Sustainability and the Dynamics of Green Building

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Abstract

Research on climate change suggests that small improvements in the "sustainability" of buildings can have large effects on greenhouse gas emissions and on energy efficiency in the economy. We analyze the dynamics of green building and the private returns to the recent surge in investments in energy-efficient office buildings. We examine a comprehensive panel of "green" office buildings and nearby controls first observed in 2007, estimating changes in the economic premium for energy efficiency between 2007 (when green office space was 7 percent of the national inventory and unemployment rates were 4.6 percent) and 2009 (when green space was 14.9 percent of the inventory and the unemployment rate was 9.3 percent). Surprisingly, we find that the large increases in the supply of green buildings during 2007-2009, and the recent downturns in property markets, have *not* significantly affected the returns to green buildings relative to those of comparable high quality property investments.

We employ an analogous research design to document precisely the very substantial economic returns to energy efficiency and sustainability in commercial property markets using a much larger cross section of office buildings which had been "certified" by independent rating agencies in 2009. We estimate separately the increment to market rents and asset values enjoyed by buildings which have been certified by the two major rating agencies – the U.S. Green Building Council and U.S. Department of Environmental Protection. We relate the estimated premiums for green buildings to the particulars of the rating systems that underlie certification. The analysis of samples of more than 27,000 buildings confirms that the attributes rated for *both* thermal efficiency and sustainability contribute to increases in rents and asset values. Among green buildings, increased energy efficiency is fully capitalized into rents and asset values.

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I. Introduction

"Sustainability" has become an increasingly important attribute of economic activities describing methods of production, but also qualities of consumption and attributes of capital investment. In part, this reflects popular concern with environmental preservation, but it may also reflect changes in tastes among consumers and investors. "Sustainability" may also be a marketing device which can be employed successfully by large corporations and small businesses alike.

The built environment and “sustainability” are closely intertwined, and popular attention to "green building" has greatly increased over the past decade. This may reflect the potential importance of real property in matters of environmental conservation. For example, buildings and their associated construction activities account for almost a third of world greenhouse gas emissions. The construction and operation of buildings account for about forty percent of worldwide consumption of raw materials and energy. Influential analyses of climate mitigation policies have pointed out that the built environment offers a great potential for greenhouse gas abatement (Per-Anders Enkvist, Thomas Naucler and Jerker Rosander, 2007, IPCC, 2007, Nicholas Stern, 2008). Thus, small increases in the "sustainability" of buildings, or more specifically in the energy efficiency of their construction, can have large effects on their current use of energy and on their life-cycle energy consumption. Projected trends in urban growth in developed countries (Matthew E. Kahn, 2009) and in the urbanization of developing economies (Edward L. Glaeser and Matthew E. Kahn, 2010, Siqi Zheng *et al*., 2009) suggest that the importance of energy efficiency in building will increase further in the coming decades.

But the impact of energy costs directly affects occupants, building managers, and investors as well. Energy represents about thirty percent of operating expenses in the typical office building in the U.S. This is the single largest and most manageable expense in the provision of office space. Rising energy costs can only increase the salience of this issue for the private profitability of investment in real capital.

As noted, the increase in attention to “green building” by planners, developers, and investors has been remarkable. Figure 1 provides some evidence on the popular importance of these issues. It reports on the occurrence of the term "green building" in the U.S. popular press. The popular usage of this term almost tripled between 2005 and 2009. The figure also reports a tripling during the past three years of the number of participants at the major international conference on green building (“Greenbuild”). Figure 2 illustrates the growing importance of “green building” in the marketplace. It reports the fraction of commercial office space that is certified as “green” in the one hundred largest core-based statistical areas (CBSAs) in the U.S. These certifications are recorded by one of two national agencies described below. The figure shows that the inventory of certified green office space has increased dramatically between 2007 and 2009.[1] In some metropolitan areas, the availability of certified “sustainable” office buildings has more than doubled. There are a few metropolitan areas where “green” office space now accounts for more than a quarter of the total office stock. Appendix Table A1 provides more detail on the increase in green office space between 2007 and 2009.

In this paper, we analyze the economic significance of these trends in green building upon the private market for commercial office space. Investments improving the energy efficiency or sustainability of real capital may have implications for competition

[1] Data on the size of commercial property markets is supplied by the CoStar Group and includes “liquid” commercial office space only. Thus owner-occupied headquarters buildings and other “trophy” office properties are underreported, and the fraction of “green” space per CBSA may be overestimated.

in the market for commercial space: tenants may enjoy pecuniary and non-pecuniary benefits (e.g., lower utility bills, higher employee productivity) and there may be economic benefits to investors (e.g., higher rents, lower risk premiums).[2]

First, we investigate the price dynamics of energy efficient and sustainable commercial buildings during the recent period of turmoil and unprecedented decline in property markets. We gather and analyze a panel of certified green buildings and nearby control buildings observed in 2007 and again in 2009. The sample consists of buildings certified for energy efficiency or sustainability by the U.S. Environmental Protection Agency, EPA ("EnergyStar") or registered by the U.S. Green Building Council, USGBC (Leadership in Energy and Environmental Design, "LEED") in 2007. Certified buildings and nearby controls were matched to detailed hedonic and financial information maintained about these buildings. The data we analyze consist of an unbalanced panel of buildings observed two years apart, some of which were certified as "green" in 2007 and/or 2009.

The results show that the large increases in the supply of green buildings during 2007-2009, and the recent downturns in property markets, have *not* significantly affected the returns to green buildings relative to those of comparable high quality property investments; the economic premium for certified office space has decreased slightly, but rents and asset values are still higher than those of comparable properties.

Second, we employ an analogous research design to analyze the much larger cross section of green buildings registered by October 2009. We investigate the relationships between energy efficiency and sustainability, on the one hand, and the rents, effective rents, and the selling prices commanded by these properties, on the other hand. The

[2] See Piet M.A. Eichholtz, Nils Kok and John M. Quigley, 2010 for a more detailed discussion.

analysis also differentiates among buildings which have been registered for a label attesting to energy efficiency ("Energy Star certified"), and those which have been registered for a label that proclaims the "sustainability" of properties ("LEED certified"). This sample of some 21,000 rental buildings and 6,000 buildings which have been sold facilitates an extensive analysis of comparable buildings weighted by propensity score, under a variety of leasing terms employed in different circumstances, distinguishing among contractual arrangements for the provision of services and utilities. This section of the paper expands on the very limited body of existing work (Piet M.A. Eichholtz, Nils Kok and John M. Quigley, 2010, F. Fuerst and P. McAllister, 2011) in several respects. It exploits a much larger sample of commercial buildings, and it controls more rigorously for quality differences among buildings. Most importantly, it supports a detailed investigation of the sources of the economic premiums embedded in the individual rents and asset prices of several thousand green buildings. This latter investigation relies upon internal documents made available by the EPA and the USGBC.

The propensity-score-weighted estimates show that buildings with green ratings in 2009 command rental rates that are substantially higher than those of otherwise identical office buildings, controlling for the quality and the specific location of the buildings. Premiums in effective rents are even higher. *Ceteris paribus*, the selling prices of green buildings relative to comparable buildings nearby are higher by more than 13 percent.

As noted, this research design facilitates a detailed analysis of the sources of the rent and value increments obtained for rated buildings. Our methodology generates an estimate of the premium in rent or asset value for each green building relative to the control buildings in its immediate neighborhood. For the buildings certified by the LEED program, we obtained the raw data on "sustainability" as evaluated in the certification process. For buildings certified by the Energy Star program, we obtained the data on “energy efficiency” as measured and reported in the certification process. *Within* the population of certified green buildings, we find that variations in rents and asset values are systematically related to the energy efficiency of the buildings, and also to other indicia of sustainability which are measured in the certification process.

The remainder of this paper is organized as follows. Section II discusses the measurements and data sources documenting the energy efficiency or “sustainability” of buildings in the U.S. and their economic characteristics. It describes briefly the major programs in the U.S. that encourage and publicize sustainable building, and it introduces the sampling frames employed in the analysis. Section III analyzes short-run price dynamics -- the course of rents for green commercial buildings that were already certified in 2007, as compared with those buildings never certified. Section IV presents new evidence on the economic returns to the investments in green buildings, based upon the much larger cross section of green office buildings and nearby control buildings certified at the end of 2009. Section V analyzes the sources of increased rents and market values attributable to certification, distinguishing among energy efficiency and the other characteristics of properties that are evaluated for the award of a green label. Section VI is a brief conclusion.

II. “Green” Commercial Buildings: Measurements and Data Sources

In the U.S., there are two major programs that encourage the development of energy-efficient and sustainable buildings through systems of ratings to designate and publicize exemplary buildings. The Energy Star program (jointly sponsored by the U.S. Environmental Protection Agency and the U.S. Department of Energy) began as a voluntary labeling program intended to identify and promote energy-efficient products and home appliances to conserve energy. The Energy Star label was extended to new homes in 1993, and this has been promoted as an efficient way for consumers to identify builders as well as buildings constructed using energy-efficient methods. The Energy Star label is marketed as an indication of lower ownership costs, better energy performance, and higher home resale values. The label is also marketed as an indication of better environmental protection. The Energy Star label was extended to commercial buildings in 1995, and the labeling program for these buildings began in 1999.

Nonresidential buildings can receive an Energy Star certification if the source energy use of the building (that is, the total quantity of energy used in the building), as certified by a professional engineer, achieves a specified benchmark level; the label is awarded to the top quarter of all comparable buildings, ranked in terms of source energy efficiency. The Energy Star label is marketed as a commitment to conservation and environmental stewardship. But it is also touted as a vehicle for reducing building costs and for demonstrating superior management skill. Indeed, the Energy Star website draws attention to the relationship between energy conservation in buildings and other indicia of good "corporate governance."

In a parallel effort, the U.S. Green Building Council (USGBC), a private nonprofit organization, has developed the LEED green building rating system to encourage the "adoption of sustainable green building and development practices." Since adoption in 1999, separate standards have been applied to new buildings and to existing structures. The requirements for certification of LEED buildings are substantially more complex than those for the award of an Energy Star rating, and the certification process measures six distinct components of "sustainability," one of which is energy performance.[3]

It is claimed that LEED-certified buildings have lower operating costs and increased asset values and that they provide healthier and safer environments for occupants. It is also noted that the award of a LEED designation "demonstrate[s] an owner's commitment to environmental stewardship and social responsibility."[4]

Energy-Star-rated buildings are identified by street address in files available on the website of the EPA. LEED-rated buildings are identified using internal documentation provided by the USGBC. We matched the addresses of the buildings rated in these two programs as of September 2007 to the office buildings identified in the archives maintained by the CoStar Group. The CoStar service and the data files maintained by CoStar are advertised as "the most complete source of commercial real estate information in the U.S."[5] Our match yielded 694 green office buildings for which rents, occupancy rates, and building characteristics could be identified in CoStar.

