The Economics 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. This paper analyzes the economics of "green" building. First, we analyze a panel of office buildings "certified" by independent rating agencies, finding that large recent increases in the supply of green buildings and the unprecedented volatility in property markets have *not* significantly affected the relative returns to green buildings. Second, we analyze a large cross section of office buildings, demonstrating that economic premiums in rent and asset values are substantial. Third, we relate the economic premiums for green buildings to their sustainability, confirming that the attributes rated for *both* thermal efficiency and sustainability contribute to premiums in rents and asset values. Even *among* green buildings, increased energy efficiency is fully capitalized into rents and asset values.

JEL codes: Q20, Q40, R33

September 2010

The Royal Institute of Chartered Surveyors, the European Center for Corporate Engagement, and the University of California Energy Institute provided financial support for this research. We are grateful to Anthony Guma of the U.S. Green Building Council (USGBC) and Alexandra Sullivan of the U.S. Environmental Protection Agency (EPA), for help in assembling, interpreting, and verifying the USGBC and EPA data used in this analysis. We are grateful for the comments of Severin Borenstein, Lucas Davis, Lynn Fisher, Richard Green, Dwight Jaffee, Alan Sanstad, and Nancy Wallace. Manaswini Rao provided excellent research assistance.

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 reflects 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 (Royal Institute of Chartered Surveyors, RICS, 2005). 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 operation, 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., December 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 and investors as well. Energy cost represents about thirty percent of operating expenses in the typical office building in the U.S. This cost is the single largest and most manageable expense in the provision of office space. Rising energy costs will 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 the issue. It reports on the occurrence of the term “green building” in the U.S. popular press. 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 devoted to green building (“Greenbuild”).

Appendix Table A1 confirms the growing importance of “green building” in the marketplace. It reports the fraction of commercial office space that is certified as green in the twenty-five largest core-based statistical areas (CBSAs) in the U.S. These buildings are certified for energy efficiency by the U.S. Environmental Protection Agency, EPA (“EnergyStar”), or certified for sustainability by the U.S. Green Building Council, USGBC (Leadership in Energy and Environmental Design, “LEED”). The Appendix shows that the inventory of certified green office space in the U.S. has increased dramatically between 2007 and 2009.[1] In some metropolitan areas, the availability of certified 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.

[1] Newly-constructed green buildings explain part of the increase, but a large share of newly-certified buildings consists of existing buildings that recently qualified for an Energy Star or LEED certificate. 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 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 in the market for commercial space. Tenants may enjoy pecuniary and non-pecuniary benefits (e.g., lower utility bills, higher employee satisfaction), and there may be economic benefits to investors (e.g., higher rents, lower risk premiums).[2]

This paper makes three contributions. First, we investigate the price dynamics of energy efficient and sustainable commercial buildings during the recent period of turmoil and of unprecedented decline in U.S. property markets. We gather and analyze a panel of certified green buildings and nearby control buildings observed in 2007 and again in 2009. The results show that large increases in the supply of green buildings during 2007-2009, and the recent downturns in property markets, have *not* significantly affected the rents of green buildings relative to those of comparable high quality property investments; the economic premium to green building has decreased slightly, but rents and occupancy rates are still higher than those of comparable properties.

Second, we analyze a much larger cross section of green buildings certified as of October 2009. We investigate the relationships between energy efficiency and sustainability, on the one hand, and the rents, effective rents (*i.e.*, rent multiplied by the occupancy rate), and the selling prices commanded by these properties, on the other hand. This sample of some 21,000 rental buildings and 6,000 buildings which have been sold facilitates an extensive analysis of comparable buildings, identified by propensity score, 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.

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

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 them. Most importantly, our analysis 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, while explicitly 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.

An important limitation of all economic research on this topic is the absence of data directly linking specific capital investments in construction or retrofit to measures of energy efficiency or sustainability.[3] There is a large engineering literature reporting the results of simulating the effects of specific investments and retrofits on subsequent energy use, but little in the way of empirical verification. There is some evidence gleaned from experiments in construction and the subsequent operation of actual green buildings, but of course these are based upon very small samples.[4]

The third aspect of our research design is intended to confront specifically this lack of economic information about direct investment costs and consequences. Our

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[3] A recent consulting study published by Davis Langdon provides some non-statistical comparisons of construction costs for LEED certified and non-certified buildings. The comparison is limited to public buildings, however, such as schools, libraries, and laboratories, and sample sizes are very small.

