THE ECONOMICS OF GREEN BUILDING

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Abstract—We analyze the economics of green building, finding that recent increases in the supply of green buildings and the volatility in property markets have not affected the returns to green buildings. We then analyze a large cross-section of office buildings, demonstrating that economic returns to energy-efficient buildings are substantial. Finally, we relate the economic premiums for green buildings to their relative efficiency in energy use—the attributes rated for thermal efficiency, as well as sustainability, contribute to premiums in rents and asset values. Among green buildings, increased energy efficiency is fully capitalized into rents and asset values.

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 that large corporations and small businesses alike can employ successfully.

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, the Energy Information Agency predicts that the construction and operation of buildings will account for about 40% of U.S. energy consumption and almost three-quarters of U.S. electricity consumption in 2011.[1] Influential analyses of climate mitigation policies have emphasized that the built environment offers a great potential for greenhouse gas abatement (Enkvist, Naucler, & Rosander, 2007; IPCC, 2007; 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 their life cycle energy consumption. Projected trends in urban growth in developed countries (Kahn, 2009) and in the urbanization of developing economies (Glaeser & Kahn, 2010, Zheng et al., 2009) suggest that the importance of energy efficiency in building will continue to increase.

But the impact of energy costs directly affects occupants and investors as well. Energy costs represent about 30% of operating expenses in the typical office building in the United States. This 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. Use of this term almost tripled between 2005 and 2010. The figure also reports a tripling during the past three years of the number of participants at Greenbuild, the major international conference devoted to green building.

Table A1 in the Appendix 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 25 largest core-based statistical areas (CBSAs) in the United States. These buildings are certified for energy efficiency (Energy Star buildings) by the U.S. Environmental Protection Agency (EPA) or for sustainability (Leadership in Energy and Environmental Design, LEED) by the U.S. Green Building Council (USGBC). The appendix shows that the inventory of certified green office space in the United States increased dramatically between 2007 and 2009.[2] In some metropolitan areas, the availability of certified office buildings 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.[3]

In this paper, we analyze the economic significance of these trends in green building on 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 such pecuniary and nonpecuniary benefits as lower utility bills and higher employee satisfaction, and there may be economic benefits to investors, including higher rents and lower risk premiums. This paper builds on our earlier research (Eichholtz, Kok, & Quigley, 2010), in

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[1] *EIA Annual Energy Outlook 2011*. See http://www.eia.gov/forecasts/aeo/index.cfm.

[2] 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 are supplied by the CoStar Group and include 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.

[3] See Kok, McGraw, and Quigley (2011) for a more detailed discussion on the diffusion and growth of green office space.

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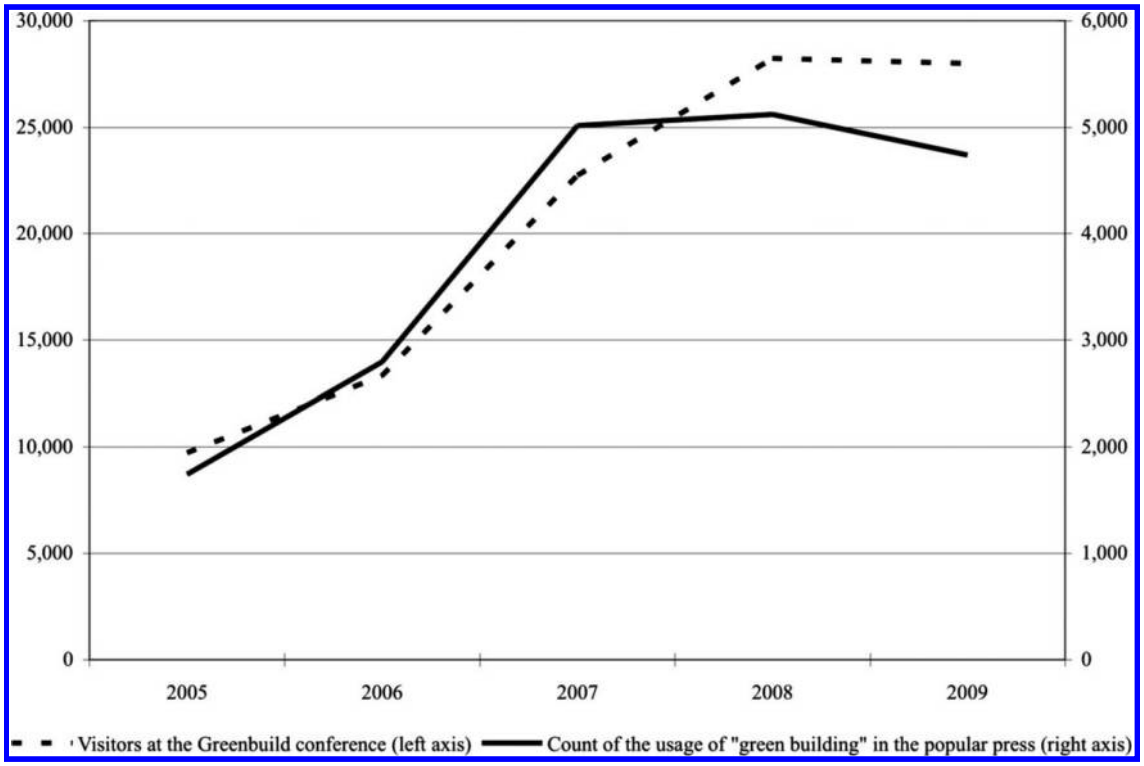
FIGURE 1.—INDICATORS OF POPULAR ATTENTION TO GREEN BUILDING, 2005–2009



LexisNexis, EPA, and USGBC.

which we provided a first exploration of green buildings in the commercial property sector, and it extends the quite limited body of existing work on the topic in three distinct ways.

