	Standardized *t*
Energy labels							
Energy index	Green	88	1.01	1.02	0.19	Yes[b]	−9.049***
	Non-green	40	1.67	1.57	0.35		
Performance Drivers							
Total return 2007–2011 (%)	Green	68	7.75	7.69	2.05	No[a]	1.348
	Non-green	33	7.15	6.96	1.91		
Income return 2007–2011 (%)	Green	68	6.22	6.37	0.67	Yes[a]	3.750***
	Non-green	31	5.70	5.71	0.57		
Rent per adjusted m^2	Green	87	€303	€226	€201	Yes[b]	−3.369***
	Non-green	39	€430	€380	€237		
Value per adjusted m^2	Green	87	€4,678	€3,397	€3,656	Yes[b]	−3.478***
	Non-green	38	€7,225	€6,145	€5,117		
Vacancy level 2007–2011 (%)	Green	71	1.04	0.00	2.16	Yes[b]	2.121**
	Non-green	32	0.32	0.00	0.76		
Operating costs 2007–2011 (%)	Green	88	10.58	10.21	3.85	No[b]	0.548
	Non-green	40	10.83	9.29	5.38		

Exhibit 4 | (continued)

Descriptive Statistics

		N	Mean	Median	Std. Dev.	Sign. Diff.	Standardized *t*
Control Variables							
Age (years)	Green	88	31	23	29	Yes[b]	−5.116***
	Non-green	40	56	48	30		
Adjusted property size (m^2)	Green	88	4,961	2,840	5,892	Yes[b]	4.277***
	Non-green	40	1,592	571	2,041		
Average m^2 per lease	Green	88	1,141	371	2,008	Yes[b]	2.020**
	Non-green	40	826	275	1,924		
Center size	Green	88	40,850	28,925	48,267	Yes[b]	−3.651***
	Non-green	40	63,922	49,424	55,060		
Catchment area	Green	88	167,821	122,442	185,282	No[b]	0
	Non-green	40	171,770	156,335	190,236		

Notes: This table presents descriptive statistics on the dataset, dividing the results in "Green" and "Non-green" energy labels. The return statistics are five year averages from the base date. Reported values are as per year-end 2011.

[a] Based on a *t*-test.

[b] Mann-Whitney test.

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

Exhibit 5 | Correlations between the Energy Index and the Control Variables

Correlation to Energy Index	ln (size of the total center)	ln (age)	ln (adjusted property size)	ln (average m^2 per lease)
Zero-order correlation	0.37***	0.44***	(0.50)***	(0.16)
Partial correlation	0.28***	0.18**	(0.13)	(0.02)

Notes:
** Significant at the 5% level.
*** Significant at the 1% level.

since the location is not a component in the Energy Index calculation. This could be caused by that fact that properties in the center of larger cities have a shop front that has more open space, so that more consumers can go in and out, but more energy is needed for heating.

Regression Analysis on Returns

In Exhibit 6, we first look at total return (Panel A). The 0.60% higher total return of green properties was not significant to start with. Within the context of the regression analysis, this relation remains insignificant. The partial correlation between the Energy Index and the total return shifts from −0.08 in the first to +0.09 in the fifth model. The influence of the Energy Index on total return is also very low, with a standardized beta of 0.09 in the last model. The dominance of value fluctuations is apparent from the regressions. Total returns are not explained by the factors used. The adjusted R^2 remains low in all cases, reaching 0.22 in the last model.

The income return (Exhibit 6, Panel B) removes the valuation movements from the equation and leads to a far better model fit. The *t*-test shows that green and non-green properties initially show a significantly different income return (at the 99% level). This is supported by the regression analysis. When in model 4 property size is added as an explanatory variable, this relation disappears. In model 6, where age is added, the relation between the energy index and income return becomes even more insignificant ($P = 0.855$). The partial correlation also decreases from −0.41 in Panel A to +0.01 in model 6. This leads us to conclude that the higher income return is not due to the better energy label in itself, but due to the fact that properties with a green label are located in smaller centers (which is in line with the general retail theories), have a larger size, and are younger.

Regression Analysis on Rents and Values

We now turn to rents and values. Exhibit 7 shows that *non-green* properties had a *higher rent and value* than green properties. This can also be seen in the first

Exhibit 6 | Energy Label Impact on Variation in Total and Income Returns

Regression Model	1	2	3	4	5	6	
Variable Added	Energy Index	Location	Center Size	Catchment Area	Property Size	Age	Standardized Beta
Panel A: Total return							
Constant	7.653***	7.462***	11.105***	7.497***	3.454		
Energy Index	(0.573)	(0.851)	(0.433)	(0.225)	0.643		0.09
Dummy for large centers		3.032***	2.402***	2.097***	1.957***		0.33
ln (Center size)			(0.370)*	(0.569)**	(0.433)**		(0.25)
ln (Catchment area)				0.488**	0.426*		0.22
ln (Adjusted property size)					0.430***		0.35
Partial Correlation							
Energy Index with Total Return	(0.083)	(0.128)	(0.059)	(0.033)	0.094		
Model Fit							
R^2	0.007	0.096	0.126	0.167	0.264		
Adjusted R^2	(0.004)	(0.077)	(0.098)	(0.131)	(0.223)		

Exhibit 6 | (continued)

Energy Label Impact on Variation in Total and Income Returns

Regression Model	1	2	3	4	5	6	
Variable Added	Energy Index	Location	Center Size	Catchment Area	Property Size	Age	Standardized Beta
Panel B: Income return							
Constant	6.223***	6.301***	9.220***	7.328***	6.613***	7.386***	
Energy Index	(0.935)***	(0.806)***	(0.451)**	(0.086)	(0.097)	0.030	0.01
Dummy for large centers		(0.823)***	(0.342)*	(0.388)**	(0.451)***	(0.498)***	(0.24)
ln (Size of the total center)			(0.297)***	(0.247)***	(0.221)***	(0.204)***	(0.35)
ln (Adjusted property size)				0.182***	0.144***	0.101***	(0.24)
ln (Average m^2 per lease)					0.119***	0.120***	0.21
ln (Age)						(0.190)***	(0.21)
Partial Correlation							
Energy Index with Income Return	(0.41)	(0.39)	(0.25)	(0.05)	(0.06)	0.02	
Model Fit							
R^2	0.166	0.319	0.493	0.633	0.667	0.687	
Adj. R^2	0.157	0.305	0.477	0.617	0.648	0.666	
Change in Adj. R^2	0.157	0.148	0.172	0.140	0.031	0.018	

Notes: The table presents results on the regression models, subsequently adding variables in a stepwise regression. For each model we present the effect of the added variable on the coefficient for the energy label as well as the model fit. Panel A provides the results on the total return level, whereas panel B focuses on the income return component. Standardized betas are given for the fifth model. The sample size in Panel A is 96; the sample size in Panel B is 98.

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

Exhibit 7 | Energy Label Impact on Variation in Rent and Value

Regression Model	1	2	3	4	5	6	Standardized Beta
Variable Added	Energy Index	Location Dummy	Center Size	Catchment Area	Property Size	m^2 / Lease	Model 6
Panel A: Rent: ln(rent per adj. m^2)							
β-values							
Constant	5.517***	5.528***	3.022***	1.309***	2.469***	3.549***	
ln (Energy Index)	0.662***	0.400***	0.004	0.037	(0.140)	(0.125)	(0.06)
Dummy for large centers		0.813***	0.363***	0.176	0.193*	0.277***	0.15
Dummy for peripheral large retail		(0.737)***	−0.750***	(0.964)***	(0.741)***	(0.498)***	(0.24)
ln (Size of the total center)			0.259***	0.166***	0.145***	0.129***	0.26
ln (Catchment area)				0.233***	0.233***	0.206***	0.34
ln (Adjusted property size)					−0.127***	(0.100)***	(0.25)
ln (Average m^2 per lease)						(0.135)***	(0.25)
Partial Correlations							
Energy Index with Value per m^2	0.31	0.24	0.00	0.03	(0.11)	(0.11)	
Model Fit							
R^2	0.10	0.43	0.60	0.68	0.75	0.79	
Adj. R^2	0.09	0.42	0.59	0.67	0.74	0.78	
Change Adj. R^2	0.09	0.33	0.17	0.08	0.07	0.04	

Exhibit 7 | (continued)

Energy Label Impact on Variation in Rent and Value

Regression Model	1	2	3	4	5	6	Standardized Beta
Variable Added	Energy Index	Location Dummy	Center Size	Catchment Area	Property Size	m^2 / Lease	Model 6
Panel B: Value: ln(value per adj. m^2)							
β-values							
Constant	8.191***	8.193***	5.429***	3.501***	4.886***	5.986***	
ln (Energy Index)	0.804***	0.495**	0.062	0.101	(0.110)	(0.094)	(0.04)
Dummy for large centers		1.000***	0.502***	0.288**	0.298**	0.381***	0.18
Dummy for peripheral large retail		(0.812)***	(0.827)***	(1.069)***	(0.801)***	(0.552)***	(0.23)
ln (Size of the total center)			0.286***	0.183***	0.146***	0.139****	0.25
ln (Catchment area)				0.261***	0.266***	0.239***	0.34
ln (Adjusted property size)					(0.156)***	(0.130)***	(0.28)
ln (Average m^2 per lease)						(0.137)***	(0.22)
Partial Correlations							
Energy Index with Rent per m^2	0.33	0.26	0.04	0.07	−0.08	(0.07)	
Model Fit							
R^2	0.11	0.46	0.61	0.69	0.77	0.80	
Adj. R^2	0.10	0.45	0.60	0.68	0.76	0.79	
Change Adj. R^2	0.10	0.35	0.16	0.08	0.08	0.03	

Notes: In the table we provide the results of the regression analyses on Rent (Panel A) and Value (Panel B), subsequently adding variables. For each model we present the effect of the added variable in a stepwise regression on the coefficient for the energy label as well as the model fit. Standardized betas are given for the sixth model. The sample size in Panel A is 125; the sample size in Panel B is 124.

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

model of the rent and value regression analyses. This significant relation disappears completely when in the third model the size of the total center is added. The partial correlation between the Energy Index and the rent and value even changes signs when the catchment area, property size, and size of the unit are added.

The regression models help us to explain the differences in rent and value to a large extent. Thus, we conclude that the energy label as such does not affect the rent and value in this portfolio of retail properties. The difference is caused by the fact that the non-green properties are located in larger centers, have a larger catchment area, and a smaller unit and property size than green properties.

The findings that properties in a larger center, with a larger catchment area, have higher rents (and values) are in line with the general retail theories of Reilly (1931), Christaller (1933), and Alonso (1964) and consistent with the literature (e.g., Hardin and Wolverton, 2000, 2001; Mejia and Benjamin, 2002). The finding that smaller properties have higher rents is also consistent with earlier reported results, such as Eppli and Benjamin (1994).

Regression Analysis on Operating Costs and Vacancies

In contradiction with the evidence in the literature for office properties, the Mann-Whitney test shows that the Energy Index in this sample of retail properties did not have any significant influence on the operating costs. Also in the regression analysis in Exhibit 8, this relation is insignificant. With a partial correlation of 0.12 in the last model, the relationship between the Energy Index and the operating costs is very weak. The operating costs for retail properties are influenced by the size of the units and the property, if a shopping center is covered, as well as the size of the city. The vacancy level influences operating costs highly: if the vacancy rate increases by 1%, the operating costs increase by 0.6%.

The Mann-Whitney test shows that green properties in the sample have a significantly higher vacancy rate than non-green properties. This effect can also be seen in the initial model of the regression analysis. The relation disappears completely in subsequent models, after the introduction of control variables. The β-value between the energy label and the vacancy level is also highly insignificant in the third panel. The partial correlation is already weak in the first model and stays weak.

The only variables that have a significant effect on the vacancy rate are the property size and the average unit size. These results show that larger properties have a higher vacancy rate and that properties with large units have lower vacancy rates. This can be explained since the larger properties with smaller retail units are mainly shopping centers, which have more vacancy on the higher floors of the shopping center. The large properties are mostly supermarkets and peripheral retail properties, which have relatively low vacancy rates in this sample. Since the average vacancy in the sample is only 0.82% and 66 of the 103 properties did not have any vacancy in the sample period between 2007 and 2011, the distribution of the vacancy has a high kurtosis. The residuals are not normally

Exhibit 8 | Regression Analysis of Operating Costs and Vacancy

Regression Model	1	2	3	4	5	6	Standardized Beta
Variable Added	Energy Index	Location Dummy	Property Size	m^2 / Lease	Retail Type	Vacancy	Model 6
Panel A: Operating costs							
β-values							
Constant	10.511***	10.345***	9.402**	16.851***	15.415***	14.797***	
Energy Index	1.075	0.699	0.979	0.751	1.523	1.591	0.11
Dummy for large city centers		1.813	1.839	2.284**	2.565**	2.786**	0.22
ln (Adjusted property size)			0.122	0.810***	0.988***	0.789***	0.29
ln (Average m^2 per lease)				(2.040)***	(2.089)***	(1.841)***	(0.51)
Dummy for standard units—covered					3.327**	3.732***	0.23
Average vacancy 2007–2011						0.579***	0.25
Change (%) in rent 2007–2011							
Energy Index with Operating Costs	0.07	0.05	0.06	0.05	0.11	0.12	
Model Fit							
R^2	0.05	0.02	0.03	0.28	0.32	0.37	
Adj. R^2	(0.01)	0.00	(0.00)	0.25	0.28	0.33	
Change Adj. R^2	(0.01)	0.01	(0.01)	0.25	0.03	0.05	

Exhibit 8 | (continued)

Regression Analysis of Operating Costs and Vacancy

Regression Model	1	2	3	Standardized Beta
Variable Added	Energy Index	Property Size	m^2/lease	Model 3
Panel B: Vacancy (2007–2011)				
β-values				
Constant	0.918**	(0.948)	0.642	
Energy Index	(0.521)	(0.036)	(0.020)	(0.00)
ln (Adjusted property size)		0.244*	0.395***	0.33
ln (Average m^2 per lease)			(0.440)***	(0.28)
Partial Correlation				
Energy Index with Vacancy 2007–2011	(0.083)	(0.005)	(0.003	
Model Fit				
R^2	0.01	0.04	0.11	
Adj. R^2	(0.00)	0.02	0.08	
Change Adj. R^2	(0.00)	0.03	0.06	

Notes: In this table, we provide the results of the regression analyses on Operating Costs (Panel A) and Vacancies (Panel B), subsequently adding variables. For each model we present the effect of the added variable on the coefficient for the energy label as well as the model fit. Standardized betas are given for the sixth model. The sample size in Panel A is 101; the sample size in Panel B is 102.

