

Dynamics of Green Rentals over Market Cycles: Evidence from Commercial Office Properties in San Francisco and Washington DC

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Abstract This study examines the rental rate dynamics of green commercial office properties in the San Francisco and Washington DC metropolitan areas. We match the list of U.S. Green Building Council (USGBC)-certified commercial office properties in the two areas with property-level temporal and non-temporal data derived from USGBC and CoStar for the period 2007:Q1 to 2010:Q1. We find that, similar to previous studies, green office properties enjoy rental rate premiums over comparable non-green buildings. However, we also find the premiums to be dynamic instead of constant. Our models suggest that green property rents may provide a hedge in down markets.

Recognition of the adverse effects of urban sprawl, changing consumer preferences, and a heightened awareness of environmental concerns has contributed to the growth of the green building design and construction movement in the United States. Nelson (2007) suggests that public concern about global warming, the environment, and sustainability have provided a major impetus to the increased activity in this realm. For example, the number of commercial office building applications filed for Leadership in Energy and Environmental Design (LEED) labeling,¹ awarded by U.S. Green Building Council (USGBC), has increased substantially in recent years—from less than 50 in 2000 to above 8,000 in 2009 according to January 2010 USGBC data. Another source of demand for green commercial office properties comes from U.S. government agencies who, in 2000, built 42% of all commercial office properties that were candidates for USGBC green labeling.

The literature establishes a “premium” on various performance measures that green (or “Eco-labeled”) properties enjoy over their non-green counterparts. For example, Fuerst and McAllister (2009) used OLS and quantile regression models to conclude that LEED-labeled and ENERGY STAR-labeled offices have 8% and 3% higher occupancy rates respectively while controlling for age, height, building class, and quality. Dermisi (2009) analyzed a dataset of 351 buildings across 36 states gathered during 2009 using OLS, maximum likelihood spatial error regression and fixed effects regression methods, and finds that the ENERGY STAR designation increases the market and assessed values of office properties substantially. The effect of LEED ratings is also a function of geographic

aggregation. Similarly, Eichholtz, Kok, and Quigley (2009), Miller, Pogue, Gough, and David (2009), and Fuerst and McAllister (2011) establish a premium on rental rates and sale prices enjoyed by green buildings compared to similar non-green counterparts. However, most of these studies are cross-sectional in nature and overlook the variations over time. Our study examines how the rental rate premium varies over time in a dynamic market cycle. In addition, we focus on LEED-certified buildings rather than broader based “eco-labeled” buildings. Our analysis suggests that the green premium is higher during down markets compared to up markets. The results are robust when we perform a cross-sectional analysis of three specific quarters. In addition, we find leasing activity and vacant area to be significant predictors of the rental rate of green properties. To our knowledge, these variables have not been recognized as determinants of rental rates in any other study.

The additions from our study to the body of knowledge are as follows. Green rental premiums are dynamic and vary across market cycles. Green rental office properties may offer a hedge to owners in down markets due to an increased premium. Total leasing activity, rental rate change in the previous quarter, and vacant square footage are significant explanatory variables for the hedonic modeling of green rentals. Real estate analysts, lenders, and corporate real estate professionals dealing in green commercial office properties may be able to make a more accurate estimate of future rental patterns. This may not be true for comparable non-green properties.

The remaining paper is organized as follows. We begin with a survey of literature that has two parts: literature on green buildings and literature on rental rate modeling. The literature synthesis is followed by a description of the data. In the third section, we discuss the research procedures, which are followed by the fourth section in which we empirically analyze the data and present the results of the analysis. The fifth section concludes.

Literature Review

Green Properties

Empirical studies examining the financial performance of green buildings are a relatively new paradigm of academic research, primarily the result of historical data paucity. Thus, several researchers had to resort to the typology of “eco-labeled” properties as compared to “green” properties. A number of studies have established the distinction between the rental rate (or value) pattern of green properties compared with those of non-green properties including Miller, Spivey, and Florance (2008), Eichholtz, Kok, and Quigley (2009), and Fuerst and McAllister (2009, 2011).

Wiley, Benefield, and Johnson (2008) and Dermisi (2009) conclude that LEED certification has a strong positive effect on a property’s assessed value and market value. Wiley, Benefield, and Johnson (2008) and Fuerst and McAllister (2009) also find that green buildings enjoy higher occupancy rates. Jackson (2009)

concludes that LEED-labeled and ENERGY STAR-rated buildings yield very high internal rates of return (IRR) and that the probability of a lower IRR for such buildings is very low. However, Jaffee, Stanton, and Wallace (2010) contend that the ENERGY STAR label does not contribute to property prices after controlling for key asset pricing factors of expenses, income, and capitalization rates.

The boundary between “green” and “energy-efficient” buildings has been blurred in several studies, as LEED- and ENERGY STAR-certified properties are treated equally as “green” or “eco-labeled.” While ENERGY STAR certification is primarily based on the criteria of energy efficiency, the LEED-certified buildings offer additional efficiencies such as water efficiency, waste reduction, environmentally preferred materials, sustainability, etc. Thus, LEED-certified buildings fulfill the criteria of resource efficiency as defined by the U.S. Environmental Protection Agency (EPA).² In this study, we focus on LEED-labeled properties which, we argue, is a closer proxy for “green” properties as opposed to a more generic group of “eco-labeled” properties.

The paradigm of green real estate research has enjoyed international exploration. For example, Brounen and Kok (2010) found that, in the Netherlands, homebuyers are willing to pay a premium for homes that are labeled as more energy efficient, or “green.” Alternatively, Yoshida and Sugiura (2011) study 1,504 projects in Tokyo between 2002 and 2010 and report that green condominiums are priced 5%–10% lower as the higher maintenance costs are capitalized by the buyers. Chegut, Eichholtz, and Kok (2010) analyze the 78 BREEAM³-certified offices in the United Kingdom and report a 16%–20% premium on the rental rates of eco-certified properties. Deng, Li, and Quigley (2011) analyze 36,512 transactions in the Singapore housing market and conclude that the “Green Mark⁴” labeling offers a 4% premium on the price. In Australia, IPD (2011) reports that the “Green Star⁵”-labeled properties offer a 400 basis point spread on the return and a negative 40 basis point cap rate spread with respect to non-labeled properties.