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 from 2007 to 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 exploit the growth of green buildings in the marketplace and analyze a large cross-section of green buildings certified as of October 2009—some 21,000 rental buildings and 6,000 buildings that have been sold. This sample facilitates an extensive analysis of the relationships between energy efficiency and sustainability, on the one hand, and the rents, effective rents (rent multiplied by the occupancy rate), and selling prices commanded by these properties, on the other hand. We rigorously control for quality differences between rated buildings and nonrated buildings, thereby addressing concerns about the comparability of these two groups.

The propensity-score-weighted estimates show that buildings with green ratings in 2009 command higher rental rates and occupancy rates and command transaction prices that are substantially higher than those of otherwise identical office buildings, after distinguishing among contractual arrangements for the provision of services and utilities and after controlling explicitly for the quality and the specific location of the buildings. We also document that the vintage of the label is negatively related to the size of the premium, which possibly reflects technological progress in building.

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. 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.[4] Some evidence has been gleaned from experiments in construction and the subsequent operation of actual green buildings, but these are based on very small samples.[5]

[4] A consulting study by Morris and Matthiessen (2007) provides some nonstatistical comparisons of construction costs for LEED-certified and noncertified buildings. The comparison is limited to public buildings, however, such as schools, libraries, and laboratories, and sample sizes are very small.

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

The third aspect of our research design is intended to confront specifically the dearth of economic information about direct investment costs and consequences. 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 buildings certified by the LEED program, we obtained access to the raw data on sustainability as evaluated in the certification process. For the buildings certified by EPA's Energy Star program, we were granted access to the data on energy efficiency (kBTU use per square foot) as measured and reported in the certification process, allowing us to make crude estimates of the utility costs for each certified building. We find that within the population of certified buildings, variations in rents and asset values are systematically related to indicia of sustainability, which are measured in the certification process. We also find that variations in energy efficiency are fully capitalized into rents and asset values. Importantly, these estimates of the capitalization of energy savings do not depend on uncertain estimates of the costs of constructing or retrofitting buildings. These findings provide consistent and systematic evidence on the economic efficiency of the property market in valuing energy efficient and sustainable buildings relative to the stock of conventional office space.

The paper is organized as follows. Section II discusses the measurements and data sources documenting the energy efficiency or sustainability of buildings in the United States 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

Two major programs in the United States 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 EPA 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 Energy Star certification if the source energy consumption of the building achieves a specified benchmark level. "Source energy" 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. The label is awarded to the top quarter of buildings that are most efficient relative to their predicted energy consumption, which is in turn based on inferences from the Commercial Building Energy Consumption Survey (CBECS).[6] 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 usage costs and 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 its adoption in 1999, separate standards have been applied to new buildings and 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: sustainable sites, water efficiency, materials and resources, indoor environmental quality, innovation, and energy performance.[7]

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."[8]

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.[9] 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."[10] 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 com-

[6] See http://www.energystar.gov/ia/business/evaluate_performance/office_tech_desc.pdf.

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

[8] In the short time since these rating systems for buildings were developed in the United States, quite similar certification procedures have been adopted in many other countries, including the BREEAM rating system in the United Kingdom, 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 "ecolabel" for the certification of commercial and residential buildings.

[9] Energy Star–rated buildings are identified by street address in files available on the EPA website. LEED-rated buildings are identified using internal documentation provided by the USGBC.

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

mercial buildings in the same market. Based on 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 mile) contains one rated building and at least one nonrated nearby building.[11] 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.

In October 2009, we matched these same buildings to the current financial information and building characteristics maintained by CoStar. In this way, we defined a panel of commercial office buildings, including all rental buildings, that had been certified green 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.

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 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.

III. The Short-Run Price Dynamics of Green Buildings

The 2007–2009 period witnessed a substantial contraction in U.S. economic activity as the unemployment rate for full-time workers rose from 4.4% in 2007:I to 10% 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 City 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 30%. Despite these trends, the data in table A1 indicate a substantial increase in the available stock of green office space in New York City 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—on the market for green buildings. We adapt the well-known hedonic relationship between the economic characteristics of properties and their market values to model directly changes in contract rents. This isolates precisely the differential of interest:[12]

$$[\log R_{inT} - \log R_{in\tau}] = (\alpha_T - \alpha_\tau) + \beta_i(X_{iT} - X_{i\tau}) + (\delta_T g_{iT} - \delta_\tau g_{i\tau}) + (\varepsilon_{inT} - \varepsilon_{in\tau}). \quad (1)$$