[4] See Benjamin Birt and Guy R. Newsham (2009) for a terse review of many of these studies -- monitoring six high performance buildings in the U.S., eleven LEED-certified buildings in the Pacific Northwest, etc. See also U.S. Green Building Council - Chicago Chapter (http://www.usgbc-chicago.org) for a detailed analysis of 25 retrofit projects in Illinois.

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 buildings certified by EPA's Energy Star program, we were granted access to the data on energy efficiency (i.e., kBTU usage per square foot) as measured and reported in the certification process. For the buildings certified by the LEED program, we obtained access to the raw data on sustainability as evaluated in the certification process. We find that, *within* the population of certified buildings, variations in energy efficiency are fully capitalized into rents and asset values. Importantly, these estimates of the capitalization of energy savings do not depend upon uncertain estimates of the costs of constructing or retrofitting buildings. We also find that variations in rents and asset values are systematically related 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 that encourage and publicize sustainable building, and it introduces the sampling frames employed in the analysis. Section III analyzes short-run price dynamics based on a panel of green commercial buildings. Section IV presents new evidence on the economic returns to the investments in green buildings. Section V analyzes the sources of increased rents and market values attributable to certification. 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 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.

In a parallel effort, the U.S. Green Building Council, 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.[5]

It is claimed that LEED-certified buildings have lower operating costs and increased asset values and that they provide healthier and safer environments for

[5] For more information on the rating procedures and measurements, see http://www.usgbc.org/leed.

occupants. It is also noted that the award of a LEED designation "demonstrate[s] an owner's commitment to environmental stewardship and social responsibility."[6]

We matched the addresses of the buildings rated in these two programs[7] 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."[8] Our match yielded 694 green office buildings for which contract rents, occupancy rates, and building characteristics could be identified in CoStar.

To investigate the effect of energy efficiency and sustainability on the returns to 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 nearby office buildings. Each small cluster – 0.2 square miles – contains one rated building and at least one nonrated nearby building.[9] 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.

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[6] 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.

[7] 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.

[8] 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.

[9] Each cluster includes exactly one treated (green) building. But clusters may overlap; thus a building may be used as a control in more than one cluster. Recognizing this in our statistical models has no effect.

In October 2009, we matched these same buildings to the then-current financial information and building characteristics maintained by CoStar. 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 2007 and 2009 financial and hedonic characteristics. All buildings are 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* buildings then-rated by the EPA or the USGBC 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 noted in Appendix Table A1. 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:

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

In this formulation R_{in} is the contract 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 one 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.[10]

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 employment, output, and earnings contracted, so did the demand for office space. For instance, average contract rents for office buildings in downtown New York 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 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. 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 returns to green buildings is to adapt the hedonic relationship described in Equation (1) to several time periods:

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

[10] In this way, we acknowledge the adage that the three most important determinants of property values are "location, location, and location." We experimented with several other definitions of the clusters, involving a trade-off between proximity and sample size, without significant differences in results.

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. The model also includes a set of 694 dummy variables, one for each of the clusters n associated with the rated buildings observed in 2007. ε_{int} is an error term, assumed iid.

Columns 1 and 2 of Table 1 present the results of estimating the hedonic model using the pooled data on office buildings observed in 2007 and 2009. In column 1, the results 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 (perhaps inducing substantial new construction). Also, nominal rents for commercial office buildings declined by about 5.4 percent between 2007 and 2009, *ceteris paribus*.

Most importantly, 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.

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:

$$(3)\quad \left[\log R_{inT} - \log R_{in\tau}\right] = \left(\alpha_T - \alpha_\tau\right) + \beta_i\left(X_{iT} - X_{i\tau}\right) + \delta g_i + \left(\varepsilon_{inT} - \varepsilon_{in\tau}\right)$$

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. $\left(X_{iT} - X_{i\tau}\right)$ is the change in the hedonic characteristics of property *i* between τ and *T*. δ is the change in the average rental increment for a green-rated building at times *T* and τ, and $\left(\varepsilon_{inT} - \varepsilon_{in\tau}\right)$ is an error term, assumed iid.