These studies generally establish green real estate as a financially advantageous proposition. However, this broad notion of financial benefits is less than adequate for prudent investment decisions. The understanding of variables that drive changes in the property market rental rates and thus values is posited to be critical (Geltner and Mei, 1995). So far, little attention has been paid to the determinants of rental rate variability in green real estate. Our research argues that the rental rates of green properties may be driven in part by a different set (or, at least, a different set of relative effect sizes) of variables. Also, there is no strong reason to believe that the rental premium of green buildings remains the same across different stages of market cycles. Understanding the variation of the premium over market cycles is therefore critical for investment decisions.

Rental Rate Modeling

Case and Shiller (1989) contend that price movement in individual properties is not sufficiently explained by market-wide factors. Plazzi, Torous, and Valkanov (2008) suggest that the cross-sectional differences in property characteristics can affect rental rate changes, even if market-wide economic shocks propagate

uniformly across the properties. A large amount of research has examined the effects of cross-sectional variables on the rental rate of real property. Dunsen and Jones (1998) establish the physical characteristics of the building, locational features, and contract terms as prime determinants of rental rates. Clapp (1980) finds that taller buildings enjoy higher rental rate premiums. Slade (2000), however, finds a quadratic relationship such that rents increase at a decreasing rate with respect to floor height. Shilton (1994) finds that building height and size are highly correlated. Frew (1988), Sivitanidou (1995), Bollinger and Ihlanfeldt (1998), and Fuerst and McAllister (2009) identify building age as a strong predictor, such that rental rates diminish with building age. Clapp (1980), Brennan and Colwell (1984), Colwell and Sivitanidou (1995), Trefzger (1998), and Slade (2000) advocate a log-linear [$\ln(\text{Rent}/\text{SF})$] model for rental rates while regressing rental rates against a set of independent variables (e.g., lease term, location, distance from a landmark, etc.). Fuerst and McAllister (2009) include some novel continuous and indicator independent variables (e.g., lease type, lot size, geographic coordinates, asking rent, etc.) in studying the occupancy rate of eco-labeled buildings.

In most rental rate studies, the set of explanatory variables has differed depending on the study. Although these studies provide insights about the determinants of rental rates in terms of building characteristics, most of them are cross-sectional in nature. Thus, they do not describe the amount of variability defined by time-based explanatory variables including vacant area and leasing activity. In addition, the existing body of knowledge lacks studies that explore whether the pattern of rental rate change is uniform across properties of varying temporal and non-temporal characteristics. In other words, we did not find any studies that explore the determinants of rental rate change over time as a function of the physical characteristics of offices, as well as time-based variables such as vacant square feet and leasing activity. Moreover, most of the studies examining rental rate dynamics are more than ten years old. The increasing popularity of green buildings along with the recent availability of sufficient green building data make this study timely and relevant.

Data and Methodology

We examine the rental rate dynamics of green commercial office properties in the San Francisco and Washington DC areas using data derived from USGBC and CoStar for the period 2007:Q1 to 2010:Q1 (Exhibit 1). The choice of the property-type and the locations are driven by several factors. Green labeling has been more popular among commercial office properties as opposed to some other property types such as residential.⁶ Thus, selecting commercial offices as the property type affords us a larger sample size. In addition, explanatory variables of our models require the attributes of a property to be collected from two different sets of data, namely, CoStar and the USGBC. We chose San Francisco and Washington DC because they offer the largest sample of green rental office buildings that are also identifiable by us in the CoStar data set. The matching of the properties in the two data sets is a tedious, manual process. We conducted the matching process

Exhibit 1 | Summary of the Characteristics of the Sample Properties

	Min.	Max.	Mean
Panel A: Green Property Quarters (2010:Q1)			
Total gross rent (\$/sq. ft./yr.)	12.00	75.52	36.56
Number of stories	2	48	11.00
Year built	1924	2009	1998
Washington DC	60%		
Downtown	15%		
Panel B: Non-Green Property Quarters (2010:Q1)			
Total gross rent (\$/sq. ft./yr.)	12.00	155.82	37.00
Number of stories	2	48	9.36
Year built	1924	2009	1990
Washington DC	61%		
Downtown	19%		

Notes: This table describes the green properties included in our analyses and the criteria on which the control sample of non-green properties was selected.

for 10 leading metros based on the number of green office properties as suggested by the USGBC data set. Metropolitan areas other than the two included in our sample offered a smaller number of matched green properties, particularly early in the sample. The final dataset consists of property information collected from the two metropolitan areas yielding a combined 53 green office properties (60% from Washington DC), with an average rental rate of \$36.56/sq. ft./year. These properties were built between 1924 and 2009 and ranged in height from 2 to 48 floors. We apply these green building characteristics as constraints in the CoStar database to obtain a control sample of similar but “non-green” properties, and select 70 of these properties as a control group. In order to maintain a balance of total number of properties from the two metros, we select a larger number (i.e., 60%) of the control sample properties from San Francisco. In total, we have an aggregate of 123 unique office properties, providing a total of 1,256 property-quarter observations.

The dataset is further stratified into various sub-samples based on their green status or across time for robustness checks. The data are divided into four samples: panel data (including all available properties-quarters) and cross-sectional data (for three individual quarters: 2007:Q4, 2008:Q4, and 2009:Q4). We collect rental data on commercial office properties in the San Francisco market and the Washington DC Metropolitan Statistical Area for the time period between 2007: Q1 and 2010:Q1. Rental rates and property-specific characteristics are obtained from CoStar. As the rental rate data from CoStar are available on a quarterly basis only and the event of earning green status by a property may fall in the middle of a quarter, we assign

the green status to a property if the date of the awarding of the green status falls in the first half of a quarter. The CoStar database is a repository of information for both temporal and non-temporal property-specific attributes. Moreover, it also provides rich aggregated information at the metro area level. An examination of the overall metro area data allows us to label each quarter as an “up market” or “down market,” depending on the direction of average market rental rate change with respect to the previous quarter.