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 $\tau - T$. $(X_{iT} - X_{i\tau})$ is the change in the hedonic characteristics of property i between τ and T. δ_T and δ_τ are the average rental increments for a green-rated building at times T and τ; g_{iT} and $g_{i\tau}$ are dummy variables with a value of 1 if building i is rated by Energy Star or LEED and 0 otherwise. α, β, and δ are estimated coefficients, and $(\varepsilon_{inT} - \varepsilon_{in\tau})$ is an error term, assumed to be independ and identically distributed (i.i.d.).[13]

Table 1 presents the rent change models using the panel of data on the same office buildings observed in 2007 and in 2009.[14] Column 1 is a standard first-differences model, relating rent changes to an indicator of renovations in the building between 2007 and 2009 and a measure of the metropolitan change in office vacancy rates between 2007 and 2009. The model also includes a variable measuring the change in the rental increment for buildings that were registered for energy efficiency or sustainability in 2007 and 2009.

The regression results indicate that declines in nominal rents were larger in metropolitan areas where the general vacancy rate in the office market decreased. The results also suggest that, ceteris paribus, the rents in buildings that were green-rated in 2007 and 2009 declined by an additional 3% 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. The results show that class A buildings, which represent higher-quality, newer buildings experienced stronger rental declines than class C buildings, which are typically older, smaller, and in more remote locations. In regions where prior employment growth was strong, inducing increased supply, markets

[11] 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. We also experimented with several other definitions of the clusters, involving a trade-off between proximity and sample size, without significant differences in results.

[12] An alternative method for investigating the effects of recent changes in economic conditions on the economic premiums for green buildings would simply adapt a one-period hedonic equation to multiple time periods. The results of this robustness check, reported in table A2, show that the economic premium for certified office space has decreased slightly, but rents and effective rents are still higher than those of comparable properties.

[13] In some variations of the model, we also include a set of locational dummy variables, $(\gamma_{nT} - \gamma_{n\tau}) \times c_n$, where γ_{nT} and $\gamma_{n\tau}$ are rent increments for cluster n at times T and τ and c_n is a dummy variable with a value of 1 if building i is in cluster n and 0 otherwise. In this way, we acknowledge the adage that the three most important determinants of property values are "location, location, and location."

[14] These regressions are based on the balanced panel of observations: 9,082 observations on 4,541 buildings observed in both 2007 and 2009.

TABLE 1.—GREEN RATINGS AND RENT DYNAMICS
2007—2009 PANEL OF GREEN BUILDINGS AND NEARBY CONTROL BUILDINGS

	Rent (per square foot)			Effective Rent[a] (per square foot)		
	(1)	(2)	(3)	(4)	(5)	(6)
Green rating in 2007 and 2009 (1 = yes)	−0.030**	−0.014	0.005	−0.052***	−0.032**	−0.010
	[0.012]	[0.013]	[0.013]	[0.014]	[0.016]	[0.016]
Renovated between 2007 and 2009 (1 = yes)	0.031	0.019	0.068***	0.064	0.048	0.086**
	[0.024]	[0.024]	[0.026]	[0.043]	[0.042]	[0.040]
Change in CBSA vacancy rate, 2007–2009 (%)	−0.094***	−0.065***	−0.121*	−0.165***	−0.110***	−0.075
	[0.013]	[0.014]	[0.071]	[0.019]	[0.020]	[0.118]
Building size (millions of square feet)		0.008	−0.006		0.028***	0.011
		[0.005]	[0.006]		[0.008]	[0.009]
Change in fraction occupied, 2007–2009		−0.023	−0.024			
		[0.015]	[0.016]			
Building class						
Class A (1 = yes)		−0.041***	−0.032*		−0.065***	−0.043
		[0.015]	[0.019]		[0.022]	[0.026]
Class B (1 = yes)		−0.022*	−0.014		−0.036**	−0.013
		[0.012]	[0.014]		[0.018]	[0.020]
Net rental contract (1 = yes)		0.027	0.010		0.058***	0.038
		[0.017]	[0.021]		[0.022]	[0.026]
Employment growth, 2006–2008 (%)		−0.383***	0.882		−0.488***	5.266*
		[0.060]	[2.717]		[0.093]	[3.031]
Age						
0–10 years (1 = yes)		−0.052**	−0.029		−0.099***	−0.050
		[0.024]	[0.028]		[0.033]	[0.040]
11–20 years (1 = yes)		−0.014	−0.022		−0.042**	−0.028
		[0.015]	[0.017]		[0.021]	[0.023]
21–30 years (1 = yes)		−0.014	−0.008		−0.045***	−0.024
		[0.010]	[0.012]		[0.014]	[0.017]
31–40 years (1 = yes)		0.019	0.021		−0.008	0.007
		[0.013]	[0.015]		[0.018]	[0.020]
Renovated (1 = yes)		0.021**	0.008		−0.004	−0.024*
		[0.009]	[0.010]		[0.011]	[0.013]
Stories						
Intermediate (1 = yes)		0.018*	0.011		0.025*	0.007
		[0.009]	[0.011]		[0.013]	[0.016]
High (1 = yes)		0.032**	0.026		0.017	−0.003
		[0.014]	[0.016]		[0.018]	[0.021]
Amenities (1 = yes)[b]		−0.012	−0.023***		−0.043***	−0.053***
		[0.009]	[0.009]		[0.012]	[0.012]
Constant	−0.005	−0.089	0.066	0.003	−0.258***	−0.174*
	[0.006]	[0.059]	[0.080]	[0.007]	[0.084]	[0.105]
Location clusters[c]	No	No	Yes	No	No	Yes
N	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
Adjusted R^2	0.013	0.030	0.124	0.022	0.043	0.110