To investigate the effect of energy efficiency and sustainability on the returns of commercial buildings, we matched each of the rated buildings in this sample to nearby commercial buildings in the same market. Based upon the latitude and longitude of each rated building, we used GIS techniques to identify all other office buildings in the CoStar database within a radius of one quarter mile. In this way, we created 694 clusters of

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[3] For more information on the exact rating procedures, see http://www.usgbc.org/leed.

[4] In the short time since these rating systems for buildings were developed in the U.S., quite similar certification procedures have been codified in many other countries, for example, the "BREEAM" rating system in the U.K., "Greenstar" in Australia, "BOMA-Best" in Canada, and "Greenmark" in Singapore. An analogous system is under development in China, and the European Union is currently negotiating an "eco-label" for the certification of commercial and residential buildings.

[5] The CoStar Group maintains an extensive micro database of approximately 2.4 million U.S. commercial properties, their locations, and hedonic characteristics, as well as the current tenancy and rental terms for the buildings. Of these 2.4 million commercial buildings, approximately 17 percent are offices, 22 percent are industrial properties, 34 percent is retail, 11 percent is land, and 12 percent is multifamily. A separate file is maintained of the recent sales of commercial buildings.

nearby office buildings. Each small cluster – 0.2 square miles – contains one rated building and at least one nonrated nearby building. On average, each cluster contained about a dozen buildings. There were 8,182 commercial office buildings in the 2007 sample of green buildings and control buildings with hedonic and financial data.[6]

In October 2009, we matched these same buildings to the then-current financial information and building characteristics maintained by CoStar; we also matched them again to the files maintained by the EPA and the USGBC, identifying those buildings that had been certified during the intervening period. In this way, we defined a panel of commercial office buildings, including all rental buildings which had been green-certified in 2007, as well as nearby control buildings matched to their 2009 financial and hedonic characteristics. Buildings are thus observed at two points in time. This panel of buildings is analyzed in Section III below.

In October 2009, we also matched the addresses of *all* rated buildings in the EPA and USGBC files to the archives maintained by the CoStar Group. This match yielded a much larger sample of certified buildings, reflecting the substantial recent increase in rated buildings reported in Figure 2. We used the same GIS techniques to identify nearby commercial buildings, ultimately creating 2,687 clusters, each containing one rated building and at least one nonrated nearby building. This cross section of 26,794 buildings is analyzed in Section IV below.

The point of departure for the analyses reported in Sections III and IV is the well-known hedonic relationship between the economic characteristics of properties and their market values,

[6] These cross-sectional data formed the basis for the analysis reported in Piet M.A. Eichholtz *et al*. (2010).

$$(1) \quad \log R_{in} = \alpha + \beta_i X_i + \sum_{n=1}^{N} \gamma_n c_n + \delta g_i + \varepsilon_{in}$$

In this formulation R_{in} is the rent (or asset value) per square foot commanded by building i in cluster n; X_i is the set of hedonic characteristics of building i, and ε_{in} is an error term. To control more precisely for locational effects, we include a set of dummy variables, one for each of the N clusters. c_n has a value of one if building i is located in cluster n and zero otherwise. g_i is a dummy variable with a value of 1 if building i is rated by EPA or USGBC and zero otherwise. α, β_i, γ_n and δ are estimated coefficients. δ is thus the average premium, in percent, estimated for a labeled building relative to those buildings in its 0.2 square mile geographic cluster .

Throughout the analyses presented and the statistical models reported in Sections III and IV, we include as regressors the set of variables, c_n, $n = 1, \ldots, N$, identifying the geographical cluster in which each building is located.[7]

III. The Short-Run Price Dynamics of Green Buildings

The period 2007-2009 witnessed a substantial contraction in U.S. economic activity, as the unemployment rate for full-time workers rose from 4.4 percent in 2007:I to 10 percent in 2009:IV. As unemployment, output, and earnings contracted, so did the demand for office space. Figure 3 illustrates these trends in the central business districts (CBDs) of two large metropolitan markets, New York and San Francisco. Unemployment rates in New York went from five to ten percent between the beginning of 2008 and the end of 2009, average asking rents for office buildings declined from $65 to $42 per square foot, and vacancy rates increased by a third. During the same period, commercial rents in San Francisco declined by thirty percent. Despite these trends, the data reported

[7] In this way, we acknowledge the adage that the three most important determinants of property values are "location, location, and location."

in Figure 2 and in Appendix Table A1 indicate that there was a substantial increase in the available stock of green office space in these and other large metropolitan areas. Recently-constructed "sustainable" buildings can explain a small part of the increase, but a large share of newly-certified buildings consists of existing buildings that were recently awarded an Energy Star or LEED certificate.[8]

In this section, we investigate the implications of these trends – substantial increases in green office space in a stagnant or declining market for commercial office space – upon the market for green buildings. The most straightforward method for investigating the effects of recent changes in economic conditions upon the economic premiums for green buildings is to adapt the hedonic relationship described in Equation (1) to several time periods.

$$(2)\quad \log R_{\text{int}} = \alpha_0 + \alpha_t + \beta_i X_{it} + \sum_{n=1}^{N} \gamma_n c_n + \delta_t g_{it} + \varepsilon_{\text{int}}$$

In this formulation, rent or asset value, R_{int}, varies with time t, and α_t is the percent increase or decrease in nominal rent for an identical building at t as compared to the baseline. Hedonic characteristics, X_{it}, may vary over time. g_{it} is a dummy variable with a value of one if building i is green-rated at t. δ_t is the premium for a green building which may vary over time. ε_{int} is an error term, assumed iid.

Table 1 presents the results of estimating the hedonic model using the pooled data on office buildings observed in 2007 and 2009. In addition to the variables reported in the table, each regression also includes a set of 694 dummy variables, one for each of the clusters associated with the rated buildings observed in 2007.

[8] In addition, the lead-time between LEED registration and the ultimate award of a certificate can take considerable time. Thus, green buildings may have been on the market in 2007, but were only recognized as "green" in 2008 or 2009.

In column 1, the results indicate that, *ceteris paribus*, nominal rents for commercial office buildings declined by about 5.4 percent between 2007 and 2009. Rents in buildings that were rated for energy efficiency or sustainability in 2007 are higher by about 4.1 percent, but in 2009 the rents of rated buildings were just 1.2 percent higher (*i.e.*, 4.1 minus 2.9 percent) than those of nonrated buildings.

The regression results also indicate that rents are substantially higher in office buildings that have been recently renovated; rents are significantly lower in metropolitan areas where the growth in employment in the service sector had been larger before the economic downturn.

In column 2, the estimated magnitudes are larger when the model is used to explain variations in effective rents (*i.e.*, rent multiplied by the occupancy rate). The coefficients indicate that effective rents for office buildings declined in nominal terms by 7.5 percent between 2007 and 2009. Effective rents in buildings that were rated for energy efficiency or sustainability were higher by about 7.5 percent in 2007, but this economic premium decreased by 5.1 percent during the economic downturn.

In the model explaining effective rent, the coefficient signifying buildings that were recently renovated is about zero, as compared to a large and significant coefficient (of 0.22) in the models explaining rent. This may reflect the lag in leasing up buildings after a major renovation, especially in a declining market. (Alternatively, this may reflect the fact that it is cheaper to undertake a building renovation when vacancy rates are higher.)

The coefficients of the hedonic variables for building quality, age, etc. are consistent with expectations and with prior analyses of commercial properties (*e.g.*, William C. Wheaton and Raymond G. Torto, 1994).

With this panel, it is of course possible to model changes in rents directly. This isolates more precisely the differential of interest, but the first difference in rent may be more prone to measurement error:

$$(3) \quad [\log R_{inT} - \log R_{in\tau}] = (\alpha_T - \alpha_\tau) + \beta_i (X_{iT} - X_{i\tau}) + \delta_T g_{iT} - \delta_\tau g_{i\tau} + (\varepsilon_{inT} - \varepsilon_{in\tau})$$

In this formulation, the dependent variable is the logarithmic change in rent between times τ and T. The intercept, $(\alpha_T - \alpha_\tau)$, measures the nominal change in log rents during the interval τ - T. $(X_{iT} - X_{i\tau})$ is the change in the hedonic characteristics of property i between τ and T. δ_T and δ_τ are the rental increments for a green-rated building at times T and τ respectively, and $(\varepsilon_{inT} - \varepsilon_{in\tau})$ is an error term, assumed iid.

Table 2 presents the rent change models using the panel of data[9] on the same office buildings observed in 2007 and in 2009. Column 1 is the most basic model, relating rent changes to an indicator of renovations in the building between 2007 and 2009. Also included is a measure of the metropolitan change in office vacancy rates and in the stock of available office space between 2007 and 2009. The model also includes a variable measuring the rent increment for buildings that were registered for energy efficiency or sustainability in 2007 and 2009.

The regression indicates that declines in nominal rents were larger in metropolitan areas where vacancy rates in office space increased and in markets where the stock of office space increased. These finding are consistent with Table 1; in regions where prior employment growth was strong, inducing increased supply, markets recorded larger declines in rents.

[9] Obviously these regressions are based upon the balanced panel of observations: 11,082 observations on 4,541 buildings observed in both 2007 and 2009, not 11,350 observations on buildings observed in either 2007 or in 2009.

The results also suggest that, *ceteris paribus*, the rents in buildings that were green-rated in 2007 and 2009 declined by an additional three percent during the interval. Buildings that were renovated between 2007 and 2009 had insignificant increases in rents.

In column 2, the assumption that β_i is constant over time is relaxed. The importance of the hedonic characteristics is permitted to vary between 2007 and 2009. Higher quality, younger buildings experienced stronger rental declines than older, "Class C" buildings. The incremental rent change for buildings green-rated in 2007 and 2009 is estimated to be about zero.

In column 3, the assumption that γ_n (see Equation 1) is constant over time is also relaxed. Rent increments are permitted to vary for each of the 694 clusters in the sample. In this more general model, the estimate of the rental change for buildings that were green-rated in 2007 and 2009 is also about zero. When controlling for price variation in hedonic and location characteristics, green buildings had returns that were not significantly different from those of otherwise comparable office space.

When the change in effective rents is analyzed in columns 4, 5, and 6, the estimated magnitudes are larger, but the pattern of results is quite similar. The nominal effective rental change for buildings rated in 2007 and in 2009 is negative (but insignificant in the most general model, column 6). The rent change estimated for buildings that are registered as green in 2007 and 2009 is negative, but in the most general specification the change in effective rent is insignificantly different from zero.

In columns 3 and 6, a variable measuring the percentage increase in green buildings within each cluster is also included. Its coefficient indicates that rental returns are significantly lower for buildings in these clusters. These large effects strongly suggest that the competition from close proximity to previously certified buildings reduced the premium for certified green buildings during the recent downturn in the property market.