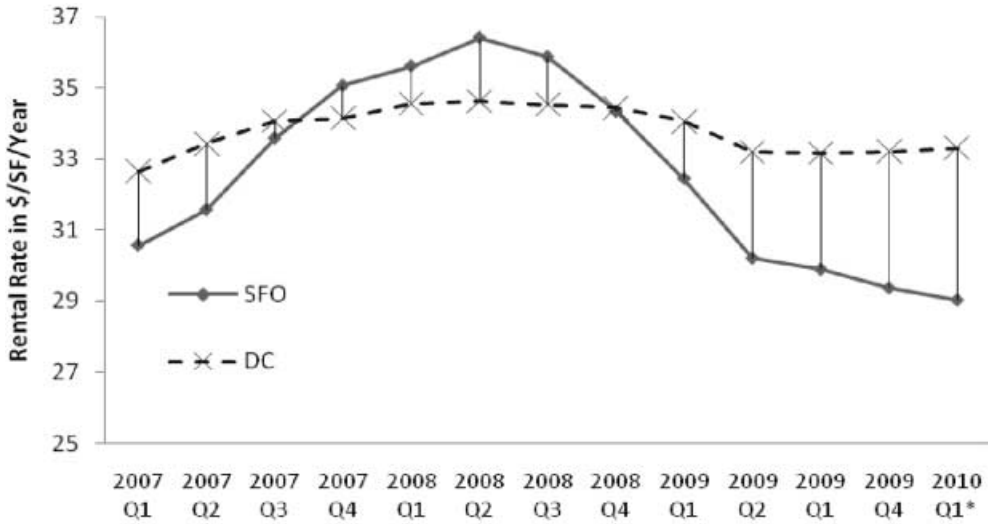
Exhibit 2 suggests that the metro-area wide trends in San Francisco and Washington DC differed slightly. Therefore, in our sample, the market conditions (“up” vs. “down” markets) can vary by both time and location. To analyze the quarterly change in the rental rate of a property, we need the rental rate data on a property in at least two consecutive quarters. This leads to a reduction in our sample size as a property’s rental data is available on CoStar for those quarters only when it was listed for rent. However, for these “valid” quarters of interest, CoStar provides sufficient data on our variables of interest, such as vacant square feet and leasing activity. In addition, several fixed effect variables, such as number of stories and age, are also made available by CoStar.

Not all quarters of a “green” property qualify as green since they might not have been labeled as green by USGBC in that quarter. Our unit of analysis is property-quarters as opposed to property. This allowed us to assign different “green” (versus “non-green,” through an indicator variable) status to a property based on the time period.

Variables

We focus on the effects of “green” status on the change in rental rates across time. However, as discussed earlier (Case and Shiller, 1989), the dynamics of this change may not be satisfactorily explained by market-wide factors only, suggesting the inclusion of idiosyncratic characteristics of office properties. These characteristics exhibit both cross-sectional and temporal variations requiring “panel” analysis. Although fragmented, the extant literature provides useful insights into the research questions that are central to this paper. Varying perspectives adopted by earlier studies assisted us in identifying a comprehensive approach towards answering our research questions. In addition to introducing some new explanatory variables in our model (such as leasing activity, vacant square feet, etc.), we also include the variables established by the existing literature (e.g., building age, size, height, and location). A number of variables are highly correlated, such as downtown location and parking ratio, leasable area and building height, etc. Because we are employing temporal data, the “time” variable is also included in our random-effects model to control for the inflation effect. The existing literature also provides insights into the functional form of the relationship that the independent variables share with the dependent variable. Thus, we include log-linear transformations of rental rate, leasing activity and vacancy and quadratic forms of building age and height. We also derive insights from the literature for transforming the new variables introduced by us in the model, such as leasing activity.

Exhibit 2 | Total Gross Rent of Commercial Properties Averaged Quarterly over Metropolitan Level in Washington DC and San Francisco



Panel Data

Earlier real estate studies have addressed similar research questions analyzing panel data sets. Bourassa, Haurin, Haurin, Hoesli, and Sun (2009) analyze time series data from three cities to estimate the price increase of individual properties with respect to the market. They find that if market conditions change, then the property characteristics affect the price path relative to the market. Plazzi, Torous, and Valkanov (2008) modeled the dispersion of rental growth rate as a time series over the cross section of metropolitan areas and conclude that negative economic shocks have a larger effect on cross-sectional dispersion.

The idiosyncratic cross-sectional features of the properties have mostly been recognized as responsible for “unobserved” heterogeneity in the fixed-effects models. As in most studies, these characteristics have not been recorded; the analysis of differences over time in price (rental rate in our case) has been analyzed to remove the unobserved effects from the model. Among others, Case and Quigley (1991) recommend the method proposed by Bailey, Muth, and Nourse (1963) where the fixed property characteristics are standardized with reference to themselves confining the analysis to properties those that have been repeatedly sold. Repeat sales in such studies are analogous to repeat listings in our study. This solution can be understood as in Equation (1):

$$\text{Let } R_{it} = \beta_o + \sum_{j=1}^{j'} \beta_j X_{jit} + \sum_{k=1}^{k'} \beta_k Z_{ki} + \delta t + \varepsilon_{it}, \tag{1}$$

where R is the rental rate of a property, indexed by time t and property i . X_j is the j^{th} temporal (time-dependent) characteristic of the property, Z_k is the k^{th} cross-sectional characteristic of the property, δ is the effect of time, and ε_{it} is a disturbance term assumed to satisfy the usual regression model. Considering the previous equation, we can explain the rental rate at time $(t - 1)$ as follows:

$$R_{i(t-1)} = \beta_o + \sum_{j=1}^{j'} \beta_j X_{jit(t-1)} + \sum_{k=1}^{k'} \beta_k Z_{ki} + \delta(t - 1) + \varepsilon_{i(t-1)}. \quad (2)$$

Subtracting Equation (2) from Equation (1), we find:

$$\Delta R_{it} = \sum_{j=1}^{j'} \beta_j \Delta X_{jit} + \delta + \varepsilon_{it} - \varepsilon_{i(t-1)}. \quad (3)$$