Standard errors are in brackets. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively.
[a]Effective rent equals the contract rent multiplied by the occupancy rate.
[b]One or more of the following amenities are available on-site: banking, convenience store, dry cleaner, exercise facilities, food court, food service, mailroom, restaurant, retail shops, vending areas, fitness center.
[c]"Yes" indicates that the regression includes the set of dummy variables for 694 distinct clusters as sampled in 2007.

recorded larger declines in rents. The incremental rent change for buildings green-rated in 2007 and 2009 is estimated to be about 0.

In column 3, the assumption that γ_n 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 0. 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 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 as green in 2007 and in 2009 is −5% (but is insignificantly different from 0 in the most general model, column 6).

These findings show that tenant appetite for prime office space (more recently constructed class A space with amenities) decreases in more challenging economic circumstances, as postulated by consumer theory on the volatility of demand for luxury goods over the various phases of the business cycle. (See, for example, Bils & Klenow, 1998.) Controlling for this "luxury" aspect, we find no evidence that tenant demand for space rated as green or energy efficient weakened during the period of economic decline, unlike recent evidence on the negative effects of the recession on environmental concerns (Kahn & Kotchen, 2010). This may be an indication that the market values the operational cost savings in a more efficient building, independent of the stage in the business cycle.

TABLE 2.—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 (dollars/sq. ft.)	25.83	26.75	29.28			
	(9.67)	(12.48)	(12.12)			
Effective rent[a] (dollars/sq. ft.)	22.28	22.70	25.24			
	(9.61)	(12.39)	(10.89)			
Sales price (dollars/sq. ft.)				244.60	252.80	267.80
				(137.15)	(200.45)	(157.58)
Size (thousands sq. ft.)	299.83	155.65	282.88	326.39	139.92	311.86
	(292.40)	(245.73)	(176.74)	(336.85)	(275.21)	(270.99)
Occupancy rate (%)	85.80	83.45	85.32			
	(13.11)	(16.39)	(31.54)			
Building class (%)						
Class A (1 = yes)	75.75	26.9	71.94	75.66	21.50	69.53
	(42.87)	(44.34)	(37.53)	(42.95)	(41.09)	(44.23)
Class B (1 = yes)	23.21	52.73	26.90	23.47	51.16	29.24
	(42.23)	(49.93)	(12.57)	(42.41)	(49.99)	(15.16)
Class C (1 = yes)	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 (years)	24.65	53.22	25.93	26.31	60.48	28.37
	(17.36)	(34.33)	(7.56)	(19.47)	(37.29)	(9.84)
Renovated building (%)	24.25	40.31	26.20	27.26	43.26	30.07
	(42.87)	(49.05)	(18.39)	(44.56)	(49.55)	(23.28)
Stories (number)	13.71	10.24	13.67	14.01	9.24	13.94
	(12.64)	(10.05)	(6.95)	(12.61)	(10.28)	(8.67)
On-site amenities (%)[b]	53.53	28.8	51.88	60.50	28.42	57.41
	(49.89)	(45.28)	(31.82)	(48.92)	(45.11)	(38.32)
Public transport (%)[c]	12.75	11.55	12.46	14.14	10.93	14.19
	(33.37)	(31.96)	(15.84)	(34.87)	(31.20)	(19.94)
Employment growth, 2006–2008 (%)	1.18	−0.07	−1.47	4.53	3.53	4.63
	(4.56)	(5.86)	(3.33)	(12.20)	(10.07)	(7.65)
Rental contract (%)						
Triple net (1 = yes)	22.11	14.74	22.94			
	(41.51)	(35.45)	(42.05)			
Modified gross (1 = yes)	1.31	7.94	2.58			
	(11.39)	(27.04)	(15.85)			
Plus all utilities (1 = yes)	8.81	9.51	9.86			
	(28.36)	(29.33)	(29.81)			
Gross (1 = yes)	69.07	75.76	67.20			
	(46.23)	(42.86)	(46.95)			

[a]Effective rent equals the contract rent multiplied by the occupancy rate.
[b]One or more of the following amenities are available on-site: banking, convenience store, dry cleaner, exercise facilities, food court, food service, mailroom, restaurant, retail shops, vending areas, fitness center.
[c]Public transport is coded as 1 if the building is located within 0.25 mile of a public transport station and 0 otherwise.

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.[15]

Table 2 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.[16]

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 more precisely 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 the sample of transacted buildings. The propensity score specification includes all hedonic characteristics and is estimated using a logit model.[17] The third and sixth col-

[15] Our match identified 2,687 green buildings (1,943 rental buildings and 744 buildings 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.

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

[17] See Black and Smith (2004) for one example.

umns in the table report the mean values for the control buildings weighted by the propensity scores for those buildings.[18] 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.