IV. New Evidence on the Economic Premium for Green Office Buildings

As noted in Section II, our October 2009 match of all Energy Star and LEED-rated office buildings to the financial data maintained by CoStar identified a much larger sample -- 20,801 rental buildings and 5,993 buildings sold since 2004.[10]

Table 3 summarizes the information available on these samples. The table reports the means and standard deviations for a number of hedonic characteristics of "green" buildings and control buildings, including their size, quality, and number of stories, as well as indexes for building renovation, the presence of on-site amenities, and proximity to public transport. For the metropolitan areas associated with each building, the growth in office sector employment from 2006 through 2008 is also recorded.[11] For the samples of rental buildings, the current rent per square foot is reported, as well as the effective rent (*i.e.*, rent per square foot multiplied by the fraction of rentable space occupied). Variations in contractual terms are also reported. For the sample of sold buildings, the table reports transaction prices as well as the year sold, from 2004 through 2009.

A comparison of column 1 with column 2 in the table and a comparison of column 4 with column 5 reveal that the rated buildings are of somewhat higher quality; they are much larger and are substantially newer than the control buildings located nearby. They are more likely to be rented on a triple net basis or under a modified gross rent contract.

[10] The sample consists of 2,687 green buildings: 1,943 rental buildings, and 744 buildings which had been sold between 2004 and 2009. Associated with each building is a cluster of nearby nonrated buildings, identified using GIS techniques and matched to the same source of financial data, ultimately yielding 20,801 rental buildings and 5,993 buildings sold since 2004.
[11] Data are obtained from http://www.bls.gov/data/#employment

To control for the variations in the hedonic characteristics of rated buildings and the nearby control buildings, we estimate propensity scores for all buildings in the rental sample and the sample of transacted buildings. The propensity score specification includes all hedonic characteristics and is estimated using a logit model.[12] The third and sixth columns in the table report the mean values for the control buildings weighted by the propensity scores for those buildings.[13]

When the control buildings are weighted by their propensity scores, the average values of the hedonic characteristics are much closer to the means of those buildings which have qualified for an Energy Star or a LEED rating. For example, the average size of a green office building in the sample is 300 thousand square feet, and 76 percent of them are rated as "Class A" office space. For the sample of nearby non-rated office buildings, the average size is only 156 thousand square feet, and barely 27 percent of these buildings are rated as "Class A" office space. However, when these buildings are weighted by their appropriate propensity scores, the estimated mean size is 283 thousand square feet, and 72 percent are rated as "Class A" space. For the samples of both rental and sold buildings, weighting observations by propensity score dramatically reduces the disparity in average quality measures between rated and unrated buildings.

Table 4 presents regression results relating the logarithm of office rents per square foot, effective rents per square foot, and sales prices per square foot to the hedonic characteristics of buildings. The results are based on regressions of the same form as Equation (1). As compared to the 2007-2009 panel analyzed in Tables 1 and 2, the

[12] See Dan Black and Jeffrey Smith (2004) for but one example.

[13] The propensity score reflects the probability ρ that a building is labeled as a function of its hedonic characteristics. The observations are weighted by ρ to produce the means reported in columns 3 and 6. The results presented throughout this section are quite similar when observations are weighted by log (ρ).

sample sizes are much larger, a richer set of control variables is included, and the number of geographical clusters is much larger.

In the regressions reported in Table 4, all observations are weighted by their propensity score. Column 1 presents the basic regression model, based upon 20,801 observations on rated and unrated office buildings in 1,943 clusters. The coefficients for the individual clusters are not presented.

As noted in the table, rent increases with the size of the building and with its quality. *Ceteris paribus*, a Class A building rents for about 16 percent more than a Class C building; a Class B building rents for 9 percent more than a Class C building. Newer buildings rent at a substantial premium. Office buildings less than twenty years old rent for a 7 percent premium, and those less than five years old rent at about a 15 percent premium. Buildings with more than ten stories also rent for a premium.

Compared to buildings with a "triple net" rental contract (in which the tenant separately pays for all variable costs, including utilities, trash collection, security, doorman, etc.), a "full gross" rental contract (in which the landlord pays all variable costs) is about 20 percent more expensive. A contract in which the tenant pays for all utilities is about 4 percent cheaper than a "full gross" rental contract.

Most important, holding all these hedonic characteristics of the buildings constant, an office building registered with LEED or Energy Star rents for a two percent premium.

In column 2, the green rating is disaggregated into two components: an Energy Star label and a LEED registration. The coefficients of the other variables are unaffected when the green rating is disaggregated into these component categories. The estimated premium for buildings registered with the USGBC is significantly higher (t=3.24) than the premium for Energy Star certified office buildings.[14] We also include a variable that measures the "vintage" of the Energy Star label, measured by the total number of years since the label was awarded. The results show that the premium to an Energy Star certificate decreases by about 0.4 percent per year.[15]

Columns 3 and 4 present analogous results using the logarithm of effective rent. When endogenous rent-setting policies are taken into account, the results suggest that the effect of a green label is somewhat stronger. Labeled buildings have effective rents that are almost five percent higher than those of otherwise identical nearby non-rated buildings. This reflects the higher occupancy rates, on average, in labeled buildings. The effects of most of the other variables are qualitatively similar to those in columns 1 and 2.[16]

In the last two columns, the models explain the selling prices of green buildings and nearby non-green buildings that transacted between 2004 and 2009. The boom and subsequent bust in the market for commercial office space is clearly reflected in the variable indicating the year of sale; *ceteris paribus*, selling prices in 2007 were some 45 percent higher when compared to office buildings sold in 2004. However, this premium is all but insignificantly different form zero in 2009. In terms of asset value, however, an otherwise identical green building sells for a premium of about 13 percent.[17]

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[14] For the results reported in columns 4 and 6, the coefficients are insignificantly different, t=0.06 and t=0.11, respectively.

[15] This quite possibly reflects technical progress in building. The award of an Energy Star rating is benchmarked to the analysis of survey data on building energy use (CBECS) collected several years previously.

[16] One difference is that the coefficient for the newest category of buildings ("< 5 years") is negative. This probably reflects the real time involved in leasing-up a newly-built office building under more recent market conditions.

[17] At the point of means, the capitalization rate of the rent increment is higher than the capitalization rate of the transactions increment (though insignificantly so). This suggests that property investors value the lower risk premium inherent in certified commercial office buildings.

The statistical models reported in Table 4 estimate a common percentage premium in rent or value for all labeled buildings. In a more general specification of the model, we can estimate a unique premium for each labeled building relative to the control buildings in its immediate neighborhood.

$$(4) \quad \log R_{in} = \alpha + \beta_i X_i + \sum_{n=1}^{N} \gamma_n c_n + \sum_{n=1}^{N} \delta_n \left[c_n \bullet g_i \right] + \varepsilon_{in}^{**}$$

In Equation (4), the effect of a green rating on commercial rents or selling prices may vary separately for green buildings in each of the 1,943 clusters in the rental sample and for green buildings in each of the 744 clusters in the sample of sold buildings. The increment to rent or market value for the green building in cluster *n*, relative to the prices of the other buildings in the same cluster *n*, is exp[δ_n].

Figure 4 summarizes estimates of this model. It presents the frequency distribution of the premiums, δ_n, estimated for the samples of rental and sold buildings. As indicated in the figure, there is considerable variation in the increment to effective rent and market value across the sample. The mean premium to effective market rent is about 6 percent, and the mean premium to selling price is about 13 percent.[18] But some of the estimated increments to rent (value) are as high as 155 percent (189 percent), and of course some of the point estimates are negative.

V. The Sources of Economic Premiums for Rated Buildings

As illustrated in Figure 4, the regression specified in Equation (4) yields an estimate of the premium in effective rents for each green building in the rental sample and an estimate of the value increment for each green building in the sample of sold

[18] Based on the estimated values of the premium and their standard deviations, summarized in Figure 3, the probability that the mean rental increment is negative is miniscule (0.00001) and the probability that the mean value increment is negative is the same order of magnitude (0.00001).

buildings. These increments take into account variations in the hedonic characteristics of buildings, and they are expressed relative to the valuation of buildings in clusters of nearby conventional office buildings. This section examines the sources of the economic premiums estimated for these buildings.

For LEED-rated buildings, we know whether the building was registered under the LEED program and whether, after registration, the building was certified. For a sample of certified buildings, the USGBC provided us with information on the numerical rating for sustainability awarded in the certification process. For a small sample of buildings, the USGBC was also able to provide the sustainability score achieved in the six components of the LEED evaluation: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation.

For a sample of the Energy Star-rated buildings, the EPA provided the measures of energy efficiency which had been evaluated as a part of the certification process. These measures include the site and source energy usage of each building, in thousands of British Thermal Units (kBTU) per square foot of space. Site usage refers to the energy consumed in the building that is reflected in the energy bills paid by the owners and tenants. In contrast, source energy usage refers to the aggregate of all energy used by the building, including all transmission, delivery, and production losses for both primary and secondary energy used by the building.

We analyze separately the sources of the value increments for sold buildings and sources of the effective rent increments for the rental sample. For each sample, we analyze buildings certified by the LEED and the Energy Star programs.

Table 5 provides a terse summary of the more detailed information on rated buildings made available by the USGBC and EPA. Panel A summarizes the available data on LEED-rated buildings. The detailed USGBC data file provided information on 209 of the observations on LEED-rated rental buildings analyzed in Table 4. Of these, 121 are LEED-registered and 88 are LEED-certified. We note that more than half of the 209 LEED-rated rental buildings were also Energy-Star rated.

For the 88 LEED-certified buildings, information is available on the aggregate "sustainability score" underlying the certificate.[19] For a subset of 40 of these certified buildings, information is available on the scores within six broad categories (also normalized).

Analogous data are available from the USGBC data file for the 103 sales of LEED-rated buildings which were used in the regressions reported in Table 4. Note that there are only a few certified buildings with detailed information on scores by category.

Panel B summarizes the internal data made available by the EPA for Energy Star-rated buildings. Of the 1,719 Energy Star rental buildings used in the regressions in Table 4 (40 of which were also LEED-rated), the EPA provided the underlying evaluations for 774 rated buildings. This information consists of a professional engineer's certification of actual site energy consumption and source energy consumption (both in kBTU, by type of fuel). As indicated in Table 5, annual site energy consumption is about 65 kBTU per square foot for these buildings, and source energy consumption is about three times that number. The average Energy-Star-rated building emits some 4,300 tons of CO_2 per

[19] Several rating schemes are used by the USGBC (*e.g.*, Existing Buildings, New Construction, Commercial Interiors, etc.); these schemes have changed slightly over time. We normalize all scores to a 100-point scale. The score for a building certified by the USGBC ranges from a minimum of 37 to a maximum of 100.

year.[20] The table also reports our estimate of the annual site energy cost, about $1.90 per square foot.[21]

We relate these detailed measurements of LEED and Energy Star-rated buildings to the premium in rent and value in a straightforward manner,

(5) $\hat{\delta}_i = \omega Z_i + \eta_i$.