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

distributed and therefore not in line with the general assumptions of a linear regression analysis. This is in line with findings that the vacancy rate of retail properties is highly dependent on the exact location within a retail area (Myrdal, 1957) and the number of people passing by (Locatus, 2012), which has not been taken into account due to data availability issues.

Conclusion

The literature on the impact of sustainability on investor returns on real estate has largely focused on the office sector and on the U.S. As sector characteristics and the combination of geography and market structure (e.g., age of the properties) are likely to significantly influence the findings, we use a dataset focusing on the retail sector in the Netherlands. Using a unique dataset, we show that green properties have a significantly higher direct income return. Counterintuitively, non-green properties have significantly higher rents and values. However, when this is explored further in a regression analysis, we show that the significant differences are not caused by the energy labels, but by other factors influencing the performance of a retail property. The total return, vacancy rate, and operating costs also have no significant relation to the sustainability level of a property. Therefore, we do not find evidence of a sustainability premium for sustainable retail properties.

Since the Energy Index is significantly positively related to the age and size of the total retail area, non-green properties are generally older and more prevalent in the larger centers. In the Netherlands, these larger centers consist mainly of historical city-center high streets, which are highly valued by consumers and also have higher rents, values, and lower income returns than properties in other locations. Green properties are mostly modern shopping centers just off the high streets and neighborhood centers, with lower rent, values, and higher vacancy levels and returns. In addition, non-green properties are smaller and have smaller retail units than green properties, enhancing the rent and values. Therefore, the significant difference in rent, value, and income return of green and non-green properties is not caused by the energy label, but by the size and catchment area of the (city) center, the location, and the size of the property. The age of a retail property has not been found to have a significant influence on the rent and value, which can be explained by the fact that location has more impact on rent and value than age.

The main conclusion of this study contradicts the conclusions of studies on the office and residential sectors, which all find higher rents and values for sustainable properties. An explanation might be that sustainability has been incorporated more within the office and residential sectors than in the retail sector. Also, the sensitivity of value and income of retail properties to the traditional location factors seem to be more important than for offices.

These data shows that it is of pivotal importance to understand and examine the data. The more detailed the study is and the more refined the regression analysis method is, the smaller the difference between the green and non-green properties becomes. This study has a very focused and high quality data sample with a small measurement error. This may also be the reason why the relation between the performance and energy label has been assigned to other factors.

The finding of this study that the sustainability level has no significant influence on the return is in line with other studies on the returns of sustainable funds, as shown by Eichholtz, Kok, and Yonder (2012). Larger studies on the relation between sustainability or corporate social responsibility (CSR) and the returns of investment funds indicate mixed results. Many review studies also find no significant relation and Orlitzky, Schmidt, and Rynes, (2003) finds in their large meta-analysis only a small positive correlation between sustainability and financial performance.

Furthermore, the rent (and value) of a retail unit is mainly determined on the potential sales that a retailer can realize in a specific retail unit and at a specific location. Since the rent is only approximately 10% of the sales and the energy costs only 1% of the sales, the effect of lower energy costs on the total profit is limited. A retailer is probably more eager to invest in better lighting (which might use even more energy), so that the products are lit better, look more attractive, and sell better. When a higher profit can be made out of more sales, a retailer will accept higher energy costs.

The result of this study that retail properties have higher rents, higher values, and lower vacancy levels in larger retail areas is fully in line with the general retail theories of Reilly (1931), Christaller (1933), Myrdal (1957), Nelson (1958), and Alonso (1964), and with the published articles.

Endnote

[1] The RICS Valuation Standards can be found at www.rics.org/uk/knowledge/red-book/global-red-book-valuation-standards/.

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Walk Score: The Significance of 8 and 80 for Mortgage Default Risk in Multifamily Properties

Author Gary Pivo

Abstract In this paper, I use logistic regression to study the relationship between walkability and mortgage default risk in multifamily housing in a pool of nearly 37,000 Fannie Mae loans. Walkability is measured with Walk Score, a widely available metric. Controls were introduced for loan terms, property characteristics, neighborhood conditions, and macroeconomics. Walkability reduced default risk but the relationship was nonlinear with thresholds. Default risk significantly increased where walkability was very low and significantly decreased where it was very high. The implication is that walkability and its possible benefits to health and the environment could be fostered by relaxing lending terms without adding default risk.

In this paper, I examine the relationship between Walk Score, a widely available indicator of walkability, and mortgage default risk in multifamily rental housing. The findings show that very high and very low Walk Scores significantly affect default risk. Where Walk Score is 80 or more out of 100, the relative risk of default is 60% lower than where Walk Score is less than 80, controlling for other factors that impact risk. Where Walk Score is 8 or less, default risk is 121% higher.

This is the first paper that shows Walk Score affects default risk in multifamily rental housing. It builds on prior work showing that higher Walk Scores are related to lower default risk in single-family housing (Rauterkus and Miller, 2011) and higher values in office, retail, and apartment buildings (Pivo and Fisher, 2011; Kok and Jennen, 2012; Kok, Miller, and Morris, 2012). For lenders and developers, the findings reported here indicate that Walk Score could be used to help evaluate and underwrite properties and investment risk. For researchers in real estate and urban economics, the findings deepen our knowledge of investment risk correlates and the role of local accessibility in urban economic geography. And for practicing urban planners, developers, policy-makers and others interested in fostering healthier, more sustainable cities, it strengthens the case for walkable urban development.

Background

Walkability is the degree to which an area within walking distance of a property encourages walking trips for functional and recreational purposes (Pivo and Fisher, 2011). Several physical and social attributes of an area can affect walkability including street connectivity, traffic volumes, sidewalk width and continuity, topography, block size, safety, and aesthetics (Frank and Pivo, 1994; Hoehner et al., 2005; Cao, Handy, and Mokhtarian, 2006; Lee and Moudon, 2006; Parks and Schofer, 2006; Freeman et al., 2012). However, research indicates that the presence of desired destinations, such as stores, parks and transit stops, is the most significant driver of walkability (Hoehner et al., 2005; Lee and Moudon, 2006; Sugiyama et al., 2012). Handy (1993) refers to this dimension of urban space as ‘‘local accessibility.’’ More than 30 years ago, Li and Brown (1980) noted that local accessibility was an important aspect of overall accessibility in urban areas even though accessibility was more commonly measured in relation to urban centers.

Local accessibility is the particular dimension of walkability that is measured by Walk Score, although Walk Score is correlated with other walkability correlates, such as intersection, residential, and retail destination density (Duncan, Aldstadt, Whalen, and Melly, 2011). Studies have shown Walk Score to be a reliable and valid estimator of neighborhood features linked to walking (Carr, Dunsiger, and Marcus, 2010, 2011; Duncan, Aldstadt, Whalen, and Melly, 2011; Duncan et al., 2013). It is also a better predictor of walking for non-work trips than other related indices (Manaugh and El-Geneidy, 2011).

Walk Score rates the walkability of an address by determining the distance from a location to educational (schools), retail (groceries, books, clothes, hardware, drugs, music), food (coffee shops, restaurants, bars), recreational (parks, libraries, fitness centers), and entertainment (movie theaters) destinations. Points are assigned to the location based on distance to the nearest destination of each type. If the closest establishment of a certain type is within a quarter mile, Walk Score assigns the maximum points for that type. No points are given for destinations beyond a mile. Each type of destination is weighted equally. Points for each category are summed and scores are normalized to produce a total from 0 to 100. Pivo and Fisher (2011) discuss some of the limitations and other caveats related to Walk Score. A newer version that addresses certain concerns is currently in development.

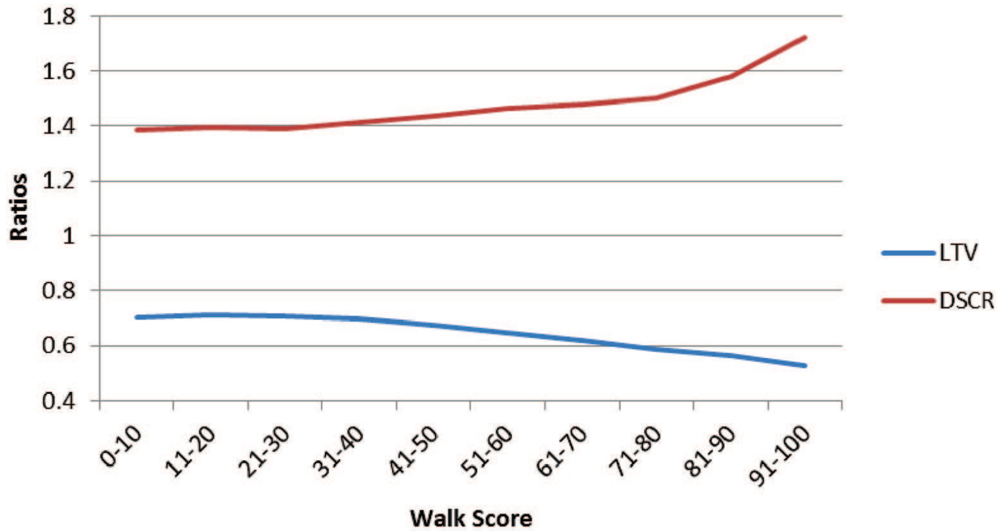
Walk Score has advantages over other systems for measuring walkability (Moudon and Lee, 2003; Parks and Schofer, 2006). One advantage is that it measures the best predictor of walking proximity to desired destinations. Another is that it is available for all addresses nationwide. Weidema and Wesnæs (1996) developed data quality indicators including reliability, completeness, temporal, and geographical correlation with the time and place being assessed, and further technical correlation, including whether the data actually represent the process of concern. Walk Score scores well on such metrics.

Increasing urban walkability is increasingly viewed as a major goal by urban planners, sustainability scientists, and public health experts for social and environmental reasons. The expected benefits remain an ongoing research topic, though a considerable body of evidence is emerging from well-controlled studies. Environmental benefits may include less air pollution, auto use, and gasoline consumption (Frank, Stone, and Bachman, 2000; Ewing and Cervero, 2001; Frank and Engelke, 2005; Handy, Cao, and Mokhtarian, 2005; Cao, Handy, and Mokhtarian, 2006). In fact, walking has been recognized as one of the main options for mitigating climate change in the transport sector (Chapman, 2007; Bosch and Metz, 2011). Social benefits may include better public health as a result of more physical activity (Lee and Buchner, 2008; World Cancer Research Fund/American Institute for Cancer Research, 2009; Berrigan et al., 2012) and increased social capital including more community cohesion, political participation, trust, and social activity (Leyden, 2003; du Toit, Cerin, Leslie, and Owen, 2007; Rogers, Halstead, Gardner, and Carlson, 2009; Wood, Frank, and Giles-Corti, 2010). Social capital has in turn been linked to the capacity of cities to transition toward greater sustainability (Portney, 2005; Geels, 2012).

Walkability can be created by developing larger scale mixed-use development projects or by infilling development in currently walkable locations. There is evidence that it is more difficult to finance walkable projects because they are perceived to be riskier, leading to more expensive financing. Financiers could be concerned about disamenities from non-residential uses, uncertainty about the performance of mixed-use buildings, entitlement risk for infill projects, or weaker economic conditions in walkable, mixed-use neighborhoods. One study focused on residential developments that were planned to be compact, scaled for pedestrians, and designed to include activities of daily living within walking distance of homes (Gyourko and Rybczynski, 2000). It found that developers, financiers, and investors perceived such projects to be ‘‘inherently riskier and more costly…arising from the multiple-use nature of the developments.’’ On the other hand, the study also found that urban infill risk premiums could be quite small where communities were willing to accept high densities. More recently, Leinberger and Alfonzo (2012) pointed out that ‘‘walkable urban places remain complex developments that still carry high risk and, as such, costly capital (both equity and debt financing).’’ Of course, not all projects in walkable locations are mixed use or complex and the Urban Land Institute recently reported that ‘‘demand and interest in apartments in ‘American infill’ locations remain hot’’ (PwC and the Urban Land Institute, 2012). Thus, while experts have noted that more walkable projects are more difficult to finance because of their riskier reputation, the degree to which this is true for all walkable projects is unclear because they can vary in location, scale, and complexity. It is also unclear exactly what it is about the projects that are cause for concern.

According to Grovenstein et al. (2005), mortgage lenders often respond to perceived risk by limiting how much they will lend. They point out that lenders could also increase interest rates on riskier projects, but that approach is constrained because higher rates can increase default risk. Assuming a given cash flow and value, limiting the amount loaned reduces the loan-to-value (LTV) ratio and increases the debt service coverage ratio (DSCR). For borrowers, a lower LTV ratio means that more walkable projects would produce a lower return on equity compared to what could be earned on more conventional projects with higher loan ratios, all else being equal, as long as positive leverage is possible (i.e., when the cost of debt financing is lower than the overall return generated by the property

Exhibit 1 | Loan Ratios by Walk Score



return on assets). A lower return on equity could cause investors to disfavor walkable investments, decrease capital flows to walkable properties, and slow the movement toward more walkable cities.