It is evident from Equation (3), that the unobserved effects may be eliminated from the regression model by analyzing the difference. The first difference fixed effect model eliminates the issue of “unobserved heterogeneity” from the model caused by the limitations of the dataset. Dougherty (2007) discusses some other issues with such models. First, the intercept term (β_o), which is fixed for individual properties, disappears from the model. Second, several degrees of freedom are lost while differencing the rental rate of two consecutive terms.⁷ Third, if the disturbance term ε_{it} satisfies the regression model assumptions, the differencing may give rise to autocorrelation due to the $\{\varepsilon_{it} - \varepsilon_{i(t-1)}\}$ term (on the contrary, if ε_{it} itself is subject to autocorrelation, the first difference estimator could be acceptable). Further, the interpretation of such models is limited to only those explanatory variables that are temporal in nature. In other words, the effects of non-temporal characteristics of a property are discounted while analyzing the change over time. For example, the model remains silent about the effect of variation in height (or age, location, and so on) on the change in their rents (or prices) over time. On the contrary, it may be possible that, say, the rents of taller buildings rise (or fall) faster over time. Dougherty (2006) explains the benefits of using “Random Effects Regression” in order to include the non-temporal effects in the model. The Random Effects model provides a capability to apply regression to the model without having to eliminate the non-temporal effects; and the equation is similar to Equation (1).

In our analyses, we start with the first difference models followed by random effect models. In the latter case, however, we treat the quarterly rental rate level as the dependent variable instead of the change in rental rate over a quarter. Due to the availability of cross-sectional characteristics of office buildings, we include the non-temporal characteristics of the office buildings from our sample in the

model. We, therefore, analyze our model both ways (i.e., including and excluding the non-temporal characteristics independent variables).

Empirical Analysis

We examine multiple models and multiple samples to study the effects of green buildings on rental dynamics. We begin the analysis with a first difference model. First, we find the effect of green status (vs. absence of it) on the rental rate changes over time through a statistical randomization approach. This allows us to include a richer set of independent variables in our model, keeping them uniform over our subsamples made up of green and non-green properties. Second, we explore the first difference model of the rental rate, controlling for the “green” attribute through sampling. That is, we split our sample of first differences into two subsamples of green and non-green properties. Due to the constant nature of the change (over time) of the “green” dummy variable in the subsamples, we lose the interaction term leading to Model Ib.

The First Difference Model

Model Ia

$$\Delta \text{LnTGR}_{it} = f(\Delta \text{UpMarket}_t, \Delta \text{LnTGR}_{i(t-1)}, \Delta \text{LnTLA}_{it}, \Delta \text{LnVac}_{it}, \Delta \text{Green}_{it}, \Delta \text{UpMarket}_t * \text{Green}_t).$$

Model Ib

$$\Delta \text{LnTGR}_{it} = g(\Delta \text{UpMarket}_t, \Delta \text{LnTGR}_{i(t-1)}, \Delta \text{LnTLA}_{it}, \Delta \text{LnVac}_{it}).$$

Where Δ signifies the change in a variable with respect to the previous quarter. *Green* and *UpMarket* are indicator variables denoting the green status (= 1 if a property is green) and the up-market scenario (= 1 if the average market rent in the sample increased from the previous quarter). *TGR* is total gross rent (\$/sq. ft./yr.), *TLA* is total leasing activity (sq. ft.), and *Vac* is total property vacancy (sq. ft.) in a given quarter.

ΔV_{it} signifies the quarterly change in the variable *V*, from the $(t - 1)$ quarter to the (t) quarter for property *i*. To examine differential performance, we divide our first-difference sample into three groups of properties-quarters: data points with (1) both consecutive properties-quarters designated as green, (2) no consecutive properties-quarters designated as green, and (3) only the latter properties-quarters designated as green signifying the transition from non-green to green. In these analyses, we omit the green status indicator variable (and, thus, its interaction with the up-market indicator variable) for the sake of intuitive comparison between the three groups; this results in two models (Ia & Ib) for the first-difference regression.

*Random Effects Model**Model II*

$$\begin{aligned} \text{LnTGR}_{it} = & h(\text{Green}_{it}, \text{DC}_i, \text{UpMarket}_t, t, \text{LnTGR}_{i(t-1)}, \text{LnTLA}_{it}, \\ & \text{LnVac}_{it}, \text{YrBlt}_i, \text{Stories}_i, \text{Stories}_i^2, \text{Downtown}_i, \\ & \text{Green}_{it} * \text{UpMarket}_t), \end{aligned}$$

where i and t index individual properties and time (quarter) respectively; and

Green_{it} = 1 if the property is LEED certified; 0 otherwise;

DC = 1 if the property is located in Washington DC; 0 otherwise;

UpMarket_{it} = 1 if the market trend of the metro area is witnessing an up-market; 0 otherwise;

t = Time period in quarters such that 2001:Q1 = 1, 2009:Q4 = 2, and so on;

TGR_{it} = Total gross rent in \$/sq. ft./year;

LnTLA_{it} = Natural log of total leasing activity in sq. ft.;

LnVac_{it} = Natural log of total vacancy in sq. ft.;

YrBlt_i = The year in which the property was first built (indicating its age);

Stories_i = Number of stories in the property;

Downtown_i = 1 if the property i is located in the downtown; 0 otherwise; and

$\text{Green}_{it} * \text{UpMarket}_{it}$ = 1 if the property is classified as green and in an up market.

Results*First Difference Models*

The first-difference model eliminates the non-temporal explanatory variables from Model Ia. To further examine the differences across green and non-green property-quarters, we control for the green status through sampling in Model Ib. The descriptive statistics for the three groups are shown in Exhibits 3–4.