In this model, the dependent variable is the estimate of the effective rent or value increment for building i in cluster n (δ_n in Equation 4) relative to its immediate geographic neighbors, and the independent variables Z_i are the measures of energy efficiency and sustainability as reported by LEED or Energy Star, respectively. Equation (5) is estimated by generalized least squares using the variance-covariance matrix of the coefficient vector $\hat{\delta}$ to obtain weights.[22]

A. The Premium for LEED Rated Buildings

Table 6 investigates the link between the attributes of buildings rated by the LEED program and their economic value as demonstrated in the marketplace. Panel A reports the results for the 209 rental buildings for which detailed ratings are available. The first two columns report the increments, using indicator variables for LEED certification and Energy Star certification. From column 1, it appears that LEED *registration* is associated with an effective rent increment of 7.9 percent. Conditional upon this, the added increment for LEED *certification* is positive, but is insignificantly

[20] For comparison, annual carbon emissions from one building are equivalent to the aggregate emissions of some 750 passenger vehicles. We note that the EPA estimates that Energy-Star-qualified office buildings emit at least one quarter less carbon than a typical office building in the U.S.

[21] This estimate is obtained by aggregating energy usage for natural gas, heating oil, and electricity using: state average price data for natural gas (http://tonto.eia.doe.gov/dnav/ng/ng_pri_top.asp) and heating oil (http://tonto.eia.doe.gov/dnav/pet/pet_pri_top.asp); and county average price data for electricity. We are grateful to Erin Mansur for providing the more detailed electricity price data.

[22] This incorporates the precision with which each individual increment to rent of asset value is estimated. See Eric Hanushek (1974).

different from zero. From Column 2, it appears that the entire increment arises from the buildings certified as energy-efficient by Energy Star.

In Columns 3 to 6, we investigate the economic value of the numerical evaluation of sustainability reported for the LEED-certified buildings. In Column 3, the results suggest that certification and the certification score – the ranking along specific measures of sustainability – are important determinants of incremental rents commanded in the marketplace. The relation between the rental increment and the LEED score is positive but non-linear.[23] Importantly, this holds when Energy Star certification is taken into account as well (Columns 4 and 6).

The results suggest that the attributes of sustainability rated in the LEED certification process do have a substantial effect on the effective rents commanded by office buildings. From Column 3, for example, it is estimated that a LEED-certified building with a normalized score of 40 (about one standard deviation below the average sustainability score of certified buildings) has an effective rent of 2.1 percent higher than the rent of an otherwise identical registered building. A LEED-certified building with a normalized score of 60 (about one standard deviation above the average score of certified buildings) has an incremental rent almost ten times as large, 20.1 percent.

When the LEED score is entered as a cubic (columns 5 and 6), the individual coefficients are insignificant, but the set of coefficients is significantly different from zero (F = 4.58). The interpretation of these coefficients suggests that the economic premium for LEED-rated buildings only becomes positive at a (normalized) score of 44, which coincides with the lower threshold for the LEED "Silver" level. The maximum

[23] In other regressions, not reported, indicator variables for the type of certification awarded by the USGBC ("Silver", "Gold", or "Platinum") are not significantly different from each other.

rental increment is reached at a (normalized) score of 75, which corresponds to the upper threshold of the LEED "Gold" level.[24]

These results are broadly consistent with those reported for the smaller sample of transactions in Panel B. Appendix Table A2 analyzes the effects of the sub scores on market rent and asset value premiums. The sample sizes for these regressions are quite small, and any inferences are quite problematic.

B. The Premium for Energy Star Rated Buildings

Table 7 investigates the link between the energy efficiency characteristics of buildings certified by the Energy Star program and economic value as demonstrated in the marketplace. Panel A reports the results for the 774 rental buildings. It relates several measures of energy use, kBTUs of energy used per square foot, normalized for regional variation in climate characteristics by the number of degree days in the metropolitan area,[25] to the effective rents of these buildings.

Quite clearly, the energy efficiency of Energy Star-certified buildings is reflected in the effective rents these buildings command. Buildings which use less site energy, controlling for building size and the weather in the metropolitan area, have substantially higher effective rents (columns 1 and 2). When this site energy usage is reflected in dollars rather than BTUs, the relationship is even stronger (columns 5 and 6). When source energy efficiency is used, the relationship between energy usage and effective rent is still present. This may reflect an increase in rent arising from a smaller negative externality imposed upon the environment[26] (but in this case it probably just reflects the

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[24] Only one building in our rental sample and two buildings in our transactions sample report the highest level of LEED certification -- the "Platinum" level.
[25] Climate data are obtained from http://lwf.ncdc.noaa.gov/oa/ncdc.html.
[26] As postulated, for example, by Matthew J. Kotchen (2006) in a related context.

very high correlation, 0.97, between site energy consumption per square foot and source energy consumption).

Panel B reports the results for the 293 buildings which were sold during the period. The pattern of magnitudes and significance is similar. Further calculations show that a one percent increase in the site energy efficiency of a building is on average associated with an 0.13 percent higher selling price (columns 1 and 2), and a one dollar saving in energy costs is associated with a 4.9 percent premium in market valuation (columns 5 and 6). The latter corresponds to an average increase in transaction price of 13 dollar per square foot -- a capitalization rate of about eight percent. This implies that commercial property investors evaluate energy efficiency quite precisely when considering investments in real capital.

C. Summary

The results in Tables 6 and 7 provide clear evidence that the attributes of energy efficiency and sustainability associated with Energy Star-rated and LEED-rated buildings command rental premiums in the market place and that these rated buildings have higher asset values. Importantly, the results also indicate that buildings with higher sustainability scores (as measured by the LEED rating scale or the Energy Star measure of energy consumption) command correspondingly higher rents and asset values.

The findings also suggest that, *within* the population of buildings rated by one system, buildings certified by the other system are more valuable. The LEED and Energy Star certification programs measure somewhat different aspects of "sustainability,"[27] and both command higher returns in the marketplace.

[27] A recent analysis of the thermal properties of LEED-certified buildings concluded that these buildings do consume less energy, on average, than their conventional counterparts. However, 18-30 percent of LEED buildings used more energy than their counterparts. "The measured energy performance of LEED buildings

VI. Conclusion

Research on climate change suggests that small improvements in the "sustainability" of buildings can have large effects on energy efficiency in the economy. Increased awareness of global warming and the extent of greenhouse gas emissions in the real estate sector have increased attention to "green" building. In this paper, we study the dynamics of these more sustainable building practices and the private returns to the recent large-scale investments in energy-efficient office buildings.

We analyze changes in rents or investment returns between 2007 and 2009 to office buildings that were already certified in 2007, compared to buildings that were never certified. Importantly, we find that recent downturns in property markets have not significantly degraded the financial performance of "green" buildings relative to those of comparable high quality property investments.

Using data gathered in late 2009, we also estimate the increment to market rents and asset values incurred by buildings which have been certified as energy efficient or sustainable by the two major rating agencies – the U.S. Green Building Council and EPA's Energy Star. We find that "green" buildings have rents and asset prices that are significantly higher than those documented for conventional office space, while controlling specifically for differences in hedonic attributes and location using propensity score weights. We then relate the estimated premiums for green buildings to the particulars of the scoring systems that underlie certification. The analysis confirms that the attributes rated for both thermal efficiency and sustainability contribute to increases in rents and asset values.

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had little correlation with the certification level for the buildings." (Guy R. Newsham, Sandra Mancici and Benjamin Birt, 2009) In our 2009 sample, there are 248 buildings with both LEED and Energy Star certification, out of 3,723 certified office buildings. The simple correlation between the LEED scores for buildings and their site energy use per square foot (per degree day) measured by Energy Star is only 0.26 (0.22). LEED and Energy Star certifications measure different attributes of commercial buildings.

These findings have implications for investors and developers of commercial office buildings. “Green building” now accounts for a considerable fraction of the market for office space, and in some U.S. metropolitan areas certified office space extends to more than a quarter of all commercial space. Measured attributes of “sustainability” and energy efficiency are incorporated in property rents and asset prices, and this seems to persist through periods of volatility in the property market. These developments will affect the existing stock of non-certified office buildings. The findings already suggest that property investors attribute a lower risk premium to more energy efficient and sustainable commercial space. Rated buildings may provide a hedge against shifting preferences of both tenants and the capital market with respect to environmental issues. Increasing market awareness of climate change, and rising energy costs can only increase the salience of this issue for the private profitability of investment in real capital.

These findings may have broader implications for current considerations of energy conservation policies and of measures to reduce global warming and climate change. It appears that modest programs by government and by nonprofit organizations to provide information to participants in the property market do have a large payoff. Buildings certified by independent entities as “energy efficient” or “sustainable” do command economic premiums in the marketplace. Energy savings in more efficient buildings are capitalized into asset values, and this is not affected greatly by the recent volatility in the U.S. property market. These results suggest that more aggressive policies – in the U.S. and elsewhere – of certifying, rating, and publicizing buildings along these dimensions, including those buildings that score low on measures of energy efficiency, can have a large payoff in affecting energy use and perhaps the course of global warming.