We relate 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 by estimating

$$\log R_{in} = \alpha + \beta_i X_i + \sum_{n=1}^{N} \gamma_n c_n + \delta_{gi} + \varepsilon_{in}. \quad (2)$$

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 1 if building i is located in cluster n and 0 otherwise. g_i is a dummy variable with a value of 1 if building i is rated by EPA or USGBC and 0 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.

Table 3 presents regression results, where each observation is weighted by its propensity score. Column 1 presents the basic regression model, based on 20,801 observations on rated and unrated 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. A class A building rents for about 16% more than a class C building; a class B building rents for 10% more than a class C building. Newer buildings rent at a substantial premium. Office buildings less than twenty years old rent for a 7% premium, and those less than five years old rent at about a 15% 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, and doorman), a full gross rental contract (in which the landlord pays all variable costs) is about 20% 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 3% premium on average. 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 0. 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 contractual agreements.)

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.[19] 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% per year.[20]

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 8% higher than those of otherwise identical nearby nonrated 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 use.) The effects of the other variables are qualitatively similar to those in columns 1 and 2.[21]

In the last two columns, the models explain the selling prices of green buildings and nearby nongreen buildings that were transacted between 2004 and 2009. Both models include time-fixed effects to control for the price dynamics of the commercial property market. In terms of asset value, an otherwise identical green building sells for a premium of about 13%.

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 indi-

[18] 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).

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

[20] This quite possibly reflects technological progress in building. The award of an Energy Star rating is benchmarked to commercial buildings using survey data on building energy use (CBECS) collected several years ago.

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

TABLE 3.—GREEN RATINGS, RENTS, AND SALES PRICES
PROPENSITY-SCORE WEIGHTED OBSERVATIONS, 2009 SAMPLE FRAME

	Rent (per square foot)		Effective Rent# (per square foot)		Sales Price (per square foot)	
	(1)	(2)	(3)	(4)	(5)	(6)
Green rating (1 = yes)	0.026***		0.076***		0.133***	
	[0.007]		[0.010]		[0.017]	
Green rating × gross (1 = yes)	−0.011		−0.037***			
	[0.008]		[0.012]			
Green rating × modified gross (1 = yes)	−0.024		0.016			
	[0.035]		[0.053]			
Green rating × plus utilities (1 = yes)	−0.001		−0.049**			
	[0.013]		[0.019]			
Energy Star (1 = yes)		0.021***		0.065***		0.129***
		[0.005]		[0.007]		[0.0191]
Label vintage (years)		−0.004**		−0.010***		−0.017*
		[0.002]		[0.002]		[0.011]
LEED (1 = yes)		0.058***		0.060***		0.111***
		[0.010]		[0.015]		[0.0419]
Building size (millions of square feet)	0.034***	0.034***	0.076***	0.076***	−0.049***	−0.049***
	[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 (1 = yes)	0.156***	0.156***	0.165***	0.166***	0.213***	0.213***
	[0.013]	[0.013]	[0.020]	[0.020]	[0.041]	[0.041]
Class B (1 = yes)	0.095***	0.095***	0.107***	0.108***	−0.038	−0.039
	[0.013]	[0.013]	[0.019]	[0.019]	[0.034]	[0.034]
Rental contract						
Gross (1 = yes)	0.198***	0.195***	0.269***	0.263***		
	[0.005]	[0.004]	[0.007]	[0.007]		
Modified gross (1 = yes)	0.240***	0.238***	0.283***	0.281***		
	[0.010]	[0.010]	[0.015]	[0.015]		
Plus utilities (1 = yes)	0.213***	0.211***	0.297***	0.289***		
	[0.009]	[0.009]	[0.013]	[0.013]		
Employment growth, 2006–2008 (%)	0.155***	0.134***	0.235***	0.205***	−0.052	−0.043
	[4.196]	[4.204]	[6.295]	[6.309]	[0.157]	[0.157]
Age						
0–5 years (1 = yes)	0.153***	0.148***	−0.078***	−0.081***	−0.024	−0.029
	[0.008]	[0.008]	[0.012]	[0.012]	[0.045]	[0.045]
6–10 years (1 = yes)	0.073***	0.072***	0.134***	0.133***	0.353***	0.353***
	[0.007]	[0.007]	[0.010]	[0.010]	[0.034]	[0.034]
11–20 years (1 = yes)	0.073***	0.073***	0.082***	0.083***	0.115***	0.117***
	[0.006]	[0.006]	[0.009]	[0.009]	[0.033]	[0.033]
21–30 years (1 = yes)	0.021***	0.021***	0.015*	0.015**	0.087***	0.087***
	[0.005]	[0.005]	[0.008]	[0.008]	[0.026]	[0.026]
31–40 years (1 = yes)	0.004	0.004	0.002	0.002	0.045	0.045
	[0.005]	[0.005]	[0.008]	[0.008]	[0.029]	[0.029]
Renovated (1 = yes)	−0.005	−0.005	−0.029***	−0.029***	0.015	0.017
	[0.004]	[0.004]	[0.005]	[0.005]	[0.019]	[0.019]
Stories						
Intermediate (1 = yes)	0.053***	0.053***	0.028***	0.028***	0.167***	0.169***
	[0.004]	[0.004]	[0.006]	[0.006]	[0.023]	[0.023]
High (1 = yes)	0.061***	0.061***	0.019**	0.020**	0.338***	0.335***
	[0.006]	[0.006]	[0.009]	[0.009]	[0.029]	[0.029]
Amenities (1 = yes)[b]	−0.005	−0.005*	−0.019***	−0.019***	0.032*	0.032*
	[0.003]	[0.003]	[0.005]	[0.005]	[0.019]	[0.019]
Public transport (1 = yes)[c]	0.023***	0.023***	0.032***	0.032***	−0.124***	−0.126***
	[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
N	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
Adjusted R^2	0.816	0.817	0.709	0.710	0.616	0.616