As the Exhibit 3 suggests, the data points for the green property-quarters have a generally even distribution of up-market (56%) and down-market scenarios. In our sample, the quarterly rental change of green properties has ranged between -36% ⁸ and 40% .⁹ On an average, the quarterly rental change has been 0.07% .¹⁰ Exhibit 4 suggests that the proportion of properties going through a transition in the market cycle over two consecutive quarters ($\Delta\text{UpMarket} \neq 0$) is almost half (48%) while the remaining portion belongs to the properties that did not witness any

Exhibit 3 | Descriptive Statistics for the First-Difference Model of the Data Points Wherein Both Consecutive Quarters are Designated as “Green”

	<i>N</i>	Min.	Max.	Mean	Std. Dev.
$\Delta \ln TGR$ (Dependent)	126	-0.44	0.47	0.001	0.08
$\Delta \ln TGR_{(t-1)}$	126	-0.44	0.77	0.001	0.10
$\Delta \ln TLA$	126	-11.51	11.51	-0.64	5.16
$\Delta \ln Vac$	126	-1.01	1.08	0.004	0.18
		Freq.	Percent		
$\Delta UpMarket \neq 0$	70	55.6			

Notes: “ Δ ” signifies the change in a variable with respect to the previous quarter. *TGR*, *TLA*, *Vac*, and *UpMarket* represent the total gross rent (\$/sq. ft./yr.), total leasing activity (sq. ft.), total vacancy (sq. ft.) and up-market indicator (= 1 when the market exhibits upward trend from the previous quarter) respectively of a properties in a quarter. Data collected from a sample of those properties which were designated as green in two consecutive quarters from the San Francisco and Washington DC markets for the period between 2007:Q1 to the date of data collection in 2010:Q1.

Exhibit 4 | Descriptive Statistics for the First-Difference Model of the Data Points Wherein Neither of the Two Consecutive Quarters are Designated as “Green”

	<i>N</i>	Min.	Max.	Mean	Std. Dev.
$\Delta \ln TGR$ (Dependent)	1,069	-0.53	0.57	-0.003	0.10
$\Delta \ln TGR_{(t-1)}$	1,069	-1.27	1.15	0.01	0.15
$\Delta \ln TLA$	1,069	-11.90	11.99	-0.02	5.61
$\Delta \ln Vac$	1,069	-11.46	11.72	0.13	2.23
		Freq.	Percent		
$\Delta UpMarket \neq 0$	512	47.9			

Notes: “ Δ ” signifies the change in a variable with respect to the previous quarter. *TGR*, *TLA*, *Vac*, and *UpMarket* represent the total gross rent (\$/sq. ft./yr.), total leasing activity (sq. ft.), total vacancy (sq. ft.) and up-market indicator (= 1 when the market exhibits upward trend from the previous quarter) respectively of a properties in a quarter. Data collected from a sample of those properties which were designated as green in two consecutive quarters from the San Francisco and Washington DC markets for the period between 2007:Q1 to the date of data collection in 2010:Q1.

Exhibit 5 | Descriptive Statistics for the First-Difference Model of the Data Points Wherein a property Transitions from “Non-green” Status to “Green” Status

	N	Min.	Max.	Mean	Std. Dev.
$\Delta \ln TGR$ (Dependent)	38	-0.39	0.21	-0.01	0.08
$\Delta \ln TGR_{(t-1)}$	38	-1.25	0.69	-0.04	0.25
$\Delta \ln TLA$	38	-10.58	10.99	0.25	5.13
$\Delta \ln Vac$	38	-0.20	0.47	-0.01	0.10
	Freq.	Percent			
$\Delta UpMarket \neq 0$	12	31.6			

Notes: “ Δ ” signifies the change in a variable with respect to the previous quarter. *TGR*, *TLA*, *Vac*, and *UpMarket* represent the total gross rent (\$/sq. ft./yr.), total leasing activity (sq. ft.), total vacancy (sq. ft.) and up-market indicator (= 1 when the market exhibits upward trend from the previous quarter) respectively of a properties in a quarter. Data collected from a sample of those properties which were designated as green in two consecutive quarters from the San Francisco and Washington DC markets for the period between 2007:Q1 to the date of data collection in 2010:Q1.

changes to the market cycle. Comparing this data with the green properties (Exhibit 3) suggests that in our sample, on average, while the green rentals appreciated by 0.07% on quarterly basis, the non-green properties actually witnessed a negative change of 0.03%.¹¹

Exhibit 5 suggests that the 38 properties that changed their status from non-green to green in our sample actually saw the rental rates shrink by 0.8% on average. For the properties-quarters undergoing a transition from non-green to green status, the overall sample size is small. Moreover, the first difference of market-scenario (up-market) is an under-represented variable.

Exhibit 6 describes the results of the first-difference models (Ia and Ib) with $\Delta \ln TGR$ as the dependent variable. The model (Ia) with the complete panel data is statistically insignificant and explains only 0.02% of the variability. The regression analyses (Model Ib) when run separately for non-green and transition properties also turn out to be insignificant. However, despite a relatively smaller sample size (125), our hedonic model for green office rentals (Exhibit 6) is substantially more efficient ($R^2 = 18.9\%$) compared to all other first-difference models. Moreover, only the green sample yielded statistically significant explanatory variables.

It is evident that the first-difference model is meaningful only when applied to green properties. All temporal variables (total leasing activity, total vacancy, and quarterly rental change in the previous quarter) pertaining to green properties in a quarter are statistically significant. As expected, changes to the rental rate in green properties are significant and positively related to changes in the leasing

Exhibit 6 | First Difference Regression Model

	Model Ia	Model Ib		
	All Properties	Green Properties Only	Non-Green Properties Only	Transition Properties Only
δ	-0.002 (0.391)	0.002 (0.722)	-0.003 (0.334)	-0.01 (0.477)
$\Delta Green^e$	-0.006 (0.697)	N/A	N/A	N/A
$\Delta UpMarket_t$	-0.001 (0.878)	0.007 (0.685)	-0.001 (0.884)	0.02 (0.567)
$\Delta Green * UpMarket$	0.002 (0.905)	N/A	N/A	N/A
$\Delta LnTGR_{(t-1)}$	-0.004 (0.818)	-0.194*** (0.003)	0.003 (0.879)	0.047 (0.430)
$\Delta LnTLA$	0.001 (0.202)	0.002* (0.055)	0.001 (0.249)	-0.003 (0.243)
$\Delta LnVac$	0.001 (0.526)	-0.156*** (0.000)	0.001 (0.475)	0.189 (0.204)
R ²	0.002	0.189	0.002	0.084
Adj. R ²	-0.002	0.163	-0.002	-0.027
F	0.422	7.070***	0.487	0.759