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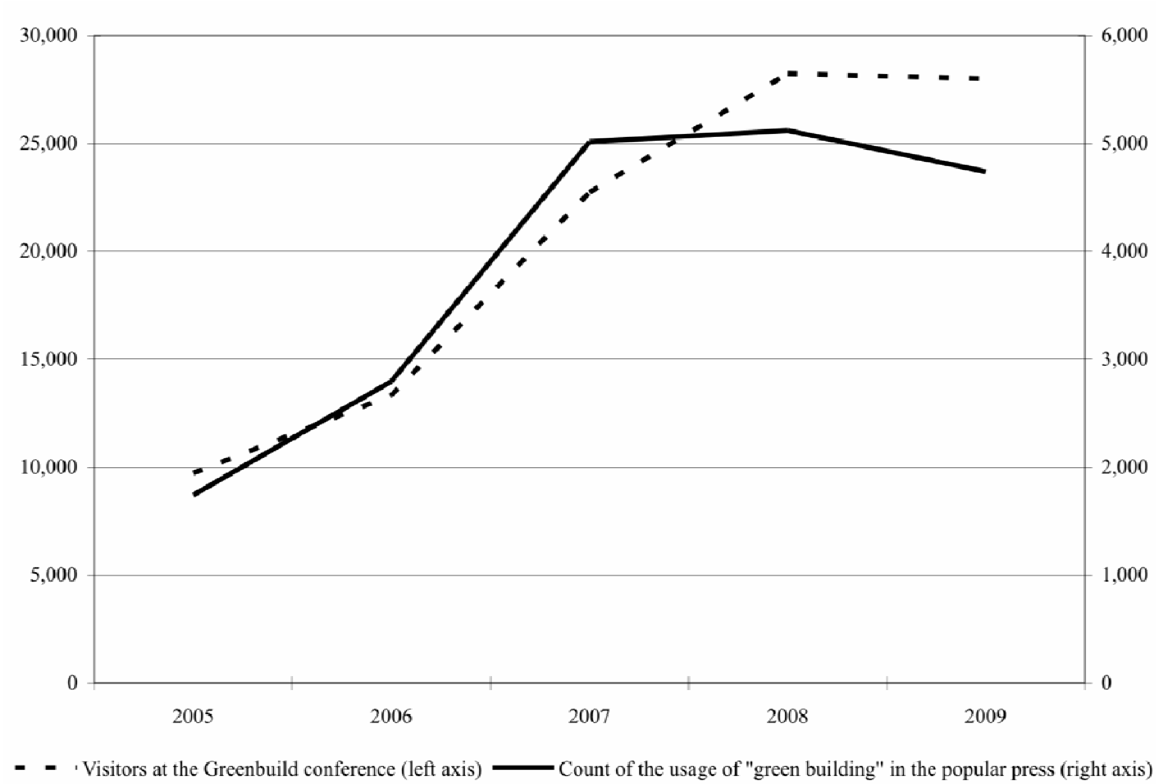
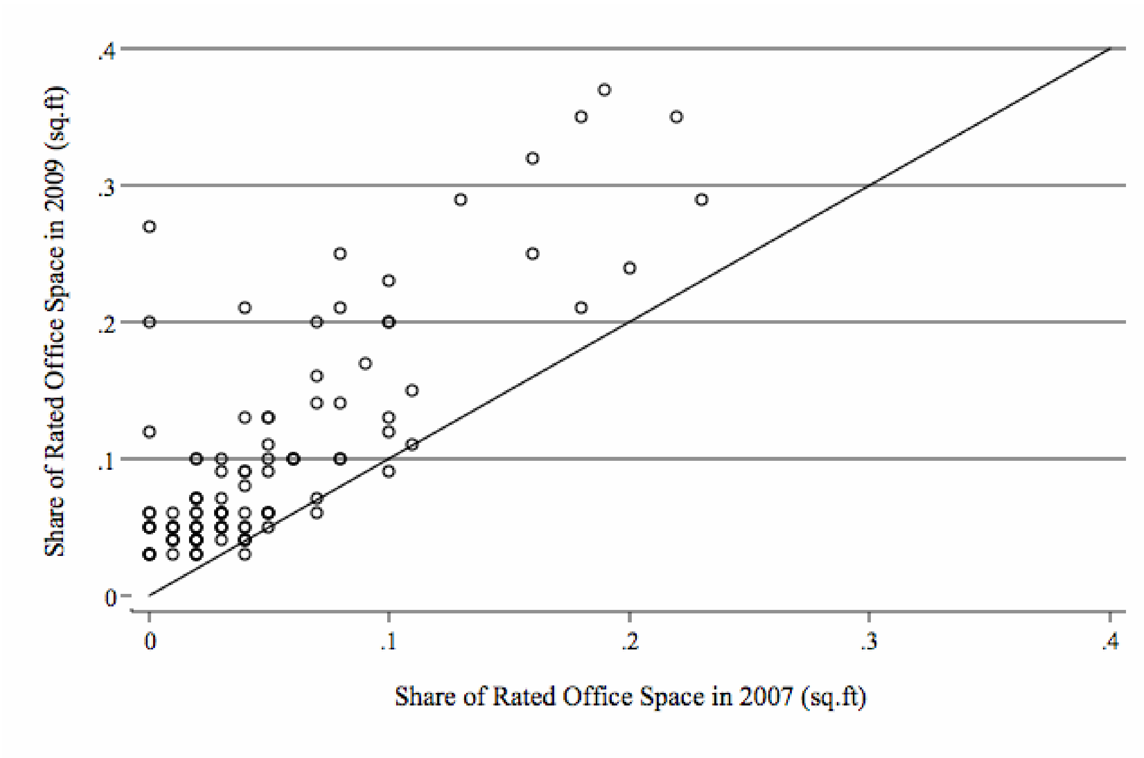
Figure 1
Indicators of Popular Attention to Green Building
2005-2009



Notes:

Sources: LexisNexis, EPA, and USGBC

Figure 2
Green Labeled Office Space as a Fraction of Total Office Space by CBSA
2007 and 2009

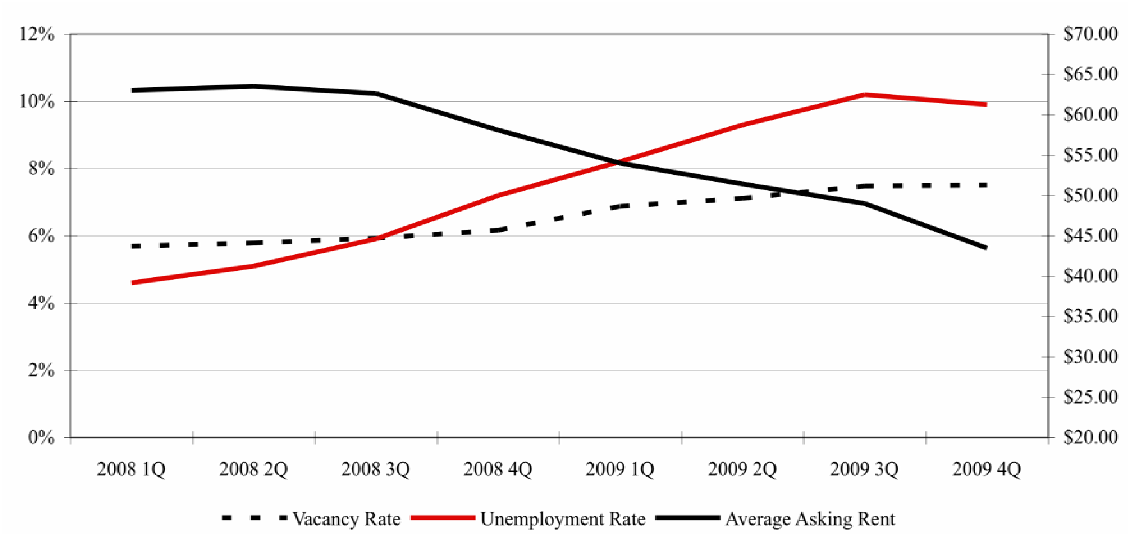


Notes:

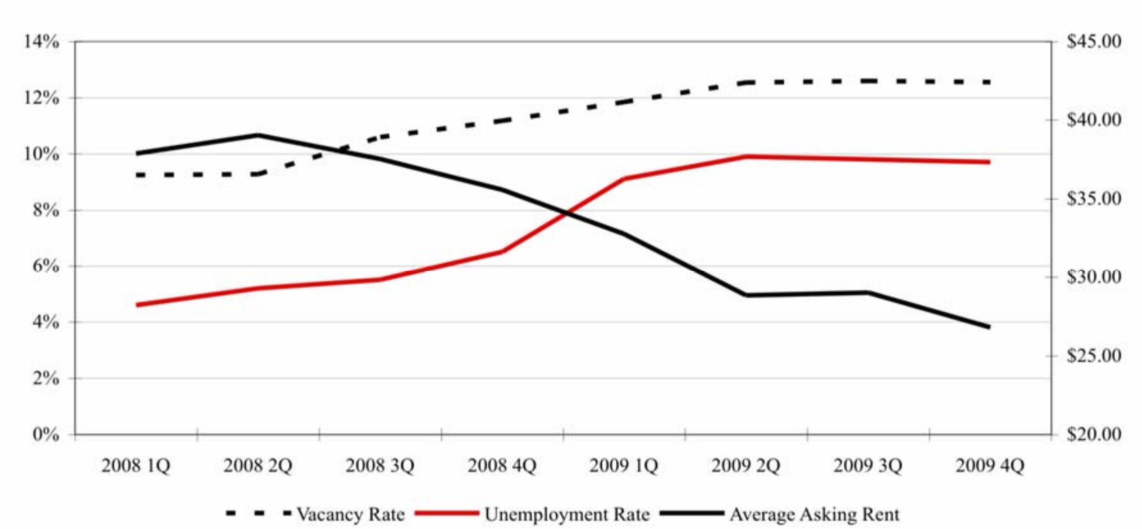
Sources: CoStar Group, EPA, and USGBC

Figure 3
Commercial Office Market Dynamics
Rents, Vacancy Rates and Unemployment
January 2008 – December 2009

A. New York Downtown Market



B. San Francisco Downtown Market

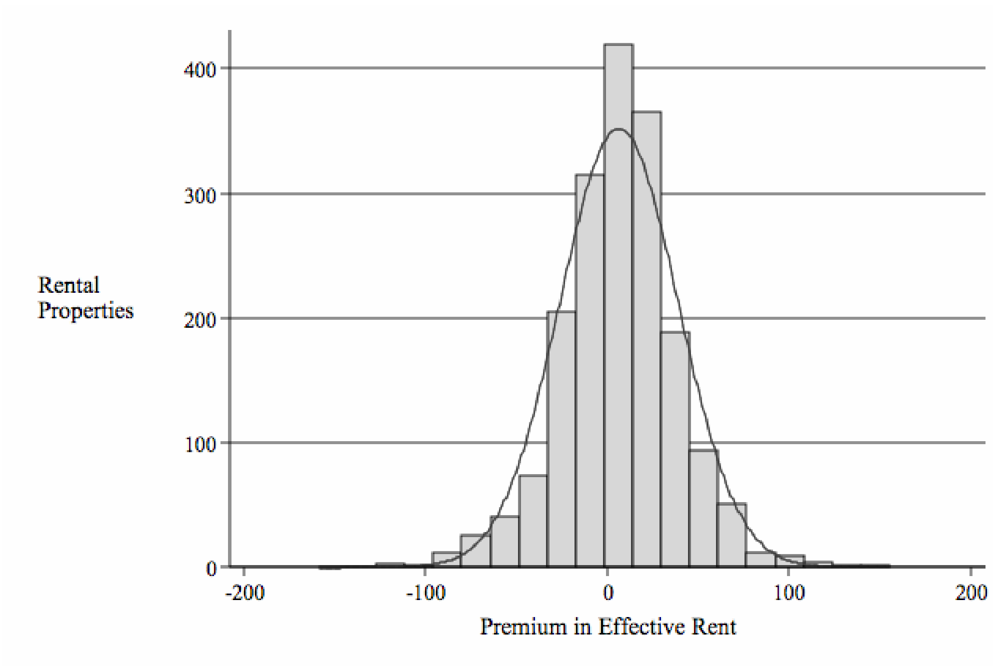


Notes:

Sources: CoStar Group and U.S. Bureau of Labor Statistics

Figure 4
Frequency Distribution of Estimated Premiums for Labeled Buildings
(in percent)