Standard errors are in brackets. Significance at the 0.10, 0.05, and 0.01 levels indicated by *, **, and ***, respectively. 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.

[a]Effective rent equals the contract rent multiplied by the occupancy rate.

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

[c]Public transport is coded as 1 if the building is located within one quarter-mile of a public transport station and 0 otherwise.

cate that the implicit discount rate investors use is about 3% at the point of means. This strongly suggests that property investors value the lower risk premium—perhaps insurance against future increases in energy prices—inherent in certified commercial office buildings.

The results in this section complement earlier findings on the private evaluation of Energy Star and LEED labels in the commercial real estate market. Using samples that are larger in magnitude by a factor of 3, a more robust set of observables, and, importantly, propensity score weightings to reduce the disparity between the treated and nontreated sample, we document point estimates for the green increments that are just slightly (though insignificantly) smaller as those reported in Eichholtz et al. (2010).[22] The value of energy efficiency to tenants and investors persists through large increases in the supply of green space and a strong exogenous demand shock, which reinforces the findings in section III.

V. Sources of Economic Premiums for Rated Buildings

The statistical models reported in table 3 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:

$$\log R_{in} = \alpha + \beta_i X_i + \sum_{n=1}^{N} \gamma_n c_n + \sum_{n=1}^{N} \delta_n [c_n \times g_i] + \varepsilon_{in}^{**}. \quad (3)$$

In equation (3), 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 $\exp[\delta_n]$. 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, to investigate further the capitalization of relative building efficiency in the marketplace.

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.[23]

The detailed USGBC data file provided information on 209 of the observations on LEED-rated rental buildings analyzed in table 3. Of these, 121 are LEED registered and 88 are LEED certified. 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.[24] We note that more than half of the 209 LEED-rated rental buildings were also Energy Star rated (see table 4).

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 3.

Of the 1,719 Energy Star rental buildings used in the regressions in table 3 (40 of which were also LEED rated), the EPA provided the underlying measures of energy efficiency for 774 buildings. This information consists of a professional engineer's assessment of actual site energy consumption and source energy consumption (measured in thousands of British thermal units, kBTU, per square foot of space, by type of fuel). These data are evaluated as part of the certification process.[25] Table 4 reports that 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, in dollars per square foot. This estimate is obtained by combining use of natural gas, heating oil, and electricity with state average price data for natural gas and heating oil and county average price data for electricity.[26] Annual site energy cost for each building is about $1.90 per square foot.

We analyze separately the sources of the value increments for sold buildings and the 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:

$$\hat{\delta}_i = \omega Z_i + \eta_i. \quad (4)$$

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 (3)—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 (4) is estimated by

[22] The increments are also slightly smaller than the premiums recently reported by Fuerst and McAllister (2011).

[23] For an even smaller sample of buildings, the USGBC also provided the sustainability score achieved in the six components of the LEED evaluation, but these sample sizes are quite small.

[24] Several rating schemes are used by the USGBC (for example, for existing buildings, new construction, and commercial interiors); 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.

[25] Site use refers to the energy consumed in the building that is reflected in the energy bills that the owners and tenants pay. In contrast, *source energy use* 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.

[26] 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). We are grateful to Erin Mansur for providing the more detailed electricity price data.

Table 4.—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 (1 – 100)[a]	50.27	45.00
	(11.06)	(19.90)
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 (kBTU per square foot per year)[b]	65.15	66.64
	(15.62)	(15.82)
Source energy consumption (kBTU per square foot per year)[c]	198.88	203.44
	(43.25)	(44.51)
Emissions (tons of carbon dioxide per building per year)	4,326	4,331
	(5,222)	(4,401)
Estimated energy cost ($ per square foot)	1.88	1.89
	(0.54)	(0.51)
Total degree days	4,452	4,684
	(1,480)	(1,942)

[a]Several rating schemes are used by the USGBC (for example, existing buildings, new construction, commercial interiors); 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.
[b]*Site energy consumption* refers to the energy consumed in the building that is reflected in the energy bills that the owners and tenants pay.
[c]*Source energy consumption* 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.

generalized least squares (GLS) using the variance-covariance matrix of the coefficient vector $\hat{\delta}$ as weights.[27]

A. *Premium for LEED-Rated Buildings*

Table 5 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. The section on the effective rent increment 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%. Conditional on 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 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 nonlinear. From column 2, for example, it is estimated that a LEED-certified building with a normalized score of 40 (about 1 standard deviation below the average sustainability score of certified buildings) has an effective rent 2.1% higher than the rent of an otherwise identical registered building. A LEED-certified building with a normalized score of 60 (about 1 standard deviation above the average score of certified buildings) has an incremental rent almost ten times as large: 20.1%.