Notes: The dependent variable is $\Delta LnTGR$, the first difference of the natural log of total gross rent with respect to the previous quarter. "All Properties" denotes the regression results of the following model:

$$\Delta LnTGR_{it} = f(\Delta UpMarket_{it}, \Delta LnTGR_{i(t-1)}, \Delta LnTLA_{it}, \Delta LnVac_{it}, \Delta Green_{it}, \Delta UpMarket_{it} * Green_{it}).$$

Columns 3–5 denote the regression result run on the same sample where the green status is being controlled for by sampling such that the first sample consists of green-only, the second of non-green only, and the third of the only properties-quarters witnessing a transition from non-green to green status, where Δ signifies the change in a variable with respect to the previous quarter. *Green* and *UpMarket* are indicator variables denoting the green status (= 1 if a properties is green) and Up-Market scenario (= 1 if the average market rent in the sample increased from the previous quarter), *TGR* is total gross rent (\$/sq. ft./yr.), *TLA* is total leasing activity (sq. ft.) and *Vac* is total property vacancy (sq. ft.) in a given quarter. Columns 3–5 describe the results of the first different regression model wherein the first differences of the green status and its interaction with the *UpMarket* variables have been omitted. *P*-values are in parentheses. Total degrees of freedom for column 2 = 1,255, for column 3 = 125, for column 5 = 1,068, and for column 6 = 37.

* Significant at < 0.1

** Significant at < 0.05.

*** Significant at < 0.005.

Exhibit 7 | Descriptive Statistics for Panel Data

	N	Min.	Max.	Mean	Std. Dev.
TGR ¹	1,256	12	156	40.16	19.83
TLA ²	1,256	0	161,886	5,039.31	1,278.32
Vac ³	1,256	0	347,749	28,795.79	38,746.54
Stories ⁴	1,256	2	48	9.58	8.08
YrBl ⁵	1,256	1924	2009	1991	12.86
	Freq.	Percent			
Green ⁶	168	13.4			
UpMarket ⁷	610	48.6			
DC ⁸	642	51.1			
Downtown ⁹	234	18.6			

Notes: 1: total gross rent (\$/sq. ft./yr.), 2: total leasing activity (sq. ft.), 3: vacant properties (sq. ft.), 4: number of stories, 5: year of original construction, 6: equals 1 if green, else 0; 7: equals 1 if the average market rent increased from the previous quarter, 8: equals one if located in Washington DC, and 9: equals one if located in downtown. All statistics for a commercial office properties in a quarter.

activity. However, they are significantly yet negatively related to their own previous value and changes in vacant area. This suggests that a positive change in the rental rate in green buildings usually follows a negative movement in the rental rate showing signs of elasticity. Our model suggests that these explanatory variables are unique to modeling green rental rates and are insignificant for non-green samples.

Random Effects Model

For Model II, we first analyze the panel data that includes all property-quarters for the time period between 2007:Q1 and 2010:1. Exhibit 7 describes the data used in the random-effects panel data analysis for the complete period of analysis. While the data suggests an even distribution of the location (Washington DC: 51% vs. San Francisco: 49%) and the market cycle (up-market: 49% vs. down-market: 51%), the proportions of green (13%) versus non-green (77%) properties and downtown (19%) versus non-downtown (81%) locations are not comparable.

As a robustness check, we analyze the same model for three individual quarters, thus stratifying the sample into cross-sectional data. Evidently, in the period-specific cross-sectional sub-samples, the unit of analysis shifts to property from property-quarters as in the panel-data. We choose three quarters at yearly intervals (2009:Q4, 2008:Q4, and 2007:Q4). This selection covers the overall sample evenly across time, and also incorporates periods of different market cycles (up-markets and down-markets). Moreover, one of these quarters (2009:Q4) allows us to model both up-markets and down-markets in a single set of cross-sectional data, which

is described in Exhibit 8. This is possible as the two metro areas for that quarter were witnessing opposite concurrent market cycles. The descriptive statistics for these samples are presented in Exhibits 9–11.

The descriptive statistics (Exhibit 9) reveals that there is approximately equal representation from both San Francisco and Washington DC, as well as from the up-market and down-market scenarios. The proportion of green properties is relatively small (13%) in the panel data. However, it is clear that the majority of green properties appear in the cross-sectional analysis during the period of 2009:Q4.

Among the cross-sectional sub-samples, the 2007:Q4 set has only one green property.¹² This further supports our decision to include rental data no earlier than 2007 to avoid under-sampling green properties. Breaking up of the panel data into cross-sectional samples is employed only for a greater understanding of the phenomenon; however, we draw our conclusions from the panel data analysis. For the control variables, we have also been able to sample a satisfactory range of observations. Almost all of our observations are Class A office properties. The only exception is a Class B green property in San Francisco; thus, building-class may not be a significant explanatory variable in our sample.

Exhibit 8 presents the regression results for Model I. Time is a meaningful independent variable for panel data only as the remaining models are cross-sectional. Hence the time variable is omitted from the quarter-specific regression models. Also, during 2009:Q4, only Washington DC was witnessing an up-market, hence the variable *DC* was perfectly collinear with the *UpMarket* variable, leading to zero tolerance. The data redundancy is removed by avoiding the *DC* variable and retaining the *UpMarket* variable so as to retain the interaction-term (*Green* * *UpMarket*) in the model. In the other two quarters, both markets were witnessing either upward (2007:Q4) or downward (2008:Q4) trends.