Panel A. Effective Rent



Panel B. Asset Value

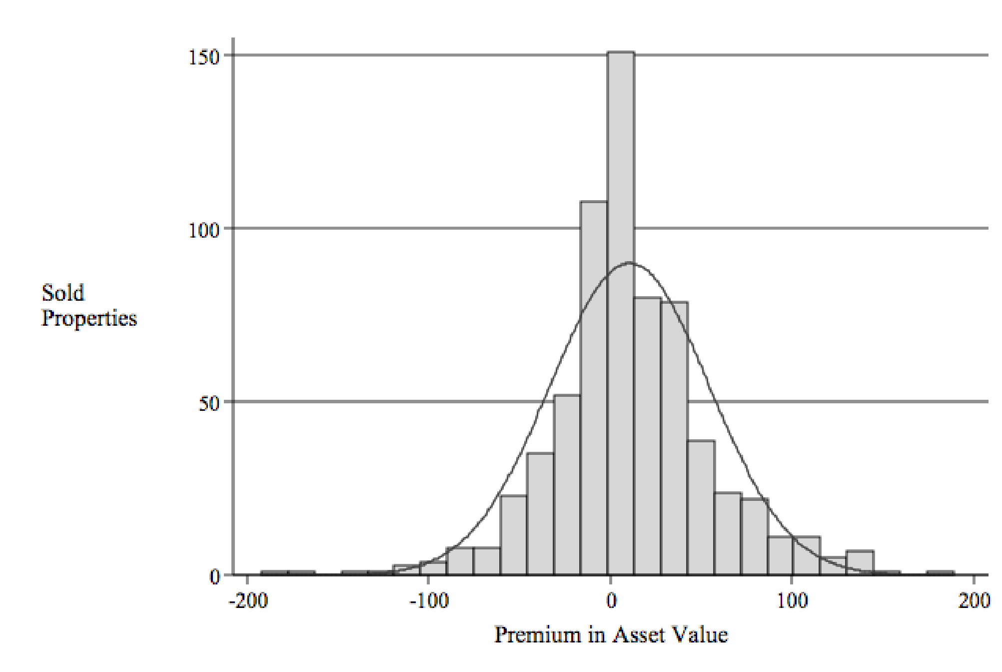


Table 1
Green Ratings, Office Rents, and Effective Rents
(Pooled observations in 2007 and 2009 based on the 2007 sample frame)

	Rent (per sq. ft.)	Effective Rent (per sq. ft)[#]
Year 2009	-0.054***	-0.075***
(1 = yes)	[0.006]	[0.008]
Green Rating	0.041***	0.075***
(1 = yes)	[0.011]	[0.014]
Green Rating in 2009	-0.029**	-0.051***
(1 = yes)	[0.014]	[0.017]
Renovated, 2007-2009	0.218***	0.065
(1 = yes)	[0.038]	[0.059]
Building Size	0.032***	0.085***
(millions of sq. ft.)	[0.005]	[0.006]
Fraction Occupied	0.015	
	[0.017]	
Building Class:		
Class A	0.143***	0.135***
(1 = yes)	[0.014]	[0.018]
Class B	0.072***	0.081***
(1 = yes)	[0.010]	[0.013]
Net Rental Contract	-0.003	0.026*
(1 = yes)	[0.012]	[0.016]
Employment Growth	-0.443***	-0.462***
(fraction)[##]	[0.073]	[0.104]
Age:		
0 – 10 years	0.110***	0.131***
(1 = yes)	[0.014]	[0.021]
10 – 20 years	0.072***	0.081***
(1 = yes)	[0.011]	[0.015]
20 – 30 years	0.046***	0.064***
(1 = yes)	[0.010]	[0.012]
30 – 40 years	0.023***	0.032***
(1 = yes)	[0.009]	[0.011]
Renovated	-0.014*	-0.019**
(1 = yes)	[0.007]	[0.009]
Stories:		
Intermediate	-0.001	0.022**
(1 = yes)	[0.008]	[0.011]
High	-0.026**	-0.031**
(1 = yes)	[0.011]	[0.015]
Amenities	0.015***	0.021***
(1=yes)[###]	[0.006]	[0.008]
Constant	2.219***	1.429***
	[0.178]	[0.200]
Sample Size	11,350	11,350
R^2	0.704	0.634
R^2 adj.	0.684	0.610

Notes:

The control sample consists of all commercial buildings within a 0.25 mile radius of each rated building observed in September 2007.

Each regression also includes a set of dummy variables, one for each of the 694 clusters of rental buildings defined in September 2007.

[#] Effective Rent equals the Asking Rent multiplied by the Occupancy Rate.

[##] Employment growth in the service sector from 2004 – 2006 for the 2007 observations, and employment growth in the service sector from 2006 – 2008 for the 2009 observations.

[###] One or more of the following amenities are available on-site: banking, convenience store, dry cleaner, exercise facilities, food court, food service, mail room, restaurant, retail shops, vending areas, fitness center.

Table 2
Logarithmic Changes in Rent and Effective Rent, 2007-2009
(Based on observations in 2007 and 2009 from the 2007 sample frame)

	Rent (per sq. ft)			Effective Rent[#] (per sq. ft)		
	(1)	(2)	(3)	(4)	(5)	(6)
Green Rating	-0.030**	-0.014	0.005	-0.052***	-0.032**	-0.010
2007 and 2009	[0.012]	[0.013]	[0.014]	[0.015]	[0.016]	[0.016]
New Green Buildings in Cluster			-0.036**			-0.024
2007 – 2009			[0.015]			[0.016]
Change in CBSA Vacancy Rate	0.157	0.258	-	0.138	0.238	-
2007 – 2009 (percent)	[0.161]	[0.157]		[0.225]	[0.224]	
Change in CBSA Office Stock	-0.098***	-0.071***	-0.130***	-0.168***	-0.116***	-0.199***
2007 – 2009 (percent)	[0.013]	[0.014]	[0.036]	[0.019]	[0.020]	[0.043]
Renovated in 2008 or 2009	0.030	0.017	0.068***	0.064	0.047	0.086**
(1 = yes)	[0.024]	[0.024]	[0.026]	[0.043]	[0.041]	[0.040]
Building Size		0.007	-0.006		0.027***	0.011
(millions of sq. ft.)		[0.005]	[0.006]		[0.008]	[0.009]
Change in Fraction Occupied		-0.023	-0.024			
2007 – 2009		[0.015]	[0.016]			
Building Class:						
Class A		-0.039**	-0.032*		-0.063***	-0.043
(1 = yes)		[0.015]	[0.019]		[0.022]	[0.026]
Class B		-0.022*	-0.014		-0.036**	-0.013
(1 = yes)		[0.013]	[0.014]		[0.018]	[0.020]
Net Rental Contract		0.026	0.010		0.057**	0.038
(1 = yes)		[0.017]	[0.021]		[0.022]	[0.026]
Employment Growth		-0.378***	0.882		-0.483***	5.266*
2006 – 2008 (percent)		[0.060]	[2.717]		[0.093]	[3.031]
Age:						
0 – 10 years		-0.055**	-0.029		-0.102***	-0.050
(1 = yes)		[0.025]	[0.028]		[0.033]	[0.040]
10 – 20 years		-0.017	-0.022		-0.044**	-0.028
(1 = yes)		[0.015]	[0.017]		[0.021]	[0.023]
20 – 30 years		-0.016	-0.008		-0.047***	-0.024
(1 = yes)		[0.010]	[0.012]		[0.014]	[0.017]
30 – 40 years		0.019	0.021		-0.0084	0.007
(1 = yes)		[0.014]	[0.015]		[0.018]	[0.020]
Renovated		0.021**	0.008		-0.004	-0.024*
(1 = yes)		[0.009]	[0.010]		[0.011]	[0.013]
Stories:						
Intermediate		0.019**	0.011		0.026**	0.007
(1 = yes)		[0.009]	[0.011]		[0.013]	[0.016]
High		0.034**	0.026		0.019	-0.003
(1 = yes)		[0.014]	[0.016]		[0.018]	[0.021]
Amenities		-0.013	-0.023***		-0.043***	-0.053***
(1=yes)[##]		[0.009]	[0.009]		[0.012]	[0.012]
Constant	-0.010	-0.089	0.101	-0.001	-0.259***	-0.173
	[0.008]	[0.059]	[0.104]	[0.011]	[0.084]	[0.126]
Location Clusters[###]	No	No	Yes	No	No	Yes
Sample Size	4,541	4,541	4,541	4,541	4,541	4,541
R^2	0.014	0.034	0.233	0.023	0.046	0.221
R^2 Adj.	0.013	0.030	0.124	0.022	0.043	0.110

Notes:

[#] Effective Rent equals the Asking Rent multiplied by the Occupancy Rate.

[##] One or more of the following amenities are available on-site: banking, convenience store, dry cleaner, exercise facilities, food court, food service, mail room, restaurant, retail shops, vending areas, fitness center.

[###] "Yes" indicates that the regression includes the set of dummy variables for 694 distinct clusters as sampled in 2007.

Table 3
Comparison of Green-Rated Buildings and Nearby Control Buildings in 2009
Rental Sample and Transactions Sample
(standard deviations in parentheses)

	Rental Sample			Sales Sample		
	Rated Buildings	Control Buildings	PSM Controls	Rated Buildings	Control Buildings	PSM Controls
Sample Size	1,943	18,858	18,858	744	5,249	5,249
Asking Rent	25.83	26.75	29.28			
(dollars/sq. ft.)	(9.67)	(12.48)	(12.12)			
Effective Rent[#]	22.28	22.70	25.24			
(dollars/sq. ft.)	(9.61)	(12.39)	(10.89)			
Sales Price				244.60	252.80	267.80
(dollars/sq. ft.)				(137.15)	(200.45)	(157.58)
Size	299.83	155.65	282.88	326.39	139.92	311.86
(thousands sq. ft.)	(292.40)	(245.73)	(176.74)	(336.85)	(275.21)	(270.99)
Occupancy Rate	85.80	83.45	85.32			
(percent)	(13.11)	(16.39)	(31.54)			
Building Class						
(percent)						
A	75.75	26.9	71.94	75.66	21.50	69.53
	(42.87)	(44.34)	(37.53)	(42.95)	(41.09)	(44.23)
B	23.21	52.73	26.90	23.47	51.16	29.24
	(42.23)	(49.93)	(12.57)	(42.41)	(49.99)	(15.16)
C	1.04	20.37	1.16	0.87	27.34	1.23
	(10.15)	(40.27)	(1.31)	(9.32)	(44.58)	(1.01)
Age	24.65	53.22	25.93	26.31	60.48	28.37
(years)	(17.36)	(34.33)	(7.56)	(19.47)	(37.29)	(9.84)
Age						
(percent)						
< 5 years	7.12	2.77	7.10	4.66	2.79	5.03
	(25.72)	(16.40)	(13.88)	(21.10)	(16.47)	(12.52)
5 to 10 years	12.92	4.23	13.68	14.14	4.35	15.32
	(33.55)	(20.12)	(21.12)	(34.87)	(20.41)	(24.95)
10 to 20 years	16.53	5.82	14.86	15.74	5.03	13.95
	(37.16)	(23.41)	(18.78)	(36.45)	(21.86)	(21.54)
20 to 30 years	44.55	22.97	37.03	45.63	18.84	36.28
	(49.72)	(42.07)	(24.49)	(49.84)	(39.11)	(29.70)
30 to 40 years	10.51	12.74	14.31	7.73	9.48	12.85
	(30.68)	(33.34)	(13.51)	(26.72)	(29.29)	(15.43)
Over 40 years	8.37	51.48	13.02	12.10	59.51	16.57
	(27.71)	(49.98)	(8.59)	(32.64)	(49.09)	(12.15)
Renovated Bldg.	24.25	40.31	26.20	27.26	43.26	30.07
(percent)	(42.87)	(49.05)	(18.39)	(44.56)	(49.55)	(23.28)
Stories	13.71	10.24	13.67	14.01	9.24	13.94
(number)	(12.64)	(10.05)	(6.95)	(12.61)	(10.28)	(8.67)
Stories						
(percent)						
Low (<10)	53.75	64.19	47.81	54.23	70.08	47.15
	(49.87)	(47.95)	(26.77)	(49.86)	(45.80)	(30.62)
Medium (10-20)	23.81	23.41	31.92	21.43	18.47	30.07
	(42.60)	(42.35)	(25.24)	(41.06)	(38.81)	(28.67)
High (>20)	22.44	12.4	20.27	24.34	11.46	22.77
	(41.73)	(32.96)	(19.48)	(42.95)	(31.85)	(24.85)