In the pool of nearly 37,000 multifamily mortgages examined in this study (see Methods below for details), there is evidence that lenders treated projects in more walkable locations as if they were perceived to be riskier loans. As shown in Exhibit 1, in the study sample, as Walk Score increased, LTV fell and DSCR increased. These trends in LTV and DSCR relative to Walk Score are consistent with lenders reducing the size of loans relative to property value and income in more walkable locations in response to perceived risk.

As suggested above, less favorable loan terms for more walkable locations may not be caused by lenders' views about walkability per se but rather by concern about other features of the properties or their location such as disamenities, entitlement risk, or economic conditions. This may seem counterintuitive if one simply assumes that places with higher Walk Scores are correlated with more supply-constrained markets. It is true that in the sample used in this study there was a very weak correlation between higher Walk Score and higher supply constraint as measured by vacancy rates and price change. However, higher Walk Scores were also correlated with more poverty and lower income households in the neighborhood and with smaller loans and building size, all of which can raise the level of expected risk. It goes beyond the scope of this paper to determine precisely why loan terms appear to have been less favorable in more walkable neighborhoods. The reasons, however, probably result from a number of social and economic conditions that distinguish more and less walkable locations. In the modeling presented below, however, the effect of factors beyond Walk Score that may affect default risk are statistically controlled so as to determine how walkability itself is related to default risk, all else being equal.

I take a closer look at this risk issue by comparing default risk in more and less walkable properties (i.e., properties in more and less walkable locations). The findings show that default risk for multifamily properties in highly walkable neighborhoods is lower, not higher, than the default risk for projects in less walkable locations.

The hypothesis for this paper is as follows: Greater walkability, as measured by higher Walk Scores, reduces mortgage default risk in multifamily housing.

Studies have shown that walkability improves property values (Pivo and Fisher, 2011; Kok and Jennen, 2012; Kok, Miller, and Morris, 2012; Pivo, 2013). The higher values appear to result from both stronger cash flows and lower capitalization rates, suggesting that walkable properties are favored in both space (i.e., rental) and capital markets (Pivo and Fisher, 2010). This relationship between walkability and value should be expected, given the long known understanding that accessibility, in this case local accessibility, plays in the formation of property value. Pivo and Fisher (2011) discuss this in the context of a recent summary of the literature on the determinants of urban land and property values.

Studies also show that the major risk factors for multifamily loan default are cash flow and property value. Default risk increases if declining cash flow prevents loan repayment or if falling property value produces negative net equity (Vandell, 1984, 1992; Titman and Torous, 1989; Kau, Keenan, Muller, and Epperson, 1990; Vandell et al., 1993; Goldberg and Capone 1998, Goldberg and Capone 2002, Archer et al. 2002). In these studies, cash flow and equity are commonly measured in terms of debt service coverage ratio (DSCR), or the ratio of income to required loan payments, and loan to value ratio (LTV), or the ratio of loan amount to property value. A lower DSCR and a higher LTV, both at origination and over the life of the loan, have been linked to greater default risk. If more walkable properties produce better cash flows and property values, then they should also exhibit lower default risk because default risk is inversely related to cash flow and value (Titman and Torous 1989, Kau et al. 1990, Vandell 1984, Vandell 1992, Vandell et al. 1993, Goldberg and Capone, 1998, 2002; Archer, Elmer, Harrison, and Ling, 2002; Pivo, 2013). However, as Pivo (2013) noted, adding information on walkability to the loan origination process would only be helpful if its impact on cash flow and value was not already fully accounted for in the loan origination process. The assumption here is that the walkability premium was not fully considered in past lending decisions. That is not to say it was completely ignored, just not recognized as important in property markets as it appears to be today. Indeed, loan proposal documents regularly address locational advantages such as access to public transportation and other amenities.

Methods

Logistic regression models were used to test the effects of Walk Score on default risk. This approach has been used in several studies to estimate the effects of explanatory variables on the probability of mortgage default (Vandell et al., 1993; Goldberg and Capone, 1998, 2002; Archer, Elmer, Harrison, and Ling, 2002; Rauterkus, Thrall, and Hangen, 2010).

Logistic regression is a statistical method for predicting the value of a bivariate dependent variable (Menard, 1995) or a variable with two possible values (e.g., default/not default in the present study). The value of the dependent variable predicted by a logistic regression is the probability that a case will fall into the higher of the two categories of the dependent variable, which normally indicates the event (e.g., default) occurred, given the values for the case on the independent variables. In other words, it is the probability that an event will occur under various conditions characterized by the independent variables. The predicted value of the dependent variable is based on observed relationships between it and the independent variable or variables used in the study.

The most common alternative to the logistic regression model in mortgage default research is the proportional hazard model. Hazard models can be used to explain the time that passes before some event occurs in terms of covariates associated with that quantity of time. They have been used to estimate the probability that a mortgage with certain characteristics will default in a given period if there has been no default up until that period (Vandell et al., 1993; Ciochetti, Deng, Gao, and Yao, 2002).

A common view of the hazard model is that it is less sensitive to bias from database censuring than logistic regression. Censoring occurs when cases are removed from the database prior to observation (e.g., when a loan is paid off or foreclosed and sold prior to observation) or when the event of interest happens after observation occurs (e.g., when a loan defaults after the study observation date). However, as pointed out by Archer, Elmer, Harrison, and Ling (2002), bias is only an issue in logistic regression when the explanatory variables have a different effect on the censored and uncensored cases. In the present study, there is no reason to expect that walkability affected the odds of default differently in censored and uncensored cases. Hazard models also require a time series dataset that reports the occurrence of defaults over time and such a dataset was unavailable for the present study.

One effort to predict mortgage pre-payment using both logistic regression and hazard models found that the logistic regression model made better predictions (Pericili, Hu, and Masri, 1996), while in another study on insolvency among insurers, the two models produced equally accurate predictions (Lee and Urrutia, 1996). So, while it would be interesting to repeat this study using a hazard model, there is no a priori reason to assume that the logistic regression method used here produced results that are inferior to those that would have come from another method.

To build logistic regression models for the present study, data were provided by Fannie Mae on all the loans in its multifamily portfolio at the end of 2011:Q3. The sample included mortgages with fixed and adjustable rates and with a wide variety of seasoning, originating anywhere from September, 1971 through

September, 2011. In the study, each loan was treated as a separate case or observation. For each case, data were available on the loan age, type, terms, and lender, on various financial, physical, and locational attributes of the property, and on the number of days the loan was delinquent, if any. In addition to these data on the loans, Walk Score data and other data on neighborhood and regional attributes were collected from other sources for use in the model. Further details on the variables are given below.

Following Archer, Elmer, Harrison, and Ling (2002), cases in the Fannie Mae database with extreme values on certain variables were excluded from the study in order to filter out possible measurement error. The extreme value filters ensured that all the cases used had an original note interest rate greater than the 10-year constant maturity risk-free rate at their origination date, an original LTV ratio of 100% or less, an original DSCR greater than 0.9 and less than 5, and an original note interest rate greater than 3% and less than 15%. After these filters were applied, 36,922 loans remained in the sample out of the 42,474 loans originally provided.

As noted, default status was observed as of 2011:Q3, making the study cross-sectional rather than longitudinal. The cross-sectional study design raises some concern about the external validity of the findings (i.e., how far the findings can be generalized beyond the study sample) because the relationships between the regressors and default risk could change over time. For example, walkability could reduce default rates by a greater amount when gas prices are peaking and demand is higher for apartments in more accessible locations. Since longitudinal data were not available for this study, it would be useful to confirm the results reported here in a follow-up study using longitudinal data. Another external validity issue comes from the fact that the Fannie Mae mortgage pool had an average default rate that was about one-fourth the rate found for mortgages held by depository institutions at the time the study was completed. It would be important to know whether the effects found in this study apply to those mortgages as well. The effects of Walk Score on default could be different for riskier loan pools if, for example, the properties were located where high Walk Scores were not such an attractive feature either because of different neighborhood conditions or tenant characteristics associated with the riskier pool of loans.

Variables

Dependent and Explanatory Variables

DEFAULT was the dependent variable used in the study. It was binary, indicating whether (1) or not (0) a loan was in default as of 2011:Q3. A loan was classified as in default if it was delinquent on its payments by 90 days or more. This is an industry standard definition and matches that used by Archer, Elmer, Harrison, and Ling (2002), who pointed out that such a broad definition is useful because other resolutions in addition to foreclosure can be used to resolve defaults and they all involve delinquency-related costs to the lender.

WALK SCORE was the explanatory variable of interest. It captures the walkability of the area where each apartment building was located. As noted above, it has been found to be a reliable and valid estimator of neighborhood features linked to walking and a better predictor of walking for non-work trips than other similar indices.

Control Variables

The expectation was that *WALK SCORE* was related to default risk because it affects cash flow and value to a degree that was unaccounted for in the DSCR or LTV ratios at loan origination. However, it could also be the case that *WALK SCORE* is correlated with other factors that affect financial outcomes, such as other loan, property, neighborhood or macroeconomic variables. In that case, *WALK SCORE* could simply be a proxy for other drivers of cash flow and value, such as neighborhood vacancy rate. Therefore, in order to separate the effects of *WALK SCORE* on *DEFAULT* from other possible drivers, several control variables suggested by prior research were used in the models. The controls fall into four groups including loan, property, neighborhood, and economic characteristics.

Loan Characteristics

OLTV and *ODSCR* measured the LTV and debt service coverage ratios at loan origination. Higher *OLTV* and lower *ODSCR* were expected to be associated with greater default risk. *LOAN_AGE_MONTHS* was the number of months from the loan origination date to the observation date (2011:Q3). Previous researchers have shown that default risk declines with age, though the pattern is nonlinear, increasing rapidly in the first few years and then declining (Snyderman, 1991; Esaki, L'Heureux, and Snyderman, 1999; Archer, Elmer, Harrison, and Ling, 2002). The same pattern was observed in this study sample. Consequently, some degree of non-linearity in the logit (i.e., a nonlinear relationship with the logit form of *DEFAULT*) was detected for *LOAN_AGE_MONTHS* using the Box-Tidwell transformation (Menard, 1995). Transformations of *LOAN_AGE_MONTHS* were tried in the models but they did not improve the results and were discarded to simplify interpretation of the findings. *ARM_FLAG* was a dummy indicating whether the loan was adjustable (1) or fixed (0).

Property Characteristics

NO_CONCERNS was a dummy indicating whether or not there were no substantial concerns about the property condition at the time of loan origination. This should reduce default risk by decreasing the need to divert cash flow to deferred maintenance. *BUILT_YR* was the year the property was built. Archer, Elmer, Harrison, and Ling (2002) found that default rates increased with building age, so *BUILT_YR* was expected to be inversely related to default risk (i.e., older buildings would default more often). This was the expectation for the nation as a whole, although it could be true that in some areas the historic or design qualities associated with older buildings may be preferred, which could influence how age is related to default risk by increasing demand, cash flow, and value for older buildings. *TOT_UNTS_CNT* was the total number of units in the property. Smaller properties have been reported to experience more financial distress (Bradley, Cutts, and Follain, 2000). Perhaps this is because of the characteristics of borrowers on smaller properties who may have less experience, less access to capital, and less of a tendency to use professional property managers. Archer, Elmer, Harrison, and Ling (2002), however, looked at unit count in a multivariate analysis and found that size (and value) was unrelated to default, even though their univariate analysis showed that smaller properties had less default risk, contrary to Bradley, Cutts, and Follain (2000). So the expected effect in this study was ambiguous.

Neighborhood- and City-Scale Geographic Characteristics

Researchers have found that stress on properties is related to geographical effects. In fact, Archer, Elmer, Harrison, and Ling (2000) found geographical effects to be one of the most important dimensions for predicting multifamily mortgage default. More recently, An, Deng, Nichols, and Sanders (2013) found that local economic conditions affect commercial mortgage-backed security (CMBS) loans significantly and improve predictive power. Five control variables were created to control for these sorts of effects at the city and neighborhood level. *MEDHHINC000* was the median household income in the census tract from the 2000 census. Higher income was expected to be linked with lower default rates. *PROP_CRIME_MIL* was the annual number of property crimes per million persons at the city scale, reported by the U.S. Department of Justice. Higher crime in the city was expected to increase default risk. *VACANCY_RATE* was the vacancy rate for housing in the census block group as determined by the 2007–11 U.S. Census American Community Survey. Vacancy rate was used to control for the effect of housing supply constraint on default rates in order to rule out the possibility that *WALK SCORE* was a proxy for constrained supply. *PRINCIPAL_CITY* indicated whether the property was located in a Principal City, defined by the U.S. Census as the largest incorporated or census designated place in a core-based statistical area. Its purpose was to control for whether or not a property was centrally located within a metro- or micropolitan area because central areas have outperformed suburban locations over the past decade and Walk Score tends to be higher in central cities. Properties in Principal Cities were expected to have lower default risk. *URB_RUR* was also used to measure regional centrality. It was based on the 11 Urbanization Summary Groups defined in the ESRI Tapestry Segmentation System, which groups locations along an urban-rural continuum from Principal Urban Centers to Small Towns and Rural places. Finally, *TOP25CITY* was a dummy variable indicating whether the property was in one of the 25 largest U.S. cities.