During down-markets, green buildings had nearly a 2.4% higher rental rate,¹³ controlling for other factors. This number is the coefficient of the *Green* variable when the up-market indicator variable is assigned a value of zero, thus signifying the premium of green properties over non-green properties during the down-market scenarios. During up-markets, the premium on green buildings is calculated by adding the coefficients of the *Green* indicator and its interaction term with the *UpMarket* indicator.¹⁴ Thus, during the up-markets, the premium enjoyed by green properties over non-green properties shrinks to 0.1%¹⁵; however, the coefficient of the interaction term (-0.023) is insignificant. The amount of vacant square feet in a building (*LnVac*) is an insignificant explanatory variable of rental rates during the respective quarter, although it tends to have a negative coefficient in most cases. Higher leasing activity (*LnTLA*), as suggested by the panel data, seems to increase the bargaining power of property owners. Controlling for other factors, there is an insignificant difference between the rental rate dynamics of commercial office properties in San Francisco and Washington DC. The effect of building height had contrasting effects during the up-market and down-market scenarios (columns 2 & 3 of Exhibit 8). Also, a significant quadratic term of building height (stories) in one of the samples supports Slade's (2000) finding that the effect of

Exhibit 8 | Random-Effect Panel Data Regression Model; and Cross-Sectional Regression

	2007:Q1–2010:Q1 ^a	2009:Q4 ^b (Up-Market in DC)	2008:Q4 ^b (Down-Market)	2007:Q4 ^b (Up-Market)
Intercept	0.003 (0.994)	-2.010 (0.128)	1.045 (0.516)	-0.920 (0.545)
<i>Green</i>	0.024** (0.024)	-0.073** (0.021)	0.067** (0.012)	-0.004 (0.951)
<i>UpMarket</i>	0.030* (0.000)	0.011 (0.588)	N/A	N/A
<i>Green * UpMarket</i>	-0.023 (0.155)	0.082* (0.089)	N/A	N/A
<i>t</i>	-0.004*** (0.000)	N/A	N/A	N/A
<i>LnTGRt1</i>	0.966*** (0.000)	0.982*** (0.000)	0.942*** (0.000)	0.987*** (0.000)
<i>LnTLA</i>	0.002** (0.009)	0.004* (0.078)	0.002 (0.350)	-0.002 (0.211)
<i>LnVac</i>	-0.001* (0.065)	0.000 (0.872)	0.000 (0.873)	-0.001 (0.503)
<i>DC</i>	-0.004 (0.538)	N/A	0.026 (0.167)	-0.037** (0.045)
<i>Downtown</i>	0.011 (0.165)	0.063** (0.009)	0.024 (0.347)	0.005 (0.847)
<i>Stories</i>	-0.001 (0.165)	-0.008** (0.035)	0.008** (0.026)	0.003 (0.522)
<i>SqStories</i>	0.000 (0.180)	0.000* (0.100)	0.000*** (0.003)	0.000 (0.439)
<i>YrBl</i>	0.000 (0.701)	0.001 (0.107)	0.000 (0.563)	0.001 (0.503)
R ²	0.946	0.968	0.965	0.965
Adj. R ²	0.945	0.964	0.961	0.960

Notes: This table lays out the results of the following regression model:

$$\text{LnTGR}_{it} = h(\text{Green}_{it}, \text{DC}_{it}, \text{UpMarket}_{it}, t, \text{LnTGR}_{i(t-1)}, \text{LnTLA}_{it}, \text{LnVac}_{it}, \text{YrBl}_{it}, \text{Stories}_{it}, \text{Stories}_{it}^2, \text{Downtown}_{it}, \text{Green}_{it} * \text{UpMarket}_{it}).$$

Green is an indicator variable that assumes a value of 1 if a property is green in a quarter. *UpMarket* is an indicator variable that assumes a value of 1 if the average market rent increased over the previous quarter; else 0. *t* signifies the serial number of a quarter such that 2007:Q1 is coded as 9, 2007:Q2 as 10 and so on. *TGR* stands for total gross rent (\$/sq. ft./yr.) of a building. *TLA* signifies total leasing activity (sq. ft.) of a building. *Vac* stands for total vacancy in a building (sq. ft.). *DC*, an indicator variable assumes a value of 1 if a properties is located in Washington DC metro, zero otherwise. *Downtown* is a location variable that assumes a value of 1 if a properties is located in a downtown. *Stories* represents the number of stories in a building. *YrBl* specifies the original construction year of a building. All data are recorded for a property in a specific quarter. *P*-values are in parentheses. Total degrees of freedom for column 2 = 1,255, for column

Exhibit 8 | (continued)

Random-Effect Panel Data Regression Model; and Cross-Sectional Regression

3 = 106, for column 5 = 99, and for column 6 = 83. *F* for column 2 = 1804.11***, for column 3 = 287.21***, for column 5 = 275.27***, and for column 6 = 224.30***.

^aPanel data.

^bCross-sectional data.

*Significant at < 0.1

**Significant at < 0.05.

***Significant at < 0.005.

Exhibit 9 | Descriptive Statistics for 2009:Q4

	N	Min.	Max.	Mean	Std. Dev.
<i>TGR</i> ¹	107	12	120	39.24	21.68
<i>TLA</i> ²	107	0	161,886	6,382.85	18,133.27
<i>Vac</i> ³	107	0	320,382	34,861.21	46,778.38
<i>Stories</i> ⁴	107	2	48	9.29	7.82
<i>YrBlt</i> ⁵	107	1924	2009	1992	14.53
	Frequency	Percent			
<i>Green</i> ⁶	36	33.6			
<i>UpMarket</i> ⁷	57	53.3			
<i>DC</i> ⁸	57	53.3			
<i>Downtown</i> ⁹	24	22.4			

Notes: 1: total gross rent (\$/sq. ft./yr.), 2: total leasing activity (sq. ft.), 3: vacant properties (sq. ft.), 4: number of stories, 5: year of original construction, 6: equals 1 if green, else 0; 7: equals 1 if the average market rent increased from the previous quarter, 8: equals one if located in Washington DC, and 9: equals one if located in downtown. All statistics for a commercial office properties in a quarter.

taller buildings reverts in sign after a certain height of the building is achieved. However, our study suggests that this effect is faint. We find building age to have a statistically insignificant effect on the rental rates. As expected, the rental rate of the previous quarter is large and statistically significant.