Table 3 (continued)
Comparison of Green-Rated Buildings and Nearby Control Buildings in 2009
Rental Sample and Transactions Sample
(standard deviations in parentheses)

	Rental Sample			Sales Sample		
	Rated Buildings	Control Buildings	PSM Controls	Rated Buildings	Control Buildings	PSM Controls
On-Site Amenities[##]	53.53	28.8	51.88	60.50	28.42	57.41
(percent)	(49.89)	(45.28)	(31.82)	(48.92)	(45.11)	(38.32)
Public Transport[###]	12.75	11.55	12.46	14.14	10.93	14.19
(percent)	(33.37)	(31.96)	(15.84)	(34.87)	(31.20)	(19.94)
Employment Growth	1.18	-0.07	-1.47	4.53	3.53	4.63
2006 - 2008 (percent)	(4.56)	(5.86)	(3.33)	(12.20)	(10.07)	(7.65)
Rental Contract						
(percent)						
Triple Net	22.11	14.74	22.94			
	(41.51)	(35.45)	(23.04)			
Plus Electric	7.99	8.16	9.22			
	(27.12)	(27.38)	(13.22)			
Modified Gross	1.31	7.94	2.58			
	(11.39)	(27.04)	(5.79)			
Plus All Utilities	0.82	1.34	0.64			
	(9.03)	(11.51)	(2.89)			
Gross	67.76	67.81	64.62			
	(46.75)	(46.72)	(30.07)			
Year of Sale						
(percent)						
2004				15.16	14.58	13.16
				(35.89)	(35.30)	(17.77)
2005				24.20	20.14	21.70
				(42.86)	(40.11)	(23.76)
2006				24.34	22.59	27.66
				(42.95)	(41.82)	(27.02)
2007				24.49	25.14	23.05
				(43.03)	(43.38)	(23.42)
2008				10.50	14.08	11.90
				(30.67)	(34.78)	(17.50)
2009				1.31	3.47	2.53
				(11.39)	(18.30)	(7.57)

Notes:

[#] Effective Rent equals the Asking Rent multiplied by the Occupancy Rate

[##] One or more of the following amenities are available on-site: banking, convenience store, dry cleaner, exercise facilities, food court, food service, mail room, restaurant, retail shops, vending areas, fitness center.

[###] "Yes" indicates that the regression includes the set of dummy variables for 694 distinct clusters as sampled in 2007.

Table 4
Green Ratings, Rents, and Sales Prices
(Propensity-score weighted observations, 2009 sample frame)

Dependent Variable	Rent (per sq. ft)		Effective Rent# (per sq. ft)		Sales Price (per sq. ft)	
	(1)	(2)	(3)	(4)	(5)	(6)
Green Rating	0.018***		0.047***		0.133***	
(1 = yes)	[0.003]		[0.005]		[0.017]	
Energy Star		0.0212***		0.066***		0.129***
(1 = yes)		[0.005]		[0.007]		[0.0191]
Label Vintage		-0.004**		-0.011***		-0.017*
(years)		[0.002]		[0.002]		[0.011]
LEED		0.058***		0.059***		0.111***
(1 = yes)		[0.010]		[0.015]		[0.0419]
Building Size	0.034***	0.034***	0.076***	0.075***	-0.049***	-0.049***
(millions of sq. ft.)	[0.003]	[0.003]	[0.004]	[0.004]	[0.010]	[0.010]
Fraction Occupied	-2.47e-05	-3.23e-05				
	[9.63e-05]	[9.62e-05]				
Building Class:						
Class A	0.155***	0.156***	0.163***	0.164***	0.213***	0.213***
(1 = yes)	[0.013]	[0.013]	[0.020]	[0.020]	[0.041]	[0.041]
Class B	0.094***	0.094***	0.106***	0.107***	-0.038	-0.039
(1 = yes)	[0.013]	[0.013]	[0.019]	[0.019]	[0.034]	[0.034]
Rental Contract:						
Gross	0.196***	0.195***	-0.263***	-0.263***		
(1 = yes)	[0.004]	[0.004]	[0.007]	[0.007]		
Plus Electric	0.218***	0.217***	0.302***	0.302***		
(1 = yes)	[0.009]	[0.009]	[0.013]	[0.013]		
Modified Gross	0.238***	0.237***	0.281***	0.280***		
(1 = yes)	[0.010]	[0.010]	[0.015]	[0.015]		
Plus All Utilities	0.151***	0.150***	0.153***	0.151***		
(1 = yes)	[0.022]	[0.022]	[0.033]	[0.033]		
Employment Growth	15.64***	13.55***	23.54***	20.77***	-0.052	-0.043
2006 – 2008 (percent)	[4.195]	[4.204]	[6.294]	[6.306]	[0.157]	[0.157]
Age:						
< 5 years	0.152***	0.148***	-0.080***	-0.081***	-0.024	-0.029
(1 = yes)	[0.008]	[0.008]	[0.012]	[0.012]	[0.045]	[0.045]
5 – 10 years	0.072***	0.072***	0.132***	0.133***	0.353***	0.353***
(1 = yes)	[0.007]	[0.007]	[0.010]	[0.010]	[0.034]	[0.034]
10 – 20 years	0.0731***	0.074***	0.082***	0.083***	0.115***	0.117***
(1 = yes)	[0.006]	[0.006]	[0.009]	[0.009]	[0.033]	[0.033]
20 – 30 years	0.021***	0.021***	0.015*	0.015*	0.087***	0.087***
(1 = yes)	[0.005]	[0.005]	[0.008]	[0.008]	[0.026]	[0.026]
30 – 40 years	0.004	0.004	0.002	0.002	0.045	0.045
(1 = yes)	[0.005]	[0.005]	[0.008]	[0.008]	[0.029]	[0.029]
Renovated	-0.005	-0.006	-0.029***	-0.029***	0.015	0.017
(1 = yes)	[0.004]	[0.004]	[0.005]	[0.005]	[0.019]	[0.019]
Stories:						
Intermediate	0.0524***	0.053***	0.0272***	0.028***	0.167***	0.169***
(1 = yes)	[0.004]	[0.004]	[0.006]	[0.006]	[0.023]	[0.023]
High	0.0614***	0.061***	0.021**	0.0202**	0.338***	0.335***
(1 = yes)	[0.006]	[0.006]	[0.009]	[0.009]	[0.029]	[0.029]
Amenities	-0.005	-0.005*	-0.018***	-0.019***	0.032*	0.032*
(1=yes)##	[0.003]	[0.003]	[0.005]	[0.005]	[0.019]	[0.019]
Public Transport###	0.0231***	0.023***	0.031***	0.0314***	-0.124***	-0.126***
(1=yes)	[0.006]	[0.006]	[0.009]	[0.009]	[0.026]	[0.026]

Table 4 (continued)
Green Ratings, Rents, and Sales Prices
(Propensity-score weighted observations, 2009 sample frame)

Dependent Variable	Rent (per sq. ft)		Effective Rent# (per sq. ft)		Sales Price (per sq. ft)	
	(1)	(2)	(3)	(4)	(5)	(6)
Year of Sale						
2005					0.225***	0.226***
(1 = yes)					[0.025]	[0.025]
2006					0.349***	0.350***
(1 = yes)					[0.024]	[0.024]
2007					0.443***	0.445***
(1 = yes)					[0.025]	[0.025]
2008					0.229***	0.231***
(1 = yes)					[0.030]	[0.030]
2009					0.007	0.005
(1 = yes)					[0.051]	[0.051]
Constant	0.799	0.981	-0.393	0.153	5.078***	5.083***
	[0.646]	[0.646]	[0.969]	[0.969]	[1.952]	[1.952]
Sample Size	20,801	20,801	20,801	20,801	5,993	5,993
R^2	0.833	0.834	0.736	0.737	0.662	0.662
Adj R^2	0.817	0.817	0.710	0.710	0.616	0.616

Notes:

The control sample consists of all commercial office buildings within a 0.25 mile radius of each rated building for which comparable data are available. All observations are current as of October 2009.

Each regression also includes a set of dummy variables, one for each cluster observed in 2009 containing a rated building and nearby nonrated buildings. There are 1,943 dummy variables for clusters containing rated rental buildings and 744 dummy variables for clusters containing rated buildings sold between 2004 and 2009.

Effective Rent equals the Asking Rent multiplied by the Occupancy Rate.

One or more of the following amenities are available on-site: banking, convenience store, dry cleaner, exercise facilities, food court, food service, mail room, restaurant, retail shops, vending areas, fitness center.

Public Transport is coded as one if the building is located within one quarter-mile of a public transport station, and zero otherwise.