Regional and National Economy

Regional and national variables were used to control for difference in the economic context experienced by properties since loan origination. Dummies were created for each of the nine census divisions as proxies for regional economic conditions. Vandell et al. (1993) used a similar variable. Additional variables designed to capture regional effects were dummies for whether the property was located in New York City (*NYC*) or Washington, DC (*DC*), and changes in vacancy rates and prices in the metropolitan area in the most recent six-year period. *AVG_PRICE_6* and *AVG_OCC_6* were computed using the NCREIF Apartment Index for metro areas. They described the average increase in apartment prices and the average occupancy rate in the metro area for each property over the last six years prior to the study observation date. Prior researchers have used updates of LTV and DSCR over time to predict default on the theory that negative equity or cash flow will trigger default. Both are affected by the property's net operating income, which is in turn affected by vacancy rates and rental price indices. Therefore, changes in vacancy rates and rental price indices at the metro scale can be used to capture changes in market conditions that strengthen or weaken mortgages over time, following Goldberg and Capone (1998, 2002).

Borrower Characteristics

Lenders consider borrower characteristics to be crucial to predicting default rates. Relevant variables include borrower character, experience, financial strength, and credit history. In their "simple model of default probability," Archer, Elmer, Harrison, and Ling (2002) theorize that losses from loans depend upon the risk characteristics of the borrower, among other things, though such variables were not included in their models. Vandell et al. (1993) used borrower type (individual, partnership, corporation, other) in their analysis of commercial mortgage defaults, as did Ciochetti, Deng, Gao, and Yao (2003), who expected individuals to represent a lower risk to lenders, though neither study found these variables to be significant. Unfortunately, due to privacy rules, data on borrowers were not provided by Fannie Mae for this study. It is likely, however, that lenders adjusted the original loan terms based in part on their assessment of borrower characteristics. Therefore, *OLTV*, *ODSCR*, and *ARM_FLAG* may be proxies for borrower characteristics. *TOT_UNTS_CNT* may also be correlated with borrower characteristics, as mentioned above. It is inappropriate, however, to make assumptions about the effects of omitting variables in logistic regression. It is known that omitting relevant variables introduces bias in linear regression, but less is known about how it may bias logistic regression (Dietrich, 2003). One study showed that omitted orthogonal variables (i.e. variables that are uncorrelated with other independent variables) can depress the estimated parameters of the remaining regressors toward zero (Cramer, 2007). That would make the findings about Walk Score in this study appear to be weaker than they actually are. It would be helpful to include borrower characteristics in future work that builds on the present study.

Collinearity

Correlation among the independent variables is indicative of collinearity. Collinearity can create modeling problems including insignificant variables, unreasonably high coefficients, and incorrect coefficient signs (e.g., negatives that should be positive). Collinearity will not affect the accuracy of a model as a whole, but it can produce incorrect results for individual variables. Tolerance statistics, which check for a relationship between each independent variable and all other independent variables, were used as an initial check for collinearity and they raised no concerns (Menard, 1995). A pairwise correlation matrix among the independent variables also uncovered no issues.

Results

Univariable Analysis

The process of building the logistic regressions began with a univariable analysis of each variable as recommended by Hosmer and Lemeshow (2000). For the dummy and ordinal variables, this was done by using a contingency table to compare outcomes for properties that did and did not default. The significance of the differences was determined with the likelihood ratio and Pearson chi-squared tests. For the continuous variables, means for the default and not-default groups were compared using the two-sample *t*-test.

The results are shown in Exhibit 2 along with descriptive statistics for the total sample. Other than *TOP25CITY* and a few of the regional dummies, all of the variables, including *WALK SCORE*, were significantly related to *DEFAULT*.

Logistic Regressions

Following the univariable analysis, several different models were produced; each model has a specific purpose. The statistics for each model are given in Exhibit 3. Particular attention was paid to changes in the *WALK SCORE* coefficients across the various models.

Model 1 included all of the scientifically relevant variables. This allowed the effect of removing insignificant variables on the variables that remained in subsequent models to be observed.

The size and direction of the relationships are indicated by the unstandardized coefficients (β). β gives the change in the risk of default associated with a one-unit change in the variable while other variables are held constant. If β is positive, then default risk increases with a one-unit increase in the variable. If β is negative, the relationship is inversed. For example, in Model 1, the *B* coefficient for *WALK SCORE* (−0.018) indicates that as *WALK SCORE* rises, the risk of *DEFAULT* falls, holding the other variables constant. All of the variables in Model 1 were related to *DEFAULT* in the expected direction even though some of the relationships were statistically insignificant.

The Exp(β) statistic is the odds ratio or the number by which one would multiply the odds of default for each one-unit increase in the independent variable. An Exp(β) greater than one indicates the odds increase when the independent variable increases and an Exp(β) less than one indicates the odds decrease when the independent variable increases. For *WALK SCORE* in Model 1, Exp(β) indicate that a one-unit increase resulted in a 1.8% decrease in the odds of default (i.e., the odds of *DEFAULT* are multiplied by 0.018, which is 0.982 less than 1). Odd ratios can also be interpreted as relative risk when the outcome occurs less than

Exhibit 2 | Descriptive Statistics

	All Loans		Defaulted Loans		Non-defaulted Loans		Difference Tests		
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	*t*-test	Likelihood Ratio	Pearson Chi-Square
Dependent Variable									
Fraction of loans defaulting	0.86%		100%		0%				
Walkability Variable									
Walk Score	66.0	21.8	61.6	21.0	66.1	21.8	0.000		
Loan Characteristics									
Loan-to-value ratio at origination	61.20%	16.30%	70.40%	11.50%	61.20%	16.30%	0.000		
Debt coverage ratio at origination	1.5	0.6	1.3	0.3	1.5	0.6	0.000		
Loan age in months	73.2	52.9	67.9	33.1	73.2	53.0	0.005		
ARM flag	0.31	0.462	0.39	0.49	0.31	0.46			
Property Characteristics									
No concerns	0.29	0.45	0.12	0.32	0.29	0.45		0.000	0.000
Year built	1968.0	26.3	1955.0	32.1	1968.0	26.2	0.000		
Total units	94.6	125.0	64.2	99.5	94.9	125.2	0.000		
Neighborhood and City Characteristics									
Median household income in 2000 census tract	42,694	16,957	34,085	13,483	42,768	16,965	0.000		
Property crime per million capita in city	407.5	165.3	474.5	161.6	406.9	165.2	0.000		
Housing vacancy rate 2011 block group (%)	6.58	5.87	9.85	7.45	6.56	5.85	0.000		
Urban/Rural Continuum	1.92	1.16	2.00	1.08	1.92	1.16		0.001	0.000
Principal City	0.60	0.49	0.68	0.47	0.60	0.49		0.002	0.002
Top 25 City	0.23	0.42	0.19	0.39	0.23	0.42		0.069	0.076

Exhibit 2 | (continued)

Descriptive Statistics

	All Loans		Defaulted Loans		Non-defaulted Loans		Difference Tests		
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	*t*-test	Likelihood Ratio	Pearson Chi-Square
Geographic Variables									
New England	0.03	0.17	0.13	0.34	0.03	0.47		0.000	0.000
Mid Atlantic	0.14	0.35	0.15	0.36	0.14	0.35		0.590	0.586
East North Central	0.08	0.26	0.15	0.36	0.08	0.26		0.000	0.000
East South Central	0.02	0.14	0.02	0.14	0.02	0.15		0.906	0.906
West North Central	0.04	0.19	0.02	0.15	0.04	0.19		0.102	0.131
South Atlantic	0.09	0.29	0.22	0.42	0.09	0.29		0.000	0.000
West South Central	0.08	0.27	0.06	0.24	0.08	0.27		0.287	0.303
Mountain	0.05	0.22	0.06	0.24	0.05	0.22		0.397	0.382
Pacific	0.47	0.50	0.17	0.38	0.47	0.50		0.000	0.000
New York City	0.03	0.16	0.01	0.10	0.03	0.16		0.021	0.045
Washington, D.C.	0.01	0.08	0.01	0.08	0.01	0.08		0.895	0.893
Avg. pct. price change in MSA, past 6 yrs.	−1.3	3.5	−1.6	2.7	−1.3	3.7	0.266		
Avg. pct. leased in MSA, past 6 yrs.	91.0	3.9	90.9	3.7	91.0	3.9	0.127		

Exhibit 3 | Logistic Regression Results for *DEFAULT*

	Model 1: All Variables		Model 2: Insignificant Variables Removed		Model 3: Walk Score 80 plus or 8 minus		Model 4: Without Walk Score	
	β (sig.)	Exp(β)	β (sig.)	Exp(β)	β (sig.)	Exp(β)	β (sig.)	Exp(β)
WALK SCORE	−0.018 (.000)	0.982	−0.018 (0.000)	0.982				
WALK SCORE * ln(*WALK SCORE*)								
WALK SCORE80+					−0.924 (0.000)	0.397		
WALK SCORE8−					0.792 (0.046)	2.208		
Loan								
OLTV	0.029 (0.000)	1.029	0.028 (0.000)	1.028	0.027 (0.000)	1.028	0.032 (0.000)	1.033
ODSCR	−1.120 (0.000)	0.326	−1.133 (0.000)	0.322	−1.100 (0.000)	0.333	−1.072 (0.000)	
ARM_FLAG	0.719 (0.000)	2.053	0.758 (0.000)	2.135	0.657 (0.000)	1.929	0.775 (0.000)	2.170
LOAN_AGE_MONTHS	−0.001 (0.301)	0.999						
Property								
NOCONCERNS	−0.892 (0.000)	0.410	−0.907 (0.000)	0.404	−0.879 (0.000)	0.415	−0.952 (0.000)	0.386
BUILT_YR	−0.016 (0.000)	0.984	−0.015 (0.000)	0.985	−0.018 (0.000)	0.982	−0.013 (0.000)	0.987
TOT_UNTS_CNT	−0.005 (0.000)	0.995	−0.005 (0.000)	0.995	−0.005 (.000)	0.995	−0.005 (0.000)	0.995
Neighborhood and City								
MEDHHINC000	−0.027 (0.000)	0.974	−0.029 (0.000)	0.972	−0.030 (0.000)	0.971	−0.027 (0.000)	0.974
PROP_CRIME_MIL	0.001 (0.011)	1.001	0.001 (0.001)	1.001	0.001 (0.000)	1.001	0.001 (0.002)	1.001
VACANCY_RATE	0.023 (0.008)	1.023	0.022 (0.006)	1.023	0.022 (0.008)	1.022	0.024 (0.004)	1.025
PRINCIPAL_CITY	0.313 (0.033)	1.368						
URBAN_RURAL	−0.154 (0.015)	0.858	−0.139 (0.024)	0.870				

Exhibit 3 | (continued)

Logistic Regression Results for *DEFAULT*

	Model 1: All Variables		Model 2: Insignificant Variables Removed		Model 3: Walk Score 80 plus or 8 minus		Model 4: Without Walk Score	
	β (sig.)	Exp(β)	β (sig.)	Exp(β)	β (sig.)	Exp(β)	β (sig.)	Exp(β)
Regional Economy								
TOP25CITY	−0.203 (0.239)	0.816						
DC	−1.057 (0.151)	0.347						
NYC	−0.731 (0.212)	0.457						
REGION	unreported		unreported		unreported		unreported	
AVG_PRICE_6	0.003 (0.857)	1.003						
AVG_PCT_LEASED_6	0.021 (0.185)	1.021						
Constant	25.926 (0.000)	1.82E+11	26.909 (0.000)	4.86E+11	32.318 (.000)	1.09E+14	20.288 (0.000)	6.47E+08

Notes: The number of observations is 36,922. For Model 1, model chi-square = 621.714, −2 log likelihood = 3,063.855, Nagelkerke R^2 = 0.176, and under ROC curve = 0.845. For Model 2, model chi-square = 606.523, −2 log likelihood = 3,079.046, Nagelkerke R^2 = 0.172, and under ROC curve = 0.841. For Model 3, model chi-square = 617.482, −2 log likelihood = 3,068.087, Nagelkerke R^2 = 0.175, and under ROC curve = 0.844. For Model 4, model chi-square = 582.323, −2 log likelihood = 3111.265, Nagelkerke R^2 = 0.164, and under ROC curve = 0.837.

10% of the time, which is the case for *DEFAULT* in the study sample (Hosmer and Lemeshow, 2000). So, we can say that for every one-unit increase in *WALK SCORE*, the relative risk of default declines by 1.8%. If, for example, the default rate for properties with a particular *WALK SCORE* was 0.9% (the mean for the sample), then according to Model 1, a one-point increase in Walk Score would decrease the risk of default from 0.90% to 0.88% (i.e., $0.90 \times (1 - 0.018)$).

Model 2 is the reduced version of Model 1. Insignificant variables are dropped to produce a more parsimonious model that achieves the best fit with the fewest parameters. Using irrelevant variables increases the standard error of the parameter estimates and reduces significance (Menard, 1995). Removing controls did not alter the coefficient or significance of *WALK SCORE*, indicating that its relationship with *DEFAULT* was unaffected by any relationships between *DEFAULT* and the variables that were eliminated for Model 2.

The goodness-of-fit statistics in Exhibit 3—model chi-square, −2 log likelihood, Nagelkerke R^2, and under ROC curve—measure how well all the explanatory variables in each model, taken together, predict *DEFAULT*. The higher the chi-square and the lower the −2 log likelihood, the better the model predicts *DEFAULT*. Comparing these statistics for Models 1 and 2 indicates that goodness-of-fit declines slightly as variables are removed, which normally occurs when variables are eliminated. Goodness-of-fit was also tested using the area under the receiver operating characteristic (ROC) curve. It measures a model's ability to discriminate between loans that do and do not default. It represents the likelihood that a loan that defaults will have a higher predicted probability than a loan that does not. If the result is equal to 0.5, the model is no better than flipping a coin. For all the models, ROCs were 0.83 to 0.85, indicating excellent discrimination (Hosmer and Lemeshow, 2000). In other words, all the models did an excellent job distinguishing between loans that did and did not default.