Columns 3 and 4 present the rent change models using the panel of data on the same office buildings observed in 2007 and in 2009.[11] The importance of the hedonic characteristics is permitted to vary between 2007 and 2009. In addition, rent increments γ_n (see Equation 1) are permitted to vary for each of the 694 clusters in the sample. The

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

regression results indicate that declines in nominal rents were larger in metropolitan areas where the general vacancy rate in the office market decreased. This finding is consistent with Columns 1 and 2; in regions where prior employment growth was strong, inducing increased supply, markets recorded larger declines in rents. The results also suggest that buildings that were renovated between 2007 and 2009 had significant increases in rents. Higher quality, newer buildings, where amenities are present, experienced stronger rental declines than older, "Class C" buildings.

Using this model, the estimate of the rental change for buildings that were green-rated in 2007 and 2009 is about zero. This suggests that, when controlling for price variation in hedonic and location characteristics, the rents of green buildings have remained unchanged relative to those of otherwise comparable office space.

When the change in effective rents is analyzed in column 4, the estimated magnitudes are larger, but the pattern of results is quite similar. The relative rent change estimated for buildings that are registered as green in 2007 and 2009 is negative, but this change in effective rent is insignificantly different from zero.

IV. 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 large sample of treated (green) buildings and control buildings -- 20,801 rental buildings and 5,993 buildings sold since 2004.[12]

Appendix Table A2 summarizes the information available on these samples. The table reports the means and standard deviations for a number of hedonic characteristics of

[12] Our match identified 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.

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.[13]

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.

To control for the variations in the measured and unmeasured characteristics of rated buildings and the nearby control buildings, we estimate propensity scores for all buildings in the rental sample and in the sample of transacted buildings. The propensity score specification includes all hedonic characteristics and is estimated using a logit model.[14] The third and sixth columns in the table report the mean values for the control buildings weighted by the propensity scores for those buildings.[15] 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 2 presents regression results relating the logarithm of office contract 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), and each observation is weighted by its propensity score. Column 1 presents the basic regression model, based upon 20,801 observations on rated and unrated

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[13] Employment data are obtained from http://www.bls.gov/data/#employment

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

[15] 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).

office buildings in 1,943 clusters. The coefficients for the individual location clusters are not presented.

As noted in the table, contract 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 10 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 pays separately 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.

Most important, holding all these hedonic characteristics of the buildings constant, an office building registered with LEED or Energy Star rents for a three percent premium. Presumably, tenants who pay separately for variable costs benefit more directly from the cost savings in energy efficient buildings. To test for this effect, we include interaction terms between "Green Rating" and the type of rental contract. The results show that the coefficients on the interaction terms are all negative, but insignificantly different from zero. Tenants deciding to lease space in a green building seem to be indifferent between the types of rental contracts. (Of course, this may simply reflect that, *ex ante*, the expected total cost of occupancy is no different among the various forms of rental contracts.)

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.[16] 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.[17]

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 eight percent higher than those of otherwise identical nearby non-rated buildings. This reflects the higher occupancy rates, on average, in labeled buildings. The economic implications of a green rating are somewhat stronger for buildings with a "triple net" rental contract, which indicates that tenants prefer incurring utility costs separately when leasing space in green buildings. (This more accurately reflects true energy consumption and directly rewards reduction in resource usage.) The effects of most of the other variables are qualitatively similar to those in columns 1 and 2.[18]

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. Both models include time-fixed effects to control for the price dynamics of the commercial property

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

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

[18] 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.

market. In terms of asset value, an otherwise identical green building sells for a premium of about 13 percent.

The estimated premiums for effective rents and transactions prices are different from each other, but of course the analyses are based on two different samples, which make simple comparisons of the coefficients problematic. Calculations of the ratio of the dollar value of the rental increment to the dollar value of the transactions increment indicate that the implicit discount rate used by investors is about three percent, at the point of means. This strongly suggests that property investors value the lower risk premium -- perhaps the insurance against future increases in energy prices -- inherent in certified commercial office buildings.

V. The Sources of Economic Premiums for Rated Buildings

The statistical models reported in Table 2 estimate a common percentage premium in rent or value for all rated 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]. 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 rated buildings.

For a subsample 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.