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.[28]

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 0 ($F = 4.58$). The pattern of coefficients suggests that the economic premium for LEED-rated buildings becomes positive only at a (normalized) score of 44, which coincides with the lower threshold for the LEED "Silver" award. The maximum rental increment is reached at a (normalized) score of 75, which corresponds to the upper threshold of the LEED "Gold" level.[29]

[27] This incorporates the precision with which each individual increment to rent or asset value is estimated (see Hanushek, 1974).

[28] 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% to 30% 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" (Newsham, Mancini, & 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.

[29] 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.

TABLE 5.—SUSTAINABILITY RATINGS AND THE PREMIUM FOR LEED-RATED OFFICE BUILDINGS (GLS ESTIMATES)

	(1)	(2)	(3)	(4)
Effective rent increment				
Certified (1 = yes)	0.417**	0.483**	0.435**	0.496**
	[0.207]	[0.208]	[0.208]	[0.210]
LEED score[a]	−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 (1 = yes)		0.094*		0.092*
		[0.049]		[0.049]
Constant	0.079***	0.015	0.079***	0.017
	[0.029]	[0.044]	[0.030]	[0.044]
N	209	209	209	209
Transactions increment				
Certified (1 = yes)	0.786***	0.804***	0.804***	0.814***
	[0.213]	[0.211]	[0.212]	[0.211]
LEED score[a]	−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 (1 = yes)		0.184		0.144
		[0.121]		[0.127]
Constant	0.110	−0.027	0.110	0.003
	[0.075]	[0.117]	[0.074]	[0.120]
N	102	102	102	102

Standard errors are in brackets. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively.
[a]Several rating schemes are used by the USGBC (including existing buildings, new construction, and commercial interiors); 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.

TABLE 6.—ENERGY EFFICIENCY AND THE PREMIUM FOR ENERGY-STAR RATED OFFICE BUILDINGS (GLS ESTIMATES)

	(1)	(2)	(3)	(4)
Effective rent increment				
Site energy consumption (kBTU per sq. ft./total degree days)	−3.294**	−3.202**		
	[1.345]	[1.349]		
Utility bill (dollars per sq. ft./total degree days)[a]			−0.126***	−0.124***
			[0.043]	[0.043]
LEED certified (1 = yes)		0.063		0.096
		[0.070]		[0.072]
Constant	0.103***	0.099***	0.102***	0.099***
	[0.026]	[0.026]	[0.025]	[0.025]
N	774	774	730	730
Transactions increment				
Site energy consumption (kBTU per sq. ft./total degree days)	−7.443**	−6.886**		
	[3.361]	[3.329]		
Utility bill (dollars per sq. ft./total degree days)[a]			−0.185**	−0.168*
			[0.091]	[0.090]
LEED certified (1 = yes)		0.315***		0.315***
		[0.114]		[0.114]
Constant	0.267***	0.243***	0.237***	0.214***
	[0.058]	[0.0580]	[0.049]	[0.049]
N	293	293	293	293

Standard errors are in brackets. Significance at the 0.10, 0.05, and 0.01 levels indicated by *, **, and ***, respectively.
[a]The utility bill is estimated by aggregating energy use 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.

These results are broadly consistent with the results reported for the smaller sample of transactions in the transactions increment. Investors in commercial property evaluate the relative greenness of certified buildings when making investment decisions, not just the presence of a certificate itself.

B. *Premium for Energy Star–Rated Buildings*

Table 6 investigates the link between the energy-efficiency characteristics of buildings certified by the Energy Star program and economic value as demonstrated in the marketplace. The first part of the table, on effective rent increments, 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, to the effective rents of these buildings.[30]

Quite clearly, the energy efficiency of Energy Star–certified buildings is reflected in the effective rents these buildings command. Among these buildings, those that 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 use is estimated in dollars rather than BTUs, the relationship is even stronger (columns 3 and 4).[31]

The second part of the table reports the results for the 293 Energy Star–rated buildings sold during the period. The pattern of magnitudes and significance is similar.

Further calculations show that within the sample of rated buildings, a \$1 saving in energy costs of a building is, on average, associated with a 3.5% higher rent (column 2), and a \$1 saving in energy costs is associated with a 4.9% premium in market valuation (column 4). The former corresponds to an average increase in rent of 95 cents per square foot and an average increase in transaction price of \$13 per square foot—a capitalization rate of about 8%.[32] This strongly suggests that both tenants and property investors evaluate energy efficiency rather precisely when considering leases or investments in real capital.

VI. Conclusion

Research on climate change suggests that small improvements in the sustainability of the existing building stock 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, expanding the limited body of evidence available on this increasingly important topic.