A degree of non-linearity in the logit was detected for *WALK SCORE* using the Box-Tidwell transformation. Following that approach, a multiplicative term in the form of *WALK SCORE* times the log-normal form of *WALK SCORE* was added to Model 2. Statistically significant interaction terms indicated that linearity may not be a reasonable assumption for *WALK SCORE*.

Two graphical methods were used to further investigate the shape of the nonlinear relationship between *WALK SCORE* and *DEFAULT*. In the first approach, 20 groups of cases were created using five-point increments of *WALK SCORE*. The average *WALK SCORE* for each group was then plotted against the average *DEFAULT* for each group. The result is shown in Exhibit 4, along with a third-order polynomial fitted line. The patterns showed two thresholds; one at a Walk Score of about 8, below which there was a marked increase in default risk, and one at a Walk Score of about 80, above which there was a marked decrease in default relative to the normal default rate of about 0.9%.

This first graphical method for investigating nonlinearity did not use control variables. In order to take the controls into consideration, the grouped smooth method suggested by Hosmer and Lemeshow (2000) was employed. First, the

Exhibit 4 | Default Rate vs. Walk Score

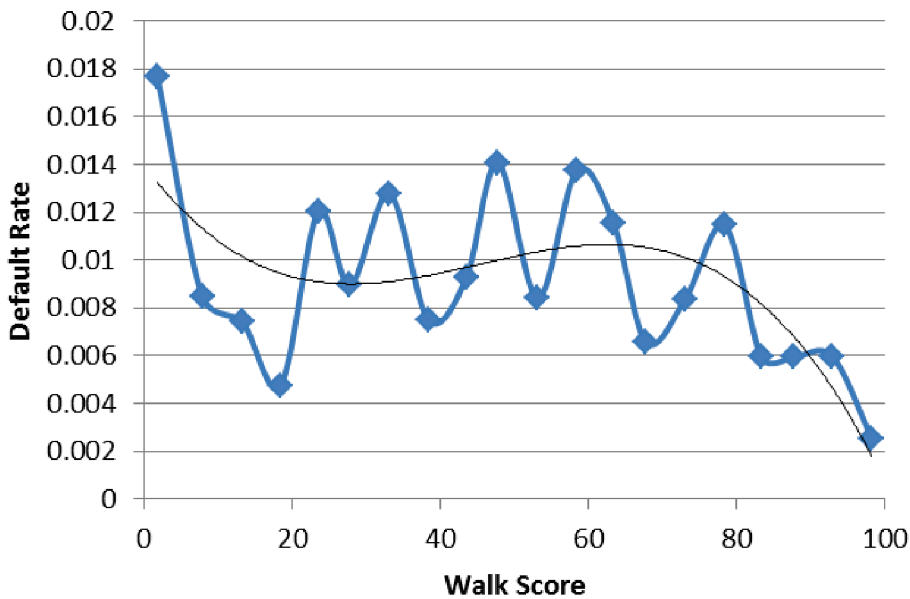
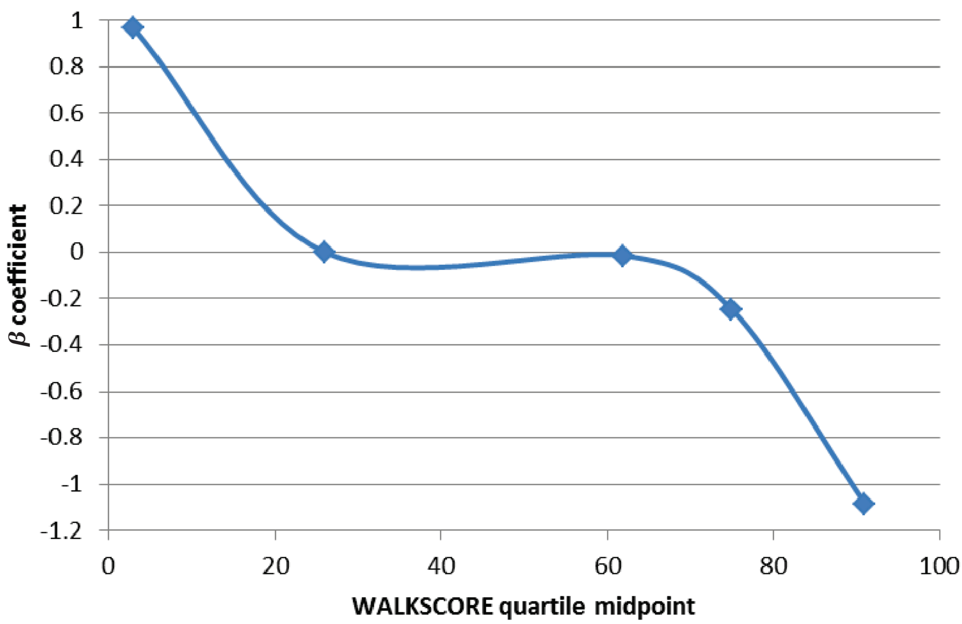


Exhibit 5 | Estimated Logistic Regression Coefficients vs. Quartile Midpoints

Range	Midpoints	β (sig.)
0–8	3	0.966 (0.019)
52–69	62	0.020 (0.888)
69–83	75	−0.222 (0.173)
83–100	91	−1.063 (0.000)

quartiles of the distribution of *WALK SCORE* were determined. Next, a categorical variable with four levels was created using the three cut-points based on the quartiles. An additional categorical variable was also created using 8 on *WALK SCORE* as the cut-point, in order to investigate the threshold of 8 found in the prior graphic analysis. Then, the multivariable model (Model 2) was refitted, replacing the continuous *WALK SCORE* variable with the four-level categorical variable and the dummy for 8 or less, using the lowest quartile as the reference group. The coefficients for each of the three categorical variables were then plotted against the midpoints for *WALK SCORE* in each of the groups. A coefficient equal to zero was also plotted at the midpoint of the first quartile. The resulting data and plot are given in Exhibits 5 and 6. The grouped smooth method confirmed that the relationship between *WALK SCORE* and *DEFAULT* was nonlinear while holding control variables constant. It also showed the existence of the previously discovered thresholds. As shown in Exhibit 5 and as indicated by the shape of the

Exhibit 6 | Grouped Smooth Method Chart



line in Exhibit 6, in the middle range of *WALK SCORE*, the coefficients were small and insignificant. This indicates that the middle range of *WALK SCORE* is unhelpful for predicting *DEFAULT*. However, at the lowest and highest levels the coefficients were larger and significant.

In an applied setting, cut-points can be more useful than continuous indicators because they allow a simple risk classification of cases into "high" and "low" and they communicate clearly the threshold above (or below) which risk will consistently be above (or below) average (Williams et al., 2006). In this case, thresholds could identify the cut-points for *WALK SCORE* above which default risk is consistently below average and below which it is consistently above average.

Using a method for finding optimal cut-points recommended by Williams et al. (2006), candidate cut-points were evaluated by comparing the default rates above and below each candidate *WALK SCORE* value and computing a *p*-value for the difference using the chi-square test. This method indicated that 80 was the most significant *WALK SCORE* cut-point at the upper level and 8 was the most significant at the lower level.

Based on this analysis, Model 3 was produced using dummy variables indicating whether or not a property had a Walk Score of 80 or more (*WALK SCORE80+*) or 8 or less (*WALK SCORE80−*). Model 3 had better goodness-of-fit statistics than Model 2, meaning that it did a better job predicting *DEFAULT* than the prior model that treated *WALK SCORE* as a continuous variable. (Recall that the lower

Exhibit 7 | Trade-off Experiments

	Model 3	Mean Case		Walk Score 80+ Case		Walk Score 8− Case	
Variables	β	Value	$\beta \times$ Value	Value	$\beta \times$ Value	Value	$\beta \times$ Value
WALK SCORE80+	−0.924	0.000	0.000	1.000	−0.924	0.000	0.000
WALK SCORE8−	0.792	0.000	0.000	0.000	0.000	1.000	0.792
OLTV	0.027	61.296	1.679	83.000	2.274	51.000	1.397
ODSCR	−1.100	1.518	−1.669	1.230	−1.353	2.010	−2.210
ARM_FLAG	0.657	0.309	0.203	0.309	0.203	0.309	0.203
NOCONCERNS	−0.879	0.286	−0.252	0.286	−0.252	0.286	−0.252
BUILT_YR	−0.018	1967.834	−35.421	1967.834	−35.421	1967.834	−35.421
TOT_UNTS_CNT	−0.005	94.643	−0.469	94.643	−0.469	94.643	−0.469
MEDHHINC000	−0.030	42.694	−1.276	42.694	−1.276	42.694	−1.276
PROP_CRIME_MIL	0.001	407.479	0.411	407.479	0.411	407.479	0.411
VACANCY_RATE	0.022	6.573	0.142	6.573	0.142	6.573	0.142
New England	0.836	0.031	0.026	0.031	0.026	0.031	0.026
ENCENT	0.612	0.076	0.046	0.076	0.046	0.076	0.046
SoAtlantic	0.924	0.093	0.086	0.093	0.086	0.093	0.086
Pacific	−1.045	0.469	−0.490	0.469	−0.490	0.469	−0.490
Constant	32.318		32.318		32.318		32.318
Sum of $\beta \times$ value			−4.665		−4.677		−4.696
Exp(sum)			0.009		0.009		0.009
1+ Exp(sum)			1.009		1.009		1.009
Predicted Probability Exp(sum)/1+ Exp(sum))			0.93%		0.92%		0.90%

the −2 log likelihood, the better the goodness-of-fit.) In Model 3, the Exp(β) for *WALK SCORE80+* was 0.397, indicating that when a property had a *WALK SCORE* of 80 or more, it had a 60.3% decrease in the odds of default (i.e., 0.397 less than 1). In terms of relative risk, we can say that the relative risk of default was 60.3% lower for the properties with a Walk Score above 80 than those below 80. Similarly, Exp(β) for *WALK SCORE8−* was 2.208, indicating that properties with Walk Scores of 8 or less had a 121% increase in the odds of default (i.e., the odds of default for properties with Walk Scores greater than 8 are multiplied by 2.208).

Model 4 was the final model produced in order to show that using *WALK SCORE* in the default model improved its goodness-of-fit. It includes the same variables as Model 3, except for *WALK SCORE80+* and *WALK SCORE8−*. Comparison of the goodness-of-fit statistics for Models 3 and 4 shows that goodness-of-fit was better for Model 3, when the Walk Score variables were in the model. That indicates that Walk Score can be used to improve our ability to predict default and discriminate between loans that do and do not default.

Conclusion

The hypothesis was that greater walkability, as measured by higher Walk Scores, reduces mortgage default risk. The results supported the hypothesis; however, the relationship was not linear. Instead, there were thresholds at Walk Scores of 8 and 80. Below 8, there was a significant increase in default risk and above 80 the risk significantly declined.

A key implication of this study is that walkability could be fostered by relaxing lending terms without increasing default risk. For example, in terms of the impact on default rate, Model 3 predicts that the risk of default would be 0.9% for a property with a *WALK SCORE* between 9 and 79 and average values on the other model variables. This includes an *OLTV* of 0.61 and an *ODSCR* of 1.52, which are the sample means. However, if *WALK SCORE* was 80 or more, the *OLTV* for the same average property could be increased to 0.83, the *ODSCR* could be reduced to 1.23 and the property would still have a predicted default risk of 0.9%, according to Model 3. Inversely, with a *WALK SCORE* of 8 or less, the loan terms would need to be tightened to an *OLTV* of .51 and an *ODSCR* of 2.01, according to Model 3, in order to produce a default risk of 0.9%. Figures for these scenarios are given in Exhibit 7.

If higher LTV ratios at origination could be obtained by borrowers on more walkable properties, they could achieve a higher return on their equity as long as positive leverage is possible (i.e., when the cost of debt financing as indicated by the mortgage constant is lower than the overall return generated by the property as indicated by the return on assets). They could also use the unused portion of their equity funds for other projects that could diversify their investment portfolios. All else being equal, more attractive loan terms could make walkable property investments more attractive to investors, increase capital flow to more sustainable buildings, and foster a transition toward more sustainable cities.

Walkability has several potential social and environmental benefits, not the least of which include improved public health and mitigation of global climate change and other environmental impacts linked to motorized transportation. Fortunately, as this paper shows, properties in highly walkable locations, as indicated by a Walk Score of 80 or more, can also reduce mortgage default risk by more than 60%. This means that lenders could be willing partners in the promotion of more walkable cities by offering better terms for walkable property investments without increasing the exposure by lenders to default risk.

Socially responsible property investing has been described as maximizing the positive effects and minimizing the negative effects of property investment on society and the natural environment in a way that is consistent with investor goals and fiduciary responsibilities (Pivo and McNamara, 2005). If it is possible to promote, as this study shows, social and environmental goals through greater walkability without increasing default risk, then it seems that ethical, responsible lenders should offer better terms for more walkable properties. It may even be possible to promote walkability while improving business outcomes. In that case, investment in walkable places is simply a smarter way of doing business.

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Green Office Buildings: A Qualitative Exploration of Green Office Building Attributes

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Abstract In this paper, we identify specific green building attributes important to tenants using a mixed-industry series of focus-groups in Chicago, Denver, Washington D.C., and the San Francisco Bay Area. The focus groups reveal the relative importance of green office building attributes and further explore the qualitative reasons for those rankings. Regional preferences were revealed through differing priorities of public transportation, indoor air quality, HVAC, and other attributes. Six out of the seven focus groups agreed that green building attributes were the most important for people, compared to the economic and environmental impact of the attributes. These focus group results provide the foundation for a future comprehensive survey of office tenants on their green building feature preferences.

Buildings have played an important role in human society throughout global history. The last 10–20 years have seen significant advances in sustainable building construction and management. Systems such as Leadership in Energy and Environmental Design (LEED) and ENERGY STAR have helped promote the adoption of these advances. We begin the process of moving beyond the current green building labels systems by asking: What sustainable building attributes are most important to tenants? Results are reported from a series of national focus groups, the first phase of a three-year long research project.[1] The focus groups provide a foundation for what building attributes are the most important to tenants and in what ways they are important.