Of the 1,719 Energy Star rental buildings used in the regressions in Table 2 (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). Annual site energy consumption is about 65 kBTU per square foot for these buildings, and source energy consumption is about three times that number. We also estimate the annual site energy cost for each building, about $1.90 per square foot.[19]

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.[20]

[19] 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.

[20] 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,

The detailed USGBC data file provided information on 209 of the observations on LEED-rated rental buildings analyzed in Table 2. 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" which formed the basis for the award of a LEED certificate.[21]

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 2.

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, relating the 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 $\hat{\delta}$ as weights.[22]

materials and resources, indoor environmental quality, and innovation. However, these sample sizes are quite small.

[21] 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.

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

A. The Premium for Energy Star Rated Buildings

Table 3 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,[23] 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. Among Energy-Star certified buildings, those which use less site energy, controlling for building size and the climate in the metropolitan area, command substantially higher effective rents (columns 1 and 2). When this site energy usage is estimated in dollars rather than BTUs, the relationship is even stronger (columns 3 and 4).[24]

Panel B reports the results for the 293 Energy-Star rated buildings which were sold during the period. The pattern of magnitudes and significance is similar.

Further calculations show that a one dollar saving in energy costs of a building is on average associated with a 3.5 percent higher rent (column 2), and a one dollar saving in energy costs is associated with a 4.9 percent premium in market valuation (column 4). The former corresponds to an average increase in rents of 95 dollar cents per square foot, and an average increase in transaction price of 13 dollars per square foot -- a

[23] Climate data are obtained from http://lwf.ncdc.noaa.gov/oa/ncdc.html.

[24] A robustness check (not reported here) shows that when source energy efficiency is used, the relationship between energy usage and effective rent is still strong. This may reflect an increase in rent arising from a smaller negative externality imposed upon the environment, as postulated, for example, by Matthew J. Kotchen (2006) in a related context (but in this case it probably just reflects the very high correlation, 0.97, between site energy consumption per square foot and source energy consumption).

capitalization rate of about eight percent.[25] This strongly suggests that both tenants and property investors evaluate energy efficiency quite precisely when considering investments in real capital.

B. The Premium for LEED Rated Buildings

Table 4 investigates the link between the attributes of buildings rated by the LEED program -- the numerical evaluation of sustainability reported by the USGBC for the LEED-certified buildings -- 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.

From column 1, it appears that LEED *registration* is associated with an effective rent increment of 7.9 percent. Conditional upon this, 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 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. The relation between the rental increment and the LEED score is positive but non-linear. From Column 2, 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 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.

[25] 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 is another indication that investors value the lower risk inherent in energy efficient buildings.

Importantly, the relationship between LEED score and the effective rental premium remains significant when Energy Star certification is taken into account as well (Columns 2 and 4). These results imply that energy efficiency and other indicia of sustainability are complementary.

When the LEED score is entered as a cubic (columns 3 and 4), the individual coefficients are insignificant, but the set of coefficients is significantly different from zero (F = 4.58). The pattern of 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 rental increment is reached at a (normalized) score of 75, which corresponds to the upper threshold of the LEED "Gold" level.[26]

These results are broadly consistent with the results reported for the smaller sample of transactions in Panel B. Investors in commercial property evaluate the "greenness" of certified buildings when making investment decisions.

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 economics of these more sustainable building practices and the private returns to the recent large-scale investments in energy-efficient office buildings.

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[26] 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. We note that only one building in our rental sample and two buildings in our transactions sample report the highest level of LEED certification -- the Platinum level.

We first 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. We find that recent downturns in the economy and in property markets have not significantly degraded the financial performance of green buildings relative to those of comparable high quality property investments, *i.e.*, the economic premium for green building has slightly decreased, but relative rents have remained unchanged.

Using a large cross section of data on commercial buildings gathered in late 2009, we then 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 -- *within* the population of certified buildings -- attributes associated with greater thermal efficiency and sustainability contribute to increases in 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 a small sample 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 had little correlation with the certification level for the buildings" (Guy R. Newsham, Sandra Mancini 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

It is important to recognize that our estimate of the capitalization of energy savings does not depend upon uncertain estimates of the costs of constructing or retrofitting buildings. Actions taken by owners to reduce energy consumption to obtain certification – retrofitting buildings, but also hiring more effective building managers, or optimizating energy usage with "smart" software – yield higher rents and prices in the marketplace.