We first analyze changes in rents between 2007 and 2009 for office buildings that were already certified as energy efficient or sustainable by one of the two major rating agencies—the U.S. Green Building Council and EPA's Energy Star—in 2007 compared to buildings that were never certified. We find that the economic premium for green buildings decreased slightly during the recent downturn in the economy, in which the inventory of green office space increased substantially in a stagnant or declining market for commercial office space. However, these trends have not significantly degraded the financial performance of green buildings relative to those of comparable high-quality property investments; 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 more efficient buildings while controlling specifically for differences in hedonic attributes and location using propensity-score weights. The point estimates of the green increments are slightly smaller relative to those documented in earlier work (Eichholtz et al., 2010), but even when controlling quite rigorously for quality differences and incorporating a much larger set of observables, we find that green buildings have rents and asset prices that are significantly higher than those documented for conventional office space. In addition, we document that the size of the Energy Star premium is affected by both the vintage of the label and the contractual arrangements for payment of the utility bill made by tenants and building owners.

We then relate the estimated premiums for rated buildings to the particulars of the scoring systems that underlie certification. The analysis shows 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, and both command higher returns in the marketplace.

It is important to recognize that our estimate of the capitalization of energy savings does not depend on 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 optimizing energy use 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 still growing diffusion of green building practices in the marketplace. Although 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

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

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

[32] 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.

buildings would allow a more complete estimation of total returns to energy-efficient and green construction practices.

Nonetheless, our findings have implications for investors and developers of commercial office buildings and for government policies as well. 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 noncertified 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 measures to reduce global warming and climate change. It appears that modest programs by government and nonprofit organizations to provide information to participants in the property market ("nudges") have a large payoff. Buildings certified by independent entities as more energy efficient or sustainable 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 United States and elsewhere—of certifying, rating, and publicizing buildings along these dimensions (including, perhaps, 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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TABLE APPENDIX

TABLE A1.—GREEN-LABELED OFFICE SPACE BY METROPOLITAN AREA RANKED BY SIZE OF THE CBSA OFFICE MARKET, 2009

CBSA	Percent of U.S. Office Market, 2009 (square feet)	Percent Green Buildings, 2007 (number)	Percent Green Buildings, 2007 (square feet)	Percent Green Buildings, 2009 (number)	Percent Green Buildings, 2009 (square feet)
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

TABLE A1.—(CONTINUED)

CBSA	Percent of U.S. Office Market, 2009 (square feet)	Percent Green Buildings, 2007 (number)	Percent Green Buildings, 2007 (square feet)	Percent Green Buildings, 2009 (number)	Percent Green Buildings, 2009 (square feet)
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

Data on the size of commercial property markets are supplied by the CoStar Group and include "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.

TABLE A2.—GREEN RATINGS AND RENT DYNAMICS
POOLED OBSERVATIONS IN 2007 AND 2009 BASED ON THE 2007 SAMPLE FRAME

	Rent (per square foot) (1)	Effective Rent (per square foot)[a] (2)
Green rating in 2007 and 2009 (1 = yes)	0.041***	0.075***
	[0.011]	[0.014]
Green rating in 2009 (1 = yes)	−0.029**	−0.051***
	[0.014]	[0.017]
Year 2009 (1 = yes)	−0.054***	−0.075***
	[0.006]	[0.008]
Change in CBSA vacancy rate 2007–2009 (%)		
Renovated between 2007 and 2009 (1 = yes)	0.218***	0.065
	[0.038]	[0.059]
Building size (millions of square feet)	0.032***	0.085***
	[0.005]	[0.006]
Fraction occupied, 2007–2009[b]	0.015	
	[0.017]	
Building class		
Class A (1 = yes)	0.143***	0.135***
	[0.014]	[0.018]
Class B (1 = yes)	0.072***	0.081***
	[0.010]	[0.013]
Net rental contract (1 = yes)	−0.003	0.026*
	[0.012]	[0.016]
Employment growth (%)[c]	−0.443***	−0.462***
	[0.073]	[0.104]
Age		
0–10 years (1 = yes)	0.110***	0.131***
	[0.014]	[0.021]
11–20 years (1 = yes)	0.072***	0.081***
	[0.011]	[0.015]
21–30 years (1 = yes)	0.046***	0.064***
	[0.010]	[0.012]
31–40 years (1 = yes)	0.023***	0.032***
	[0.009]	[0.011]
Renovated (1 = yes)	−0.014*	−0.019**
	[0.007]	[0.009]
Stories		
Intermediate (1 = yes)	−0.001	0.022**
	[0.008]	[0.011]
High (1 = yes)	−0.026**	−0.031**
	[0.011]	[0.015]
Amenities (1 = yes)[d]	0.015***	0.021***
	[0.006]	[0.008]
Constant	2.219***	1.429***
	[0.178]	[0.200]
Location clusters	Yes	Yes
N	11,350	11,350
R^2	0.704	0.634
Adjusted R^2	0.684	0.610

Standard errors are in brackets. Significance at the 0.10, 0.05, and 0.01 levels indicated by *, **, and ***, respectively. 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.

[a] Effective rent equals the contract rent multiplied by the occupancy rate.
[b] Indicates fraction occupied in 2007 for the 2007 observations and fraction occupied in 2009 for the 2009 observation.
[c] Indicates employment growth between 2004 and 2006 for the 2007 observations and employment growth between 2006 and 2008 for the 2009 observations.
[d] One or more of the following amenities are available on-site: banking, convenience store, dry cleaner, exercise facilities, food court, food service, mailroom, restaurant, retail shops, vending areas, fitness center.