Although the architectural design and the technology of building construction have evolved in different ways across regions, the fundamental functions of buildings have not changed. According to the U.S. Environmental Protection Agency (EPA) (2008), people in the United States spend about 90% of their time inside buildings. Additionally, U.S. buildings accounted for about 41% of the total U.S. energy consumption in 2010 (44% more than the energy consumption from transportation and 36% more than the industrial sector), while contributing 40% of the nation's total carbon dioxide emissions (U.S. Department of Energy, 2012). Florance, Miller, Peng, and Spivey (2009, 117) estimated that over 12 billion square feet of office space exist in the U.S., at a value of over $1.2 trillion, although this figure likely reflects all office space, of which newer, high-efficiency space is a subset.

Furthermore, the size of commercial building floor space is expected to increase by 33% by 2040 (U.S. EIA, 2013).

Part of the increasingly important role of buildings in urban society includes building construction, operation, and usage. Thus, the environmental impact of buildings has attracted attention from both researchers and policymakers (Khasreen, Banfill, and Menzies, 2009). Cole and Kernan (1996) examined the total lifecycle energy use of an office building and find the predominance of energy consumption in the operations stage of buildings. They suggested alternative designs to reduce operational energy consumption based on the assumption that energy use in buildings contributes many environmental burdens. In his recent popular book *Cubed: A Secret History of the Workplace* on the history of office space in the U.S., Saval (2014) demonstrates the changing trends in use of space, and it appears that the current trend toward open space plans is "back to the future" (i.e., a throwback to earlier open space bullpen plans from decades ago).

As a response to concerns about the environmental impact of buildings, there has been a movement towards green buildings, also called sustainable or high-performance buildings. According to the U.S. EPA (2008), a green building strives to maximize the efficiency of building resources, such as energy, water, and materials while minimizing building impacts on human health and the environment throughout the process of siting, design, construction, operation, renovation and reuse. The practice of green building emphasizes two elements of the building process: the efficient use of resources and the impact of buildings on the environment. In practice, green building adoption is driven by potential or realized costs savings, improved employee morale and/or productivity, and corporate social responsibility (CSR) objectives. These elements could be construed as profit, people, and planet in the context of a triple bottom line (Elkington, 1999).

The initiative of the green building movement has been driven by a wide variety of organizations around the world (Kibert, 2004). In the U.S., the U.S. Green Building Council (USGBC) has played an important role in developing green building practices by promulgating the LEED standards. In addition, state and local governments have been involved in the promotion of green building in various ways. At least 28 states have laws, executive orders, or grant programs requiring or encouraging LEED buildings in their state.[2] However, the broader market often interprets a LEED building certification as a package of attributes branded by an overall tier (LEED Silver, LEED Gold, etc.), which does not immediately reveal the presence or absence of specific green office building features. In fact, some state level pushback on LEED's specific bundle of attributes has occurred in several states, specifically with Alabama, Georgia, and Maine recently issuing executive orders that effectively prohibit LEED certification for state buildings.[3] The subject research findings, the first in a several year-long research program, aim to provide momentum to providing more detail on green office building features by collecting and reporting findings from market-driven data from office tenants.

In addition to policy-based efforts designed to promote green buildings, the private sector plays a critical role in driving both the supply-side and the demand-side of green buildings. On the supply side, building developers, owners and property managers, architects, and construction companies provide a variety of green building design and construction techniques to the market, making it attractive to private office tenants. On the demand side, tenants, mostly private companies, consider locating their offices in green buildings for various economic, productivity, environmental, and social benefits. Furthermore, commercial real estate brokers and agents provide services that include leasing and green building management practices. For instance, CBRE, one of the largest commercial real estate service businesses in the U.S., implements several programs in building operations that promote sustainability in the built environment, as well as through CBRE's ongoing academic research support (i.e. ''Real Green Research Challenge'').[4]

The final goal of the several-year research program, of which this current research is the beginning, is to create a green building index that ranks office buildings based on tenant's stated and revealed preferences for a building's specific green attributes. To develop the building blocks of this green building index, this research examines both the demand-side and the supply-side of green buildings.

On the demand-side, the focus groups are used to identify specific green building attributes important to tenants. These findings will be used to conduct green building tenant surveys to further understand tenant perspective on green buildings and occupant behavior. On the supply-side of green buildings, data on actual office building lease data acquired from CBRE will also be incorporated. In the broader context of this research, this paper focuses on the demand-side approach. The results from 48 participants from seven focus groups in four U.S. cities are summarized here.

Several preliminary insights are gained through the focus group process on green building attributes. First, potentially different regional preferences are revealed across different U.S. geographies. Second, while much of the research has focused on profit-oriented topics, these focus groups suggest that people-oriented benefits are the most important. This may inform future research prospects in the sustainable arena.

In addition, the single online focus group, performed through a webinar and conference call, provided similar insights to the in-person focus groups, and this format may provide a viable alternative for future qualitative research. Furthermore, the initial results indicated that both green ''evangelicals'' and green ''doubters'' are few and far between. The vast majority of participants appreciate the benefits of green buildings but feels that cost-benefit analysis should inform the implementation choice.

In the following section, previous studies on green buildings are reviewed, by focusing on empirical studies that examine the impact of green building attributes on office building rental prices and property values. In the next section, we describe the process of conducting seven focus groups in different cities. In the following section, the focus group results are summarized in two parts: the first subsection reveals the extent to which the green building attributes are relevant to the triple bottom line categories of "profit," "people," and "planet" (PPP), while the second addresses the importance of each green building attribute from a tenant perspective. We conclude with a discussion and interpretation of the study's main findings regarding the identification of specific green office building features.

Literature Review

There have been various researchers that suggest economic, environmental, and social benefits accrue to owners and occupants of green buildings. They discuss how green buildings provide benefits to one or more stakeholders through several mechanisms including but not limited to lower relative operating costs, improved occupant well-being, and/or productivity, tax incentives, and/or market goodwill (Fuerst and McAllister, 2011). Kok, Miller, and Morris (2012) find that LEED-certified buildings have a 7.1% rental premium compared to non-certified buildings. Additionally, their study demonstrates that buildings have a marginally greater rental premium when buildings have both a LEED certification and an ENERGY STAR label. Fuerst and McAllister (2011) also examine the price differentials between LEED and ENERGY STAR rated commercial buildings as compared to non-rated buildings in the U.S. They report a rental premium of 5% for LEED-certified buildings and 4% for ENERGY STAR-labeled buildings. Furthermore, they also find a price premium of 25% for LEED buildings and 26% for ENERGY STAR buildings, with higher levels of certification providing a higher premium. Additionally, Wiley, Benefield, and Johnson (2010) find a rental premium of 17% for LEED buildings and 8% for ENERGY STAR-labeled buildings by conducting a two-stage simultaneous regression analysis.

Many commercial building tenants also consider buildings as an avenue for communicating environmental achievements and outcomes. In an older study, Wood (1991) documents how some tenants reflect an attitude that green building is "the right thing to do." Carrying this theme forward, Eichholtz, Kok, and Quigley (2009) discuss corporate social responsibility (CSR) in terms of the social benefits from green buildings. Furthermore, certain public policy offers office building developers, owners, and/or tenants the opportunity to earn financial benefits from tax credits and/or tax deduction programs, as well as other policy-based preferences or incentives (Fuerst and McAllister, 2011).

A growing number of studies demonstrate the positive relationship between green office building attributes and employee productivity. Loftness et al. (2003) summarize 15 case studies analyzing changes in productivity based on building improvements. The study reveals that improved indoor air quality increases productivity by 0.5% to 11%. The same study also finds that better access to daylight in office space leads to productivity increases of 5% to 15%. Miller, Pogue, Gough, and Davis (2009) conduct a survey of over 500 tenants who moved from conventional buildings to either LEED or ENERGY STAR-labeled buildings. They report that about 54.5% of the total respondents agree that employees are more productive after moving into green-certified space. Additionally, Delmas and Pekovic (2012) survey about 10,000 employees and find that private companies that have adopted green practices and/or standards achieve up to 16% higher productivity, compared to companies that have not adopted the standards.

A complicating factor with green office buildings is the split incentive dynamic whereby the lease structure governs who achieves economic benefits from green buildings as it pertains to the building owner or the building tenants. As an example, tenants may benefit from reduced utility operating expenses found in many green buildings based on the existence of a triple net lease structure whereby tenants pay all utility costs. Under the same scenario, building owners benefit from a full service gross lease structure whereby the owner pays all utility costs as part of the base rent. In this context, we paper discuss the importance of lease structure in green building studies.

In addition to the empirical studies that investigate the impact of green buildings on economic, environmental, and social sectors, several researchers examine the effect of public policies on green building market penetration. Simons, Choi, and Simons (2009) discuss how public policies affect the green building market in different ways. They finds that executive orders are a quicker method for encouraging green buildings, while legislative-based efforts are prone to political posturing and similar motivations.

Considering the research content of published studies, there is a lack of research that focuses on the specific attributes of green buildings and their effect(s) on market behavior. In this paper, we examine various green office building attributes from a tenant perspective.

Sample Plan for Focus Groups

The main purpose of the focus groups of office market participants from Chicago, Denver, Washington D.C., and the San Francisco Bay Area[5] was to identify specific green office building attributes and then determine their relative impact on real estate markets and beyond. As a secondary goal, focus group participants were used to help refine an online survey instrument in varying degrees of completion.[6]

The initial Chicago focus group was designed to create a list of green attributes applicable to tenants. The Denver and D.C. focus groups resulted in refining a hard-copy version of the survey instrument, and the Bay Area group pre-tested the online version of the near-final survey.

The selection of focus group cities was intended to broadly represent regions in the U.S.: East Coast, Midwest, Mountain West, and California. All participants were invited to attend by CBRE. Focus group participants consisted of office building tenant representatives, developers, building managers, and commercial real estate brokers and researchers. Exhibit 1 shows the percentage of focus group participants.

The focus groups were conducted between December 2013 and May 2014. Each focus session was led jointly by the co-principal investigators. In addition to the

Exhibit 1 | The Proportion of Focus Group Participants

Project Management	Tenant Representatives	Developer / Architect / Engineer	Building Management	CBRE Brokers	Valuation / Research	Total
21%	26%	14%	12%	18%	10%	100%

Note: the average number of focus group participants was 7 for each group. The number of observations is 48.

focus group members, David Pogue, Global Director of Sustainability for CBRE, attended each session. In many cases, CBRE employee participants also acted as green facilitators in each metropolitan area, attending both morning and afternoon focus group sessions. However, facilitator survey results were only counted in aggregate participation once.

Two different focus group formats were used. The first three city sets were conducted in person, on site, in a CBRE conference room. Participants were not provided with any materials beforehand except an agenda. To maximize returns on the travel budget, two 2-hour morning and afternoon sessions were held, with different participants. The order of activities included introductions all around, identification of specific green office building features, prioritization of the importance of those features, determining their PPP (profit, people, planet) priorities, and feedback on the current version of the survey instrument.

The focus group in the fourth city (Bay Area) covered the same items, but in a different format. First, it was a webinar format, including a separate dial-up for audio, and a shared live screen managed by one of the PIs. Secondly, an online version of the entire survey was sent to all participants beforehand, and their results were recorded. A secondary goal of this focus group was to see if the different format yielded qualitatively similar results (which it did). Future research, beyond the scope of the current research, is planned to include virtual discussions, and this test supports the assertion that virtual discussions are a viable alternative to an in-person format (Reid and Reid, 2005).

Each of the four geographic regions had diverse participants in the focus groups. Participants included members of several functional groups, and included contributors from a broad variety of companies. Due to confidentiality considerations, specific companies (outside of the project sponsor, CBRE) cannot be disclosed, but an overview of the roles and expertise represented from a variety of companies in the focus groups is provided.

Project management, which included experts in tenant improvements, LEED design, and building operations, composed approximately 21% of our 48 respondents. Representatives of building tenants, the primary focus of the forthcoming survey, are roughly 26% of the participants. Although higher tenant representation throughout would have been preferred, convincing tenants without direct involvement in the project to donate several hours of their time proved challenging. By the last focus group (Bay Area), the majority of participants were tenants, since a secondary focus was to assess the efficacy of the tenant-oriented online survey. A group broadly defined as developers, architects, and engineers made up 16% of focus group participants. Building managers, whose primary role is to run day-to-day operations on a building level constituted 14%. Leasing brokers, who were a mix of tenant representative brokers and building sale/ brokers, were another 18%. Valuation, appraisal, and research professionals made up the remaining 11%.

Overall perspectives on green buildings varied throughout the groups. The bulk of the participants expressed the view that green buildings provided some value, and most stated in some form that they valued environmental benefits. Most participants seemed to balance and consider economic advantages with sustainability benefits. Each session included a discussion of who benefits from energy savings, and members examined the direction of cash flow when evaluating green features.

A few green ‘‘evangelists’’ were present, and they typically voiced opinions that more should be done to advance sustainable buildings, educate tenants, and reduce carbon footprints. On the other side, some highly economically-driven participants suggested that many of the green expenditures are wasteful, and that tenants only pay for locational attributes and direct building amenities. However, these extremes were the minority.