Of course, the analysis in this paper is restricted by the availability of data and the relatively early stage of the diffusion of green building practices in the marketplace. Even though we include a detailed set of control variables and propensity score weights in the analysis, this does not completely resolve differences in unobservables between our treated and control sample. Ideally, the analysis would include a longer time series with repeat observations of buildings that were certified during the sample period. Also, information on the thermal efficiency or sustainability of control buildings would allow us to distinguish more precisely between the economic returns to green labels and the actual valuation of energy efficiency and sustainability. Finally, systematic and credible evidence on the incremental construction costs of new green buildings or the costs of retrofitting existing buildings would allow for a more complete estimation of total returns to energy efficient and green construction practices.

Nonetheless, 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,

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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.

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 for more energy efficient and sustainable commercial space. Rated buildings may provide a hedge against higher energy prices, but also against the shifting preferences of both tenants and investors 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 also 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 *(i.e.,* "nudges") do have a large payoff. Buildings certified by independent entities as more 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 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, perhaps, those buildings that score low on measures of energy efficiency) can have a large payoff in affecting energy use and maybe the course of global warming.

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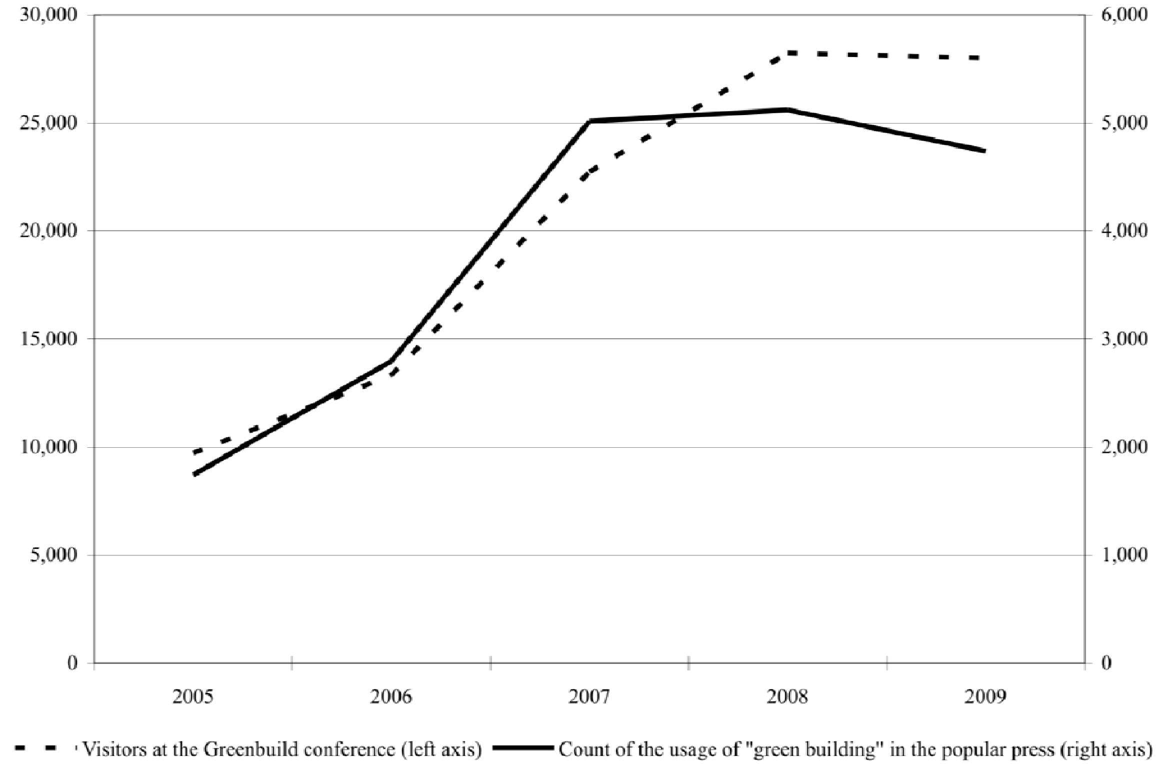
Figure 1
Indicators of Popular Attention to Green Building
2005-2009



Notes:

Sources: LexisNexis, EPA, and USGBC

Table 1
Green Ratings and Rent Dynamics
(2007 - 2009 panel of green buildings and nearby control buildings)

	Equation (2)		Equation (3)	
	Rent (per sq. ft) (1)	Effective Rent# (per sq. ft) (2)	Rent (per sq. ft) (3)	Effective Rent# (per sq. ft) (4)
Green Rating in 2007 and 2009	0.041***	0.075***	0.005	-0.010
(1 = yes)	[0.011]	[0.014]	[0.013]	[0.016]
Green Rating in 2009	-0.029**	-0.051***		
(1 = yes)	[0.014]	[0.017]		
Year 2009	-0.054***	-0.075***		
(1 = yes)	[0.006]	[0.008]		
Change in CBSA Vacancy Rate			-0.121*	-0.075
2007 – 2009 (percent)			[0.071]	[0.118]
Renovated Between 2007 – 2009	0.218***	0.065	0.068***	0.086**
(1 = yes)	[0.038]	[0.059]	[0.026]	[0.040]
Building Size	0.032***	0.085***	-0.006	0.011
(millions of sq. ft.)	[0.005]	[0.006]	[0.006]	[0.009]
Fraction Occupied##	0.015		-0.024	
2007 – 2009	[0.017]		[0.016]	
Building Class:				
Class A	0.143***	0.135***	-0.032*	-0.043
(1 = yes)	[0.014]	[0.018]	[0.019]	[0.026]
Class B	0.072***	0.081***	-0.014	-0.013
(1 = yes)	[0.010]	[0.013]	[0.014]	[0.020]
Net Rental Contract	-0.003	0.026*	0.010	0.038
(1 = yes)	[0.012]	[0.016]	[0.021]	[0.026]
Employment Growth###	-0.443***	-0.462***	0.882	0.527*
(percent)	[0.073]	[0.104]	[2.717]	[3.031]
Age:				
0 – 10 years	0.110***	0.131***	-0.029	-0.050
(1 = yes)	[0.014]	[0.021]	[0.028]	[0.040]
10 – 20 years	0.072***	0.081***	-0.022	-0.028
(1 = yes)	[0.011]	[0.015]	[0.017]	[0.023]
20 – 30 years	0.046***	0.064***	-0.008	-0.024
(1 = yes)	[0.010]	[0.012]	[0.012]	[0.017]
30 – 40 years	0.023***	0.032***	0.021	0.007
(1 = yes)	[0.009]	[0.011]	[0.015]	[0.020]
Renovated	-0.014*	-0.019**	0.008	-0.024*
(1 = yes)	[0.007]	[0.009]	[0.010]	[0.013]
Stories:				
Intermediate	-0.001	0.022**	0.011	0.007
(1 = yes)	[0.008]	[0.011]	[0.011]	[0.016]
High	-0.026**	-0.031**	0.026	-0.003
(1 = yes)	[0.011]	[0.015]	[0.016]	[0.021]
Amenities####	0.015***	0.021***	-0.023***	-0.053***
(1=yes)	[0.006]	[0.008]	[0.009]	[0.012]
Constant	2.219***	1.429***	0.066	-0.174*
	[0.178]	[0.200]	[0.080]	[0.105]
Location Clusters	Yes	Yes	Yes	Yes
Observations	11,350	11,350	4,541	4,541
R^2	0.704	0.634	0.233	0.221
Adj R^2	0.684	0.610	0.124	0.110

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 Contract Rent multiplied by the Occupancy Rate.

[##] Indicates Fraction Occupied in 2007 for the 2007 observations, and Fraction Occupied in 2009 for the 2009 observation, in Columns (1) and (2). Indicates Change in Fraction Occupied between 2007 – 2009 in Columns (3) and (4).

[###] Indicates Employment Growth between 2004 – 2006 for the 2007 observations, and Employment Growth in the service sector between 2006 – 2008 for the 2009 observations, in Columns (1) and (2). Indicates Employment Growth in the service sector between 2006 – 2008 in Columns (3) and (4).