Our analysis has certain limitations. The explanatory variables are insignificant in absence of the lagged dependent variables, which exhibit autocorrelation. There may be potential endogeneity issues between the dependent variable and some explanatory variables such as total leasing activity and vacant area. In addition, panel data analysis has its own limitations. On the other hand, the effect of cross-sectional differences in properties such as age, height, and location may have differing effects on the rental rate changes over time, which cannot be examined

Exhibit 10 | Descriptive Statistics for 2008:Q4

	N	Min.	Max.	Mean	Std. Dev.
<i>TGR</i> ¹	100	18	156	41.91	22.03
<i>TLA</i> ²	100	0	95,000	5,592.46	12,951.59
<i>Vac</i> ³	100	0	126,961	26,894.75	33,701.40
<i>Stories</i> ⁴	100	2	48	9.43	8.167
<i>YrBl</i> ⁵	100	1957	2009	1992	12.05
	Freq.	Percent			
<i>Green</i> ⁶	11	11			
<i>UpMarket</i> ⁷	0	0			
<i>DC</i> ⁸	52	52			
<i>Downtown</i> ⁹	17	17			

Notes: 1: total gross rent (\$/sq. ft./yr.), 2: total leasing activity (sq. ft.), 3: vacant properties (sq. ft.), 4: number of stories, 5: year of original construction, 6: equals 1 if green, else 0; 7: equals 1 if the average market rent increased from the previous quarter, 8: equals one if located in Washington DC, and 9: equals one if located in downtown. All statistics for a commercial office properties in a quarter.

Exhibit 11 | Descriptive Statistics for 2007:Q4

	N	Min.	Max.	Mean	Std. Dev.
<i>TGR</i> ¹	84	22.41	96	40.84	14.15
<i>TLA</i> ²	84	0	45,000	4,823.77	9,456.38
<i>Vac</i> ³	84	0	124,839	24,650.36	32,899.19
<i>Stories</i> ⁴	84	2	39	9.51	7.52
<i>YrBl</i> ⁵	84	1955	2009	1992	11.92
	Freq.	Percent			
<i>Green</i> ⁶	1	1.2			
<i>UpMarket</i> ⁷	84	100			
<i>DC</i> ⁸	44	52.4			
<i>Downtown</i> ⁹	14	16.7			

Notes: 1: total gross rent (\$/sq. ft./yr.), 2: total leasing activity (sq. ft.), 3: vacant properties (sq. ft.), 4: number of stories, 5: year of original construction, 6: equals 1 if green, else 0; 7: equals 1 if the average market rent increased from the previous quarter, 8: equals one if located in Washington DC, and 9: equals one if located in downtown. All statistics for a commercial office properties in a quarter.

through fixed-effects models. In addition, the first-difference models are not as efficient as the random-effects models as our results suggest. To address these limitations of methodology, we ran several robustness checks. The issues with the panel data are addressed by breaking up our sample into smaller, cross-sectional samples. The issues of the fixed-effects model are addressed by also running a random effects model.

Conclusion

In line with previous studies, we find that green office properties enjoy a rental rate premium. We also find evidence that green premiums are not static. Instead they tend to stabilize rental rates across various real estate market conditions thus offsetting some of the negative effects of down-markets. The green premium is counter-cyclical: positive and significant in down-markets, but substantially reduced in up-markets. This finding confirms Eichholtz, Kok, and Quigley (2011), who also report that the recent downturns in the property markets have not significantly degraded the financial performance of green buildings relative to those of comparable non-green properties. In addition, if green properties witnessed a positive rental rate percentage change from a previous quarter, it tends to offset the intrinsic pattern of the increase by a negative percentage while controlling for other factors. Quarterly changes in the property-specific temporal variables explain approximately 19% of the variability in the changes of commercial office property rental rates, resulting in a significant explanatory model. In contrast, the model examining quarterly changes in the property-specific temporal variables in non-green properties only explained 0.2% of rental rate variability. Thus, our hedonic models for rental rates are more efficient for green properties compared with non-green properties.

It is, however, critical to point out that our sample includes a time period in which the economy was going through an unusual phase of severe economic crisis. This might have influenced the pattern of green commercial office rental rates asymmetrically compared with comparable non-green office properties. It is also possible that with time, as more green developments are constructed, the issue of limited supply of green properties may become moot as the market reaches equilibrium and the dynamic nature of green premiums may diminish.

Endnotes

- ¹ In this paper, we use LEED-labeled as synonymous to “green” properties.
- ² Green building is defined as “the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition”; From the US EPA website: <http://www.epa.gov/greenbuilding/>.
- ³ BREEAM stands for BRE Environmental Assessment Method administered by Building Research Establishment in the U.K.
- ⁴ “Green Mark” is a green labeling used in Singapore for newly constructed and rehabilitated buildings.

⁵ “Green Star” is a green rating system administered by the Green Building Council of Australia.

⁶ For example, green ratings for residential real estate were instituted very recently by the USGBC.

⁷ For a more detailed discussion on this issue, see Wang and Zorn (1999).

⁸ Calculated as $100 * (e^{-0.44} - 1)\%$.

⁹ Calculated as $100 * (e^{0.47} - 1)\%$.

¹⁰ Calculated as $100 * (e^{0.0007} - 1)\%$.

¹¹ Calculated as $100 * (e^{-0.003} - 1)\%$.

¹² This information is relevant only to our sample. In fact, there were several other green properties available in that quarter, but we failed to find their information in the CoStar database.

¹³ Calculated as $100 * (e^{0.024} - 1)\%$.

¹⁴ During the up-markets, the coefficient of the green premium (on $LnTGR$) can be calculated as $0.024 - 0.023 = 0.001$.

¹⁵ Calculated as $100 * (e^{0.001} - 1)\%$.

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We are thankful to USGBC and CoStar for providing us with the data. Sincere thanks to David Harrison, Patrick McAllistor, Edward Coulson, the anonymous reviewers of the JOSRE, Julian Diaz III, Edward Rigdon, Subhashish Samaddat, and Arun Rai for valuable insights, comments or suggestions.

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