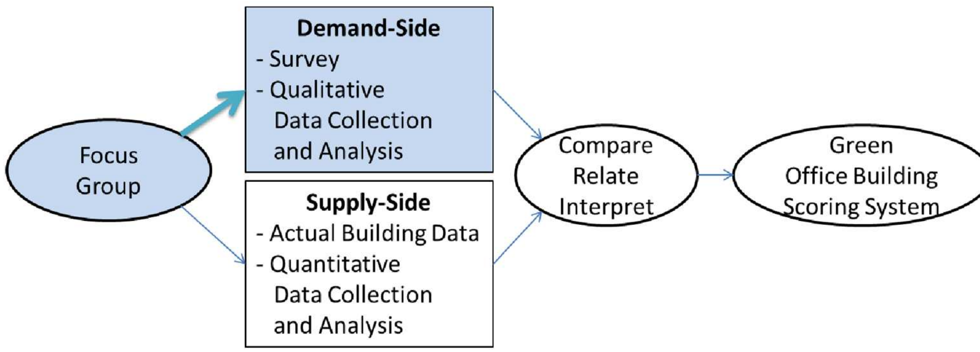
In a broader context of this research, the focus groups are designed to be used for extensive survey research on the tenants’ perspectives on green office building attributes. Exhibit 2 shows the comprehensive research design and process. Within this research process, we summarize the findings from focus groups, which are the initial stage of the overall research process.

Focus Group Results

The Triple Bottom Line (Profit, People, and Planet)

We initially examined how green building attributes are considered by office building tenants in terms of economic, social, and environmental benefits. Each sector is called ‘‘profit,’’ ‘‘people,’’ and ‘‘planet,’’ (PPP) respectively, in this study. The basic concept of the triple bottom line was coined by Elkington (1999). The triple bottom line consists of economic and environmental factors and social equity. The category ‘‘profit’’ is defined as economic values created by a green building attribute. More specifically, the economic values are considered to be manifested in return to the tenant firm’s financial bottom line. The category ‘‘people’’ is defined as social benefits from a building attribute and a tenant’s employees’ satisfaction with their working environments. The category ‘‘planet’’ is defined as environmental benefits from a specific green building attribute. Collectively, the three categories are defined as the triple bottom line of green buildings.[7]

Exhibit 2 | The Broader Context of the Research Process



The focus group participants were asked what sector was most relevant to each green building attribute. Their responses were coded into three categories that range from 0 (least relevant) to 2 (most relevant). For example, when participants agreed that the access to public transportation was "most" relevant to "people" in terms of the benefit from the attribute, the category "people" was coded as "2." Additionally, when they agreed that the public transportation access was also relevant to "planet" in terms of the benefit to an environmental sector, the planet category got one point. On the other hand, if the green building attribute was not relevant to the profit sector, the category was just coded as "0." Participants were asked about each green attribute in terms of the level of relevance to the triple bottom line. In Exhibit 3, we summarize the perspectives of participants on the triple bottom line. Appendix 1 shows these results in more detail.

As summarized in Exhibit 3, among the participants, green building attributes were collectively considered to be most relevant to the category "people." In other words, participants ($N = 48$) jointly believed that green buildings primarily bring more benefit to people, compared to economic (profit) and environmental benefits (planet). This finding was different from the research team's expectation that green buildings would be perceived to be more beneficial to the tenant firm and landlord's economic position.

When looking at each green building attribute separately, access to public transportation and the temperature control in a building received the highest score of 2.0 for the category "people" among the 10 most common green building attributes. The pooled consensus of participants indicated that people (the tenant firm's employees) prioritized access to public transportation and a temperature control system.

LEED designation, an efficient HVAC system, and the type of lease structure were the three highest ranked green building attributes that were perceived to bring more economic benefits. Main factors for the planet were efficient water use, LEED designation, and water use. This finding corresponds to the results of many previous studies that show the positive impact of LEED designation on building values and rental prices.

Exhibit 3 | Triple Bottom Line of the 10 most Common Green Building Attributes

Green Building Attribute	Profit	People	Planet
Public transportation (within 5 min. walk)	0.6	2.0	1.1
Natural light	0.7	1.9	0.3
Temperature control / comfort	1.0	2.0	0.2
LEED designation	1.3	0.8	1.5
Efficient HVAC	1.4	0.7	0.9
Lease structure rewards green behavior	1.3	0.7	0.4
Efficient lighting	0.7	1.3	0.8
Recycling (bulbs, paper, toner, solid waste)	0.7	0.7	1.7
Indoor air quality	0.2	1.8	0.4
Efficient water use	1.2	0.0	1.8
Average score ($N = 48$)	0.9	1.2	0.9

Notes: The table only shows the 10 most common green building attributes. Appendix 1 contains the full results. Scores range from 0 (not relevant) to 2 (most relevant). "Profit" refers to a tenant's and landlord's financial bottom line. "People" refers to a tenant's employees. "Planet" refers to general environmental issues.

Exhibit 4 | Triple Bottom Line Across Focus Groups In Different Cities

Focus Group	Profit	People	Planet	Sample
DC 1	1.0	1.5	0.9	8
DC 2	0.8	1.6	1.0	3
Denver 1	0.4	1.4	1.0	10
Denver 2	1.0	1.6	0.5	8
Chicago 1	1.0	0.9	0.7	6
Chicago 2	1.1	1.4	0.6	6
Bay Area	0.8	1.0	0.8	7
Average	0.9	1.3	0.8	6.9

Notes: These results, while interesting, are based on different mixes of various real estate professionals in each market. The total number of observations is 48. Scores range from 0 (not relevant) to 2 (most relevant).

Exhibit 4 shows the findings of triple bottom line analysis in different regions. Most participants agreed that green buildings were most important for people, except for the first participants in the first Chicago focus group. Although collectively the first Chicago focus group weighted green buildings as more important for economic profits, compared to social benefits, there was only a slight difference between the two categories. Bay Area participants also ranked people as the biggest winner in the green arena.

Exhibit 5 | Focus Group Results from D.C. Group 1

Green Attribute	A	B	C	D	E	F	G	H	Count	Ave. Rank
Public transportation (within 5 min.)	3	2	2	1	2	2	1	3	8	2.0
Natural light	5	4		3	1	3	3	2	7	3.0
Temperature control / comfort		5	5		4	4	4	5	6	4.5
Efficient HVAC	1	3		2		5			4	2.8
Efficient lighting	2		4					1	3	2.3
Open space layout			1				2	4	3	2.3
Floor plate size / depth			3		5	1			3	3.0
LEED designation		1							1	1.0
Column spacing					3				1	3.0
Bike racks				4					1	4.0
Lease structure rewards green behavior	4								1	4.0
Green roof				5					1	5.0
Recycling (bulbs, paper, toner, solid waste)							5		1	5.0

Notes: A–H represent the 8 respondents. Count (high numbers better) is the number of respondents who ranked each attribute in the top 5. Average rank (smaller numbers better) gives the relative weights of each green attribute. Ranks range from 1 (most important green attribute) to 5 (least important green attribute).

Importance of Green Building Attributes from a Tenant Perspective

In addition to the triple bottom line analysis, all the participants were asked which green building attributes are considered most important from a tenant's perspective.[8] The research team made the list of green building attributes based on the participants' responses, then asked them to rank each attribute from 1 (most important green attribute) to 5 (least important attribute).[9] Unranked attributes were considered unimportant.

As an example, in Exhibit 5 we summarize the results from the Washington D.C. morning focus group. They responded that access to public transportation was the most important green building attribute, with an average score of 2, and this attribute was ranked by every respondent. This result in part reflects the regional characteristic that the Metro subway system connects most office building nodes in D.C. The importance of natural light in buildings was highly rated by that same focus group, ranked by 7 out of 8 respondents.[10] See Appendices 2–7 for all other focus group results.

The first Denver focus group was the biggest focus group among the seven groups in terms of the number of attendees who fully participated.[11] The participants consisted of office building tenants, building managers, and commercial real estate brokers. Unlike the results from D.C., the importance of indoor air quality and natural light in a building were most valued by the Denver participants. Among 10 participants, 9 agreed that the indoor air quality was the most important green building attribute. In addition, 5 out of 8 participants gave a high score to the indoor air quality in another Denver focus group.

In addition to the findings summarized above, several more key themes emerged from the focus group discussions. Several tenants (a mix of decision makers and office managers) stated that a building's green status did not factor into their decision to lease. They said that location and proximity to transit were the leading factors. However, most expressed that being in a green building was a "bonus." While several brokers echoed that green buildings are not often high on the wish list for tenants, they almost universally agreed that green buildings are easier to market. So even if it is not high on a tenant's priority list, it appears that a green designation may help to market and distinguish a building.

Anecdotally, a small number of tenants said that their company was "green," and that they had to be in green buildings. This sentiment was supported by brokers and project managers who indicated that they have some clients who felt that way, but that they were the distinct minority. A tenant broker relayed a story that the leasing representative for a large nationally recognized company was unfamiliar with the LEED Existing Building (LEED EB) designation, suggesting a potential disparity in company priorities for green.[12]

Multiple tenants indicated that they believe productivity increased subsequent to moving into a green building. One tenant said, they "achieved things we didn't expect to," regarding a surprising reduction in sick days and perceived increase in productivity.

A couple of focus groups define trends as changing. Participants argued that it was more common to espouse green attributes in 2006–2007, in a more robust economy. Conversely, because of tighter budgets, companies are less willing to pay for green features today (2014).

The idea that leasing decisions "will just come down to dollars" or "cost is always the driver" was echoed throughout the sessions. Developers said that tenants often do not realize the up-front costs of building infrastructure.

Regionally, some distinct differences appear to be evident. For example, Chicago participants, adjacent to one of the Great Lakes, seemed largely unconcerned with water savings. Although all the urban-based focus groups express value on mass transit, the Denver groups placed a relatively higher import on access to transit stops. In the Bay Area, public transit was less important, while electric car charging stations were raised as a desired attribute. In Washington D.C., the current building standard for all new buildings is LEED Silver, simultaneously impressing a regional importance for green buildings, while diluting a potential market premium for green buildings.

Distilling judgments from 48 focus group participants (seven focus groups in all four cities), Exhibit 6 shows the final list of green office building attributes with counts (frequencies) and average rankings.

Exhibit 6 | Combined Focus Group Results from 48 Participants

Green Office Building Attribute	Count (Frequency)	Ave. Ranking
Access to natural light in work space	42	2.5
Public transportation (within 5 min. walk)	31	2.5
Indoor air quality	36	3.0
Temperature control / comfort	31	3.1
Efficient lighting system	26	3.5
Efficient electrical and gas use for heating and cooling	30	2.7
Open space layout	11	2.8
Lease structure rewards green behavior	10	1.6
Shower on-site	10	4.0
Water conservation	8	3.0
LEED designation	8	3.4
Recycling provided on-site	12	3.8
Outdoor amenities	5	3.6
Green cleaning	6	3.8
Floor plate size / depth	3	3.0
New / fresh / young / cool	2	2.0
Green roof	2	4.0
Column spacing	1	3.0
Bike racks	1	4.0

Notes: The maximum count number is 48, and a higher number means the attribute is more important. Ranks range from 1 (most important) to 5 (least important), so a lower number means that attribute is ranked as more important. This exhibit takes only the top five selections from the Bay Area to maintain attribute feature compatibility between groups.

The four most popular green office building features were people-oriented: natural light, convenient public transportation, good indoor air quality, and temperature control (which may not necessarily be green if it raises heating and cooling costs). Efficiency items were next: cost-effective HVAC and lighting, with a lease structure that rewards green tenant behavior (e.g., a triple net lease). Other items were lower-ranked, reflecting less universal support of common items like bike racks, recycling, and water conservation. A LEED certification itself was in the middle of the pack, with an ENERGY STAR designation not making the list at all.

Conclusion

In this paper, we attempt to fill a research gap by identifying specific green office building attributes that are important to tenants rather than existing market bundles. Mixed-industry focus groups are used to identify the relative importance of various attributes and the qualitative reasons for those rankings. The research team conducted seven focus groups in four cities: Chicago, Denver, Washington D.C., and virtually in the San Francisco Bay Area.

The focus groups reveal both regional differences and the similarity of participants' perspectives on green building features. With respect to differences, participants from D.C. express a preference for access to public transportation as the most important green building feature, whereas in the Bay Area, this is a low priority. Indoor air quality and access to natural light in a building are highly valued by the Denver and Washington D.C. participants. On the other hand, efficient HVAC systems and triple net tenant lease structure receive the highest score from the Chicago participants.

In terms of the regional similarities, most focus groups agree that green buildings are most important for people. Although the first Chicago focus group participants discuss that green building attributes are more important for the category of economic ''profits,'' compared to ''people,'' there is only a slight difference between the two categories: the category ''profit'' received a score of 1.0 while ''people'' received a score of 0.9.

The finding that ''People'' take precedence over ''Profit'' in green building qualitative value measures may demonstrate an increased understanding regarding the potential productivity benefits of green buildings. Much of the extant research focuses on the expense or revenue at the building level, while this finding suggests more research should be considered at an employee productivity level. Continuing research into tenant preferences should examine whether measures often associated with productivity, like natural light, dominate willingness-to-pay measures of rent.

Summarizing the attribute preferences of the national focus groups into the final list of green office building attributes, the top features (benefiting mostly people/employees, and then cost savings for the tenant firm) are as follows: natural light, convenient public transportation, good indoor air quality, temperature control, cost-effective HVAC, cost-effective lighting, and lease structure that rewards green tenant behavior. Surprisingly, LEED certification itself was in the middle of the pack, with an ENERGY STAR designation not making the list at all.

A caveat on the research design: the results are based on a non-random sample, and contain a mix of tenants, building managers, leasing agents, and other real estate professionals. Although all participants were specifically directed to focus their statements on what tenants would want, our findings may not necessarily be generalized to a population of real estate professionals or tenants. Nevertheless, the focus group participants' collective insights as presented provide texture into the preferences of office tenants and real estate professionals about green office building features. A list of prioritized items for further study and future research can also be extrapolated from these results.