Table 5
Detailed LEED and Energy Star Evaluations
For Rental and Transactions Samples
(standard deviations in parentheses)

	Rental Sample	Transactions Sample
A. LEED Rated Buildings		
1. Total Observations	*209*	*103*
Available Observations		
Registered LEED	121	54
Certified LEED	88	49
Certified Energy Star	110	58
2. Mean Evaluation for All Certified Buildings		
Total Points	50.27	45.00
(1 – 100)	(11.06)	(19.90)
3. Mean Evaluation for Subset of Certified Buildings		
Available Observations	40	24
Sustainable Sites	50.60	52.29
(1 – 100)	(11.22)	(18.50)
Water Efficiency	53.75	48.16
(1 – 100)	(20.34)	(18.48)
Energy& Atmosphere	37.57	42.96
(1 – 100)	(16.41)	(25.50)
Materials & Resources	44.87	60.54
(1 – 100)	(21.78)	(19.69)
Indoor Environmental Quality	55.51	77.86
(1 – 100)	(17.42)	(24.67)
Innovation	76.50	53.63
(1 – 100)	(24.28)	(10.27)
B. Energy Star Rated Buildings		
1. Total Observations		
Available Observations	1,719	638
Certified LEED	40	22
2. Mean Evaluation for Subset of Buildings		
Available Observations	774	293
Site Energy Consumption	65.15	66.64
(kBTU per sq. ft. per year)	(15.62)	(15.82)
Source Energy Consumption	198.88	203.44
(kBTU per sq. ft. per year)	(43.25)	(44.51)
Emissions	4,326.04	4,331.29
(tons of CO_2 per building per year)	(5,222.54)	(4,401.81)
Estimated Energy Cost	1.88	1.89
($ per sq.ft)	(0.54)	(0.51)
Total Degree Days	4,452.13	4,684.87
	(1,480.38)	(1,942.63)

Table 6
Sustainability Evaluations and the Premium for LEED-Rated Office Buildings

	A. Effective Rent Increment					
	(1)	(2)	(3)	(4)	(5)	(6)
Certified	0.039	0.057	0.417**	0.483**	0.435**	0.496**
(1 = yes)	[0.049]	[0.050]	[0.207]	[0.208]	[0.208]	[0.210]
LEED Score			-0.026***	-0.027***	-0.048	-0.046
			[0.010]	[0.010]	[0.032]	[0.032]
$LEED^2$			3.48e-04***	3.51e-04***	0.001	0.001
			[1.34e-04]	[1.33e-04]	[0.001]	[0.001]
$LEED^3$					-7.53e-06	-6.25e-06
					[1.01e-05]	[1.01e-05]
Energy Star		0.087*		0.094*		0.092*
(1 = yes)		[0.049]		[0.049]		[0.049]
Constant	0.079***	0.020	0.079***	0.015	0.079***	0.017
	[0.030]	[0.045]	[0.029]	[0.044]	[0.030]	[0.044]
Observations	209	209	209	209	209	209
R^2	0.003	0.018	0.036	0.053	0.039	0.055
Adj R^2	0.000	0.009	0.022	0.035	0.020	0.032
	B. Transaction Increment					
	(1)	(2)	(3)	(4)	(5)	(6)
Certified	0.192	0.223*	0.786***	0.804***	0.804***	0.814***
(1 = yes)	[0.119]	[0.119]	[0.213]	[0.211]	[0.212]	[0.211]
LEED Score			-0.037**	-0.038**	-0.123**	-0.102
			[0.015]	[0.014]	[0.060]	[0.062]
$LEED^2$			4.43e-04*	4.52e-04*	0.004*	0.003
			[2.41e-04]	[2.39e-04]	[0.002]	[0.002]
$LEED^3$					-3.13e-05	-2.38e-05
					[2.12e-05]	[2.21e-05]
Energy Star		0.195		0.184		0.144
(1 = yes)		[0.127]		[0.121]		[0.127]
Constant	0.110	-0.035	0.110	-0.027	0.110	0.003
	[0.078]	[0.122]	[0.075]	[0.117]	[0.074]	[0.120]
Observations	102	102	102	102	102	102
R^2	0.026	0.049	0.127	0.148	0.147	0.158
Adj R^2	0.016	0.029	0.101	0.113	0.111	0.114

Table 7
Energy Efficiency and the Premium for Energy-Star Rated Office Buildings

	A. Effective Rent Increment					
	(1)	(2)	(3)	(4)	(5)	(6)
Site Energy Consumption	-3.294**	-3.202**				
(kbtu/total degree days)	[1.345]	[1.349]				
Source Energy Consumption			-1.396***	-1.365***		
(kbtu/total degree days)			[0.453]	[0.455]		
Utility Bill					-0.126***	-0.124***
(dollars per sq. ft./total degree days)					[0.043]	[0.043]
LEED Certified		0.063		0.059		0.096
(1 = yes)		[0.070]		[0.070]		[0.072]
Constant	0.103***	0.099***	0.120***	0.117***	0.102***	0.099***
	[0.026]	[0.026]	[0.027]	[0.027]	[0.025]	[0.025]
Observations	774	774	774	774	730	730
R^2	0.008	0.009	0.012	0.013	0.012	0.014
Adj R^2	0.006	0.006	0.011	0.011	0.011	0.012

	B. Transaction Increment					
	(1)	(2)	(3)	(4)	(5)	(6)
Site Energy Consumption	-7.443**	-6.886**				
(kbtu/total degree days)	[3.361]	[3.329]				
Source Energy Consumption			-2.648**	-2.418**		
(kbtu/total degree days)			[1.154]	[1.144]		
Utility Bill					-0.185**	-0.168*
(dollars per sq.ft. / total degree days)					[0.091]	[0.090]
LEED Certified		0.315***		0.307***		0.315***
(1 = yes)		[0.114]		[0.114]		[0.114]
Constant	0.267***	0.243***	0.283***	0.256***	0.237***	0.214***
	[0.058]	[0.0580]	[0.061]	[0.061]	[0.049]	[0.049]
Observations	293	293	293	293	293	293
R^2	0.017	0.042	0.018	0.042	0.014	0.040
Adj R^2	0.013	0.035	0.015	0.036	0.011	0.033

Appendix Table A1
Green-Labeled Office Space by Metropolitan Area
(ranked by size of the CBSA office market in 2009)

CBSA	Percent of U.S. Office Market 2009 (sq. ft)	Percent Green Buildings 2007 (#)	Percent Green Buildings 2007 (sq. ft)	Percent Green Buildings 2009 (#)	Percent Green Buildings 2009 (sq. ft)
New York-Northern New Jersey-Long Island	11.21	0.27	2.64	0.93	10.10
Los Angeles-Long Beach-Santa Ana	5.90	1.75	16.18	2.99	25.48
Washington-Arlington-Alexandria	4.87	1.10	9.63	3.69	23.03
Chicago-Naperville-Joliet	4.66	0.62	8.49	2.06	24.68
Dallas-Fort Worth-Arlington	3.47	0.92	9.66	2.14	20.49
Boston-Cambridge-Quincy	3.30	0.81	7.03	2.03	15.79
San Francisco-Oakland-Fremont	3.04	1.75	17.99	3.97	34.70
Atlanta-Sandy Springs-Marietta	2.94	0.49	8.10	1.53	20.72
Houston-Sugar Land-Baytown	2.89	2.34	21.84	4.28	35.42
Minneapolis-St. Paul-Bloomington	1.77	1.03	15.87	2.59	32.14
Seattle-Tacoma-Bellevue	1.77	0.85	13.32	2.62	28.81
Phoenix-Mesa-Scottsdale	1.64	0.57	8.11	1.32	14.41
Denver-Aurora-Broomfield	1.60	1.91	19.26	4.86	36.86
San Diego-Carlsbad-San Marcos	1.20	1.14	9.05	2.20	16.60
San Jose-Sunnyvale-Santa Clara	1.16	0.75	5.36	1.78	11.50
Cleveland-Elyria-Mentor	1.09	0.45	4.70	0.92	10.45
Sacramento--Arden-Arcade--Roseville	1.01	0.77	10.45	2.36	20.39
Portland-Vancouver-Beaverton,	0.97	0.88	7.42	2.67	19.92
Cincinnati-Middletown	0.96	0.26	5.82	0.87	10.18
Charlotte-Gastonia-Concord	0.92	0.52	4.98	1.67	12.73
Austin-Round Rock	0.86	0.44	4.80	1.40	12.73
Riverside-San Bernardino-Ontario	0.70	0.26	2.33	0.81	10.22
Milwaukee-Waukesha-West Allis	0.69	0.72	7.50	1.84	13.74
San Antonio	0.66	0.28	10.52	0.95	14.66
Hartford-West Hartford-East Hartford	0.64	0.22	6.27	0.66	10.10

Appendix Table A2
LEED Sub Scores and the Premium for LEED-Rated Office Buildings

	(1)	(2)	(3)	(4)	(5)	(6)
A. Effective Rent Increment						
LEED Score	-0.001	-0.003	-0.026***	-0.027***		
	[0.003]	[0.003]	[0.009]	[0.009]		
$LEED^2$			3.48e-04***	3.52e-04***		
			[1.19e-04]	[1.17e-04]		
Energy Star		0.126*		0.129*		0.341**
		[0.071]		[0.068]		[0.141]
Sub Score						
Sustainable Sites					-0.006	-0.007
					[0.006]	[0.006]
Water Efficiency					0.005	0.004
					[0.003]	[0.003]
Energy & Atmosphere					0.004	-0.003
					[0.004]	[0.005]
Materials & Resources					0.002	3.29e-04
					[0.003]	[0.003]
Indoor Env. Quality					-0.001	-3.13e-04
					[0.005]	[0.004]
Innovation					5.67e-04	2.71e-04
					[0.003]	[0.003]
Constant	0.206	0.206	0.496***	0.499***	-0.068	0.084
	[0.158]	[0.157]	[0.181]	[0.178]	[0.512]	[0.482]
Observations	88	88	88	88	40	40
R^2	0.004	0.039	0.096	0.132	0.135	0.269
Adj R^2	0.008	0.016	0.074	0.101	0.022	0.109
B. Transaction Increment						
	(1)	(2)	(3)	(4)	(5)	(6)
LEED Score	-0.012***	-0.011***	-0.037***	-0.038***		
	[0.004]	[0.003]	[0.012]	[0.012]		
$LEED^2$			4.43e-04**	4.63e-04**		
			[1.98e-04]	[1.81e-04]		
Energy Star		0.406***		0.417***		0.268
		[0.138]		[0.131]		[0.233]
Sub Score						
Sustainable Sites					-5.04e-04	7.23e-04
					[0.004]	[0.004]
Water Efficiency					0.0101*	0.010*
					[0.005]	[0.005]
Energy & Atmosphere					0.013	0.008
					[0.008]	[0.009]
Materials & Resources					0.009**	0.009*
					[0.004]	[0.004]
Indoor Env. Quality					0.010*	0.010*
					[0.005]	[0.005]
Innovation					-0.015***	-0.013***
					[0.003]	[0.004]
Constant	0.780***	0.513***	0.896***	0.627***	-0.624	-0.767
	[0.162]	[0.175]	[0.164]	[0.172]	[0.596]	[0.603]
Observations	49	49	49	49	24	24
R^2	0.189	0.317	0.268	0.404	0.656	0.682
Adj R^2	0.171	0.287	0.236	0.364	0.534	0.543