[####] 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
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	0.026***		0.076***		0.133***	
(1 = yes)	[0.007]		[0.010]		[0.017]	
Green Rating * Gross	-0.011		-0.037***			
(1 = yes)	[0.008]		[0.012]			
Green Rating * Modified Gross	-0.024		0.016			
(1 = yes)	[0.035]		[0.053]			
Green Rating * Plus Utilities	-0.001		-0.049**			
(1 = yes)	[0.013]		[0.019]			
Energy Star		0.021***		0.065***		0.129***
(1 = yes)		[0.005]		[0.007]		[0.0191]
Label Vintage		-0.004**		-0.010***		-0.017*
(years)		[0.002]		[0.002]		[0.011]
LEED		0.058***		0.060***		0.111***
(1 = yes)		[0.010]		[0.015]		[0.0419]
Building Size	0.034***	0.034***	0.076***	0.076***	-0.049***	-0.049***
(millions of sq. ft.)	[0.003]	[0.003]	[0.004]	[0.004]	[0.010]	[0.010]
Fraction Occupied	-0.000	-0.000				
	[0.000]	[0.000]				
Building Class:						
Class A	0.156***	0.156***	0.165***	0.166***	0.213***	0.213***
(1 = yes)	[0.013]	[0.013]	[0.020]	[0.020]	[0.041]	[0.041]
Class B	0.095***	0.095***	0.107***	0.108***	-0.038	-0.039
(1 = yes)	[0.013]	[0.013]	[0.019]	[0.019]	[0.034]	[0.034]
Rental Contract:						
Gross	0.198***	0.195***	0.269***	0.263***		
(1 = yes)	[0.005]	[0.004]	[0.007]	[0.007]		
Modified Gross	0.240***	0.238***	0.283***	0.281***		
(1 = yes)	[0.010]	[0.010]	[0.015]	[0.015]		
Plus Utilities	0.213***	0.211***	0.297***	0.289***		
(1 = yes)	[0.009]	[0.009]	[0.013]	[0.013]		
Employment Growth	0.155***	0.134***	0.235***	0.205***	-0.052	-0.043
2006 – 2008 (percent)	[4.196]	[4.204]	[6.295]	[6.309]	[0.157]	[0.157]
Age:						
< 5 years	0.153***	0.148***	-0.078***	-0.081***	-0.024	-0.029
(1 = yes)	[0.008]	[0.008]	[0.012]	[0.012]	[0.045]	[0.045]
5 – 10 years	0.073***	0.072***	0.134***	0.133***	0.353***	0.353***
(1 = yes)	[0.007]	[0.007]	[0.010]	[0.010]	[0.034]	[0.034]
10 – 20 years	0.073***	0.073***	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	-0.005	-0.029***	-0.029***	0.015	0.017
(1 = yes)	[0.004]	[0.004]	[0.005]	[0.005]	[0.019]	[0.019]

Table 2 (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)
Stories:						
Intermediate	0.053***	0.053***	0.028***	0.028***	0.167***	0.169***
(1 = yes)	[0.004]	[0.004]	[0.006]	[0.006]	[0.023]	[0.023]
High	0.061***	0.061***	0.019**	0.020**	0.338***	0.335***
(1 = yes)	[0.006]	[0.006]	[0.009]	[0.009]	[0.029]	[0.029]
Amenities##	-0.005	-0.005*	-0.019***	-0.019***	0.032*	0.032*
(1=yes)	[0.003]	[0.003]	[0.005]	[0.005]	[0.019]	[0.019]
Public Transport###	0.023***	0.023***	0.032***	0.032***	-0.124***	-0.126***
(1=yes)	[0.006]	[0.006]	[0.009]	[0.009]	[0.026]	[0.026]
Constant	0.803	0.991	-0.397	-0.130	5.078***	5.083***
	[0.646]	[0.646]	[0.970]	[0.970]	[1.952]	[1.952]
Location Clusters	Yes	Yes	Yes	Yes	Yes	Yes
Time-Fixed Effects	No	No	No	No	Yes	Yes
Observations	20,801	20,801	20,801	20,801	5,993	5,993
R^2	0.833	0.834	0.736	0.736	0.662	0.662
Adj R^2	0.816	0.817	0.709	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 Contract 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 3
Energy Efficiency and the Premium for Energy-Star Rated Office Buildings
(GLS estimates)