Our list of green office building attributes and accompanying definitions and terminology is being used for more extensive survey research that we are administering to a population of over more than 3,000 office building tenants in 400 buildings in 17 major U.S. markets during 2014. After collecting the survey data on office building tenants, the survey results will be merged with the actual building lease data from the same tenants, from CBRE. Finally, both the demand-side and the supply-side data on green office buildings will be compared to develop a green office building scoring system. The subject research guides the terminology used to address tenant priorities in this future tenant demand study.

This paper presents the ranked building attributes from a series of national focus groups, revealing both regional and national preferences. It shows that participants believe people to be the most important aspect of the triple bottom line in the context of green building benefits. As future researchers explore the direct economic benefits and the perceived qualitative benefits of green buildings, this research may serve as a launching point for attribute discussion and qualitative assessments.

Appendix 1

Comprehensive Results of Triple Bottom Line (PPP) Analysis

Green Building Attribute	City-Session	Ave. Score	Profit	People	Planet
Public transportation (within 5 min)	DC-am	2.0	1	2	1
Natural light	DC-am	3.0	1	2	1
Temperature control / comfort	DC-am	4.5	1	2	0
Efficient HVAC	DC-am	2.8	2	1	1
Efficient lighting	DC-am	2.3	2	1	1
Floor plate size / depth	DC-am	3.0	0	2	0
Open space layout	DC-am	2.3	2	2	1
Bike racks	DC-am	4.0	0	2	1
Column spacing	DC-am	3.0	1	2	0
Green roof	DC-am	5.0	0	2	1
Lease structure rewards green behavior	DC-am	4.0	2	0	1
LEED designation	DC-am	1.0	1	1	2
Recycling provided on-site	DC-am	5.0	0	1	2
Average (DC-am)			1.0	1.5	0.9
Public transportation (within 5 min)	DC-pm	1.3	0	2	2
Lease structure rewards green behavior	DC-pm	1.5	2	0	1
Efficient HVAC	DC-pm	3.0	1	2	1
Natural light	DC-pm	3.5	1	2	0
Efficient lighting	DC-pm	4.0	1	2	1
Green roof	DC-pm	3.0	0	2	2
Outdoor amenities	DC-pm	4.0	0	2	0
Efficient water use	DC-pm	5.0	1	0	2
Temperature control / comfort	DC-pm	5.0	1	2	0
Average (DC-pm)			0.8	1.6	1.0
Green cleaning	Denver-am	5.0	0	1	2
Efficient HVAC	Denver-am	3.3	0	2	0
Indoor air quality	Denver-am	2.7	−1	2	1
LEED designation	Denver-am	4.5	1	0	2
Efficient lighting	Denver-am	2.8	0	2	0
Natural light	Denver-am	2.5	1	2	1
Open space layout	Denver-am	2.3	2	1	0
Public transportation (within 5 min)	Denver-am	3.1	0	2	1
Recycling provided on-site	Denver-am	3.7	−1	1	2
Temperature control / comfort	Denver-am	3.0	1	2	0
Efficient water use	Denver-am	3.5	1	0	2
Average (Denver-am)			0.4	1.4	1.0

Appendix 1 (continued)

Comprehensive Results of Triple Bottom Line (PPP) Analysis

Green Building Attribute	City-Session	Ave. Score	Profit	People	Planet
Green cleaning	Denver-pm	3.0	1	1	2
Indoor air quality	Denver-pm	4.0	0	2	0
Efficient HVAC	Denver-pm	2.0	2	0	1
LEED designation	Denver-pm	4.0	2	1	1
Efficient lighting	Denver-pm	4.0	1	2	0
Natural light	Denver-pm	1.3	1	2	0
New / fresh / young / cool	Denver-pm	3.0	0	2	0
Public transportation (within 5 min)	Denver-pm	4.3	1	2	1
Temperature control / comfort	Denver-pm	1.7	1	2	0
Outdoor amenities	Denver-pm	3.7	1	2	0
Workout / showers	Denver-pm	3.6	1	2	0
Average (Denver-pm)			1.0	1.6	0.5
Lease structure rewards green behavior	Chicago-am	1.3	2	1	1
Efficient HVAC	Chicago-am	3.3	1	0	2
Natural light	Chicago-am	3.4	0	1	0
Interior air quality	Chicago-am	3.8	0	1	0
Efficient water use	Chicago-am	1.5	1	0	2
Public transportation (within 5 min)	Chicago-am	2.0	1	2	1
Recycling provided on-site	Chicago-am	3.0	2	1	1
Efficient lighting	Chicago-am	4.0	0	1	0
Open space layout	Chicago-am	4.5	2	1	0
Average (Denver-pm)			1.0	0.9	0.7
Public transportation (within 5 min)	Chicago-pm	2.0	1	2	1
Natural light	Chicago-pm	2.8	1	2	0
Lease structure rewards green behavior	Chicago-pm	1.3	1	0	0
Indoor air quality	Chicago-pm	3.3	1	2	1
Efficient lighting	Chicago-pm	4.6	1	2	0
Open space layout	Chicago-pm	3.0	1	2	0
Workout / showers / bike racks	Chicago-pm	4.0	0	2	1
Temperature control / comfort	Chicago-pm	2.0	1	2	1
Efficient HVAC	Chicago-pm	3.0	2	0	1
Efficient water use	Chicago-pm	4.0	2	0	1
Average (Denver-pm)			1.1	1.4	0.6
Public transportation (within 5 min)	Bay Area	4.0	0.6	1.9	1.1
Natural light	Bay Area	1.6	0.7	1.9	0.3
Temperature control / comfort	Bay Area	3.0	1.0	2.0	0.2
LEED designation	Bay Area	4.0	1.3	0.8	1.5
Efficient HVAC	Bay Area	3.0	1.4	0.7	0.9
Efficient lighting	Bay Area	3.7	0.7	1.3	0.8
Recycling provided on-site	Bay Area	4.0	0.7	0.7	1.7
Indoor air quality	Bay Area	2.0	0.2	1.8	0.4
Efficient water use	Bay Area	2.0	1.2	0.0	1.6
Average (Bay Area)			0.9	1.2	0.9
Average (Combined)			0.9	1.2	1.0

Note: Some Denver respondents felt two attributes, recycling and indoor air quality, may have negative utility (e.g., costs more), hence the negative values above.

Appendix 2

Focus Group Results from D.C. Group 2

Green Attribute	A	B	C	Count	Ave. Rank
Public transportation (within 5 min)	2	1	1	3	1.3
Lease structure rewards green behavior	1		2	2	1.5
Efficient HVAC	3		3	2	3.0
Natural light		2	5	2	3.5
Efficient lighting	4	4		2	4.0
Green roof		3		1	3.0
Outdoor amenities			4	1	4.0
Water conservation	5			1	5.0
Temperature control / comfort		5		1	5.0

Notes: This focus group also discussed 12 more green building attributes, but all the participants did not score the 12 attributes. (The 12 attributes are bike racks, captured runoff, green cleaning products, green furnishings, green materials in construction, indoor air quality, insulation and windows, LEED designation, open space layout, operable windows, recycling of bulbs, paper, toners, and solid waste, and window shades.) Ranks ranges from 1 (most important green attribute) to 5 (least important green attribute).

Appendix 3

Focus Group Results from Denver Group 1

Green Attribute	A	B	C	D	E	F	G	H	I	J	Count	Ave. Rank
Indoor air quality	2	1	4	4		5	5	1	1	1	9	2.7
Temperature control / comfort	5		1	5	3	3		2	2		7	3.0
Public transportation (within 5 min)	4	5		2	1	2			4	4	7	3.1
Natural light	3			1	2		1	3		5	6	2.5
Efficient lighting		2	2			4			3	3	5	2.8
Open space layout	1			3	4	1					4	2.3
Efficient HVAC			5				2	4		2	4	3.3
Recycling (bulbs, paper, toner, solid waste)		3	3						5		3	3.7
Water conservation		4					3				2	3.5
LEED designation					5		4				2	4.5
Green cleaning								5			1	5.0

Note: Ranks range from 1 (most important green attribute) to 5 (least important green attribute).

Appendix 4

Focus Group Results from Denver Group 2

Green Attribute	A	B	C	D	E	F	G	H	Count	Ave. Rank
Natural light	1		1	1	1	1	3		6	1.3
Temperature control / comfort	2	1	2		2	2	1		6	1.7
Shower on-site	4			3	3	4	4	5	6	3.8
Indoor air quality	5		5	4			2	4	5	4.0
Outdoor amenities		4		2	5			3	4	3.5
Public transportation (within 5 min)			4	5	4			3	4	4.0
Green cleaning		3					5	1	3	3.0
LEED designation	3	5						2	3	3.3
Efficient lighting			3			5		2	3	3.3
Efficient HVAC		2						1	2	1.5
New / fresh / young / cool						3		1	2	2.0

Note: Ranks range from 1 (most important green attribute) to 5 (least important green attribute).

Appendix 5

Focus Group Results from Chicago Group 1

Green Attribute	A	B	C	D	E	F	Count	Ave. Rank
Efficient HVAC	5	3		2	1	2	5	2.6
Natural light	2		2	4	5	4	5	3.4
Lease structure rewards green behavior	1	2	1			1	4	1.3
Interior air quality	4		3	5	3		4	3.8
Efficient water use				1	2		2	1.5
Public transportation (within 5 min)		1				3	2	2.0
Recycling (bulbs, paper, toner, solid waste)				2	4		2	3.0
Efficient lighting	3					5	2	4.0
Open space layout		5	4				2	4.5

Note: Ranks range from 1 (most important green attribute) to 5 (least important green attribute).

Appendix 6

Focus Group Results from Chicago Group 2

Green Attribute	A	B	C	D	E	F	Count	Ave. Rank
Natural light	2	3	4	4	2	2	6	2.8
Public transportation (within 5 min)	3	1	1	1	4		5	2.0
Efficient lighting	5	4	5	5		4	5	4.6
Indoor air quality	1	5	2			5	4	3.3
Lease structure rewards green behavior		2			1	1	3	1.3
Open space layout				3		3	2	3.0
Workout / Shower on-site / bike racks			3		5		2	4.0
Temperature control / comfort				2			1	2.0
Efficient HVAC					3		1	3.0
Efficient water use	4						1	4.0

Note: Ranks ranges from 1 (most important green attribute) to 5 (least important green attribute).

Appendix 7

Focus Group Results from Bay Area

8-2. Please rank these 8 green building attributes you selected as most important in the previous question from 1 to 8, with 1 as the most important

	Rank from 1st to 8th							
Attributes	1st	2nd	3rd	4th	5th	6th	7th	8th
Indoor air quality	3	1	2	0	1	0	0	0
Access to natural light in my work space	2	3	0	0	0	0	0	0
Efficient electrical and gas use for heating and cooling (HVAC)	1	1	1	3	0	0	0	1
Temperature control	1	1	1	1	1	0	0	0
Energy efficient lighting	0	0	2	0	1	1	1	1
Recycling provided on-site	0	0	1	1	1	0	0	2
LEED Designation	0	0	0	1	0	1	1	1
Public transportation nearby (within 5-minute walk)	0	0	0	1	0	2	1	0
Water conservation (e.g. low flush toilet and flow-restricted water in showers)	0	1	0	0	0	1	2	0
Green cleaning products used on-site	0	0	0	0	1	1	1	0
Fitness facility on-site	0	0	0	0	1	0	1	0
Lease structure that financially rewards tenant conservation of resources	0	0	0	0	0	1	0	1
Shower on-site	0	0	0	0	1	0	0	1
Bike racks at building	0	0	0	0	0	0	0	0
Energy Star designation	0	0	0	0	0	0	0	0
Green roof	0	0	0	0	0	0	0	0

Note: Although the format is slightly different from the other six focus groups, this is what appeared on screen for the respondents to comment on. This set of focus group results is sorted by the top ranked feature, rather than count. The resulting order of attributes would be almost identical, with only natural light and efficient lighting moving around two positions at the top of the order.

Endnotes

1 This research project is sponsored by CBRE, Inc. as part of their Real Green Research Challenge.

2 Per legislative overview document from USGBC provided to researchers, the states are: Arkansas, Colorado, Connecticut, Florida, Hawaii, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maryland, Massachusetts, Nevada, New Jersey, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Utah, Virginia, Washington, and Wisconsin.

3 See Alabama Executive Order 39, April 11, 2013. Georgia Executive Order August 10, 2012. Maine Executive Order No 27 FY 11/12, December 7, 2011.

4 See http://www.cbre.com/o/international/RGRCEN/Pages/Home.aspx.

5 Representatives were primarily from San Francisco, Palo Alto, and San Jose.

[6] The survey went over ten sets of changes and refinements, and was approved by the authors' University Institutional Review Boards.

[7] For future research, we plan to break the profit component into landlord profit and tenant company profit to examine more closely the incidence issues of who benefits from installation of green features. This came after the Bay Area session, where we asked the question separately. For the purpose of this paper, both these categories are reported as "Profit."

[8] While focus groups were repeatedly asked to answer questions from a tenant perspective, the researchers recognize that the answers likely include some mix of personal respondent perspective, along with the tenant perspective. Also, participants suggested that office managers could effectively represent tenant decisions makers; this finding is lately corroborated in a large national survey where no statistical difference is found between decision maker responses and other staff responses (Robinson, Simons, Lee, and Kern presented at the African Real Estate Society Conference, 2014).

[9] The Bay Area group was asked to rank attributes from 1 to 8. This was done in order to see how far we could stretch the participants to make judgments. They were all able to satisfactorily provide the data.

[10] The participants in the first D.C. group also discussed three additional green attributes that are important for building tenants' decision making: green building education, shower on-site, and water conservation.

[11] The Bay Area focus group had a few more people, but not all were able to successfully complete the online survey in advance.

[12] Alternatively, it may suggest an inability of the broker/tenant/owner to understand how to communicate a LEED EB designation, rather than being indicative of a company's priorities.

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