	A. Effective Rent Increment			
	(1)	(2)	(3)	(4)
Site Energy Consumption	-3.294**	-3.202**		
(kBTU per sq. ft./total degree days)	[1.345]	[1.349]		
Utility Bill#			-0.126***	-0.124***
(dollars per sq. ft./total degree days)			[0.043]	[0.043]
LEED Certified		0.063		0.096
(1 = yes)		[0.070]		[0.072]
Constant	0.103***	0.099***	0.102***	0.099***
	[0.026]	[0.026]	[0.025]	[0.025]
Observations	774	774	730	730
R^2	0.008	0.009	0.012	0.014
Adj R^2	0.006	0.006	0.011	0.012
	B. Transactions Increment			
	(1)	(2)	(3)	(4)
Site Energy Consumption	-7.443**	-6.886**		
(kBTU per sq. ft./total degree days)	[3.361]	[3.329]		
Utility Bill#			-0.185**	-0.168*
(dollars per sq.ft. / total degree days)			[0.091]	[0.090]
LEED Certified		0.315***		0.315***
(1 = yes)		[0.114]		[0.114]
Constant	0.267***	0.243***	0.237***	0.214***
	[0.058]	[0.0580]	[0.049]	[0.049]
Observations	293	293	293	293
R^2	0.017	0.042	0.014	0.040
Adj R^2	0.013	0.035	0.011	0.033

Notes:

The utility bill is estimated 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.

Table 4
Sustainability Ratings and the Premium for LEED-Rated Office Buildings
(GLS estimates)

	A. Effective Rent Increment			
	(1)	(2)	(3)	(4)
Certified	0.417**	0.483**	0.435**	0.496**
(1 = yes)	[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		0.094*		0.092*
(1 = yes)		[0.049]		[0.049]
Constant	0.079***	0.015	0.079***	0.017
	[0.029]	[0.044]	[0.030]	[0.044]
Observations	209	209	209	209
R^2	0.036	0.053	0.039	0.055
Adj R^2	0.022	0.035	0.020	0.032
	B. Transactions Increment			
	(1)	(2)	(3)	(4)
Certified	0.786***	0.804***	0.804***	0.814***
(1 = yes)	[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		0.184		0.144
(1 = yes)		[0.121]		[0.127]
Constant	0.110	-0.027	0.110	0.003
	[0.075]	[0.117]	[0.074]	[0.120]
Observations	102	102	102	102
R^2	0.127	0.148	0.147	0.158
Adj R^2	0.101	0.113	0.111	0.114

Notes:

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.

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

Notes:

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.

Appendix Table A2
Comparison of Green-Rated Buildings and Nearby Control Buildings in 2009
(Propensity-score weighted observations; 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
Contract 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
(1 = yes)	(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
(1 = yes)	(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
(1 = yes)	(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
(1 = yes)	(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
(1 = yes)	(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
(1 = yes)	(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
(1 = yes)	(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
(1 = yes)	(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
(1 = yes)	(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
(1 = yes)	(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
(1 = yes)	(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
(1 = yes)	(41.73)	(32.96)	(19.48)	(42.95)	(31.85)	(24.85)

Appendix Table A2 (continued)
Comparison of Green-Rated Buildings and Nearby Control Buildings in 2009
(Propensity-score weighted observations; 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			
(1 = yes)	(41.51)	(35.45)	(42.05)			
Modified Gross	1.31	7.94	2.58			
(1 = yes)	(11.39)	(27.04)	(15.85)			
Plus All Utilities	8.81	9.51	9.86			
(1 = yes)	(28.36)	(29.33)	(29.81)			
Gross	69.07	75.76	67.20			
(1 = yes)	(46.23)	(42.86)	(46.95)			
Year of Sale						
(percent)						
2004				15.16	14.58	13.16
(1 = yes)				(35.89)	(35.30)	(17.77)
2005				24.20	20.14	21.70
(1 = yes)				(42.86)	(40.11)	(23.76)
2006				24.34	22.59	27.66
(1 = yes)				(42.95)	(41.82)	(27.02)
2007				24.49	25.14	23.05
(1 = yes)				(43.03)	(43.38)	(23.42)
2008				10.50	14.08	11.90
(1 = yes)				(30.67)	(34.78)	(17.50)
2009				1.31	3.47	2.53
(1 = yes)				(11.39)	(18.30)	(7.57)

Notes:

[#] Effective Rent equals the Contract 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.