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Energy Factors, Leasing Structure and the Market Price of Office Buildings in the U.S.

Dwight Jaffee[1] · **Richard Stanton**[1] · **Nancy Wallace**[1]

Abstract

This paper presents an empirical analysis of the relation between energy factor markets, leasing structures, and the transaction prices of office buildings in the U.S. We employ a large sample of 15,133 office building transactions between 2001 and 2010. In addition to building characteristics, we also include information on the operating expenses, net operating income, and market capitalization rates at sale to estimate an asset-pricing model for commercial office real estate assets. A further set of important controls in our analysis is the forward/futures contract prices for electricity and natural gas. We also include weather metrics for each building's location and sale date. Our final set of controls includes information on the dominant contractual leasing structure of the buildings. Our empirical results suggest that Energy Star labels do not explain additional variance in property prices once the key asset-pricing factors of expenses, income and market capitalization rates are included. By contrast, energy-factor market prices, the shape of the energy forward price curves, and weather metrics are consistently significant determinants of office building transaction prices, suggesting that commercial office building prices are exposed to shocks in these markets.

Keywords Energy efficiency · Commercial real estate

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✉ Richard Stanton
stanton@haas.berkeley.edu

Dwight Jaffee
jaffee@haas.berkeley.edu

Nancy Wallace
wallace@haas.berkeley.edu

[1] Haas School of Business, University of California, Berkeley, Berkeley, CA, USA

Introduction

Real estate structures account for over 40% of U.S. energy consumption, with commercial real estate alone consuming over 18% of the total (see U.S. Department of Energy 2012). An additional sobering fact is that U.S. real estate appears to be substantially less energy-efficient than comparable European buildings, even after controlling for such factors as climate, GDP, and population.[1] There is no mystery as to the reason: U.S. costs for electricity and heating oil range from 50% to 75% of the levels in most European countries (see IEA 2009). This indicates there must be feasible technologies that would allow the energy consumption of U.S. buildings to be reduced significantly. Such investments could arise as the result of building codes and comparable requirements, or as a voluntary response to high and volatile energy prices.

In this paper, we focus on the relation between energy-efficiency certification and commercial office building transaction values. Our analysis is based on a comprehensive data set of commercial office building transactions. The data set was developed to include a rich set of controls for heterogeneous building characteristics, such as each building's capacity, quality, utilization, and lease contract structure and matched building-specific market information such as the actual capitalization rate at sale, local-level wholesale energy market price dynamics and local weather pattern dynamics at the time of sale. Our goal is to determine whether there exists a significant empirical relation between the energy performance of commercial office buildings and their transaction values, after controlling for market and building characteristics.

Our sample includes office buildings found in the CoStar data that were located in U.S. office markets with 150,000 or more employees working in the employment category *Information, Finance, and Professional and Business Services* (the major office categories).[2] We develop time- and market-specific local weather station data and energy forward contract auction data from the trading hubs appropriate to each building, and link these data to each usable transaction record in the CoStar data. Our transaction data set includes 15,133 arms-length transactions[3] for office buildings located in 43 U.S. metropolitan areas between 2001 and 2010. Importantly, these data are suitable to analyze the relation between the market transaction values of U.S. office buildings and their structural, contractual, energy- and market-related characteristics.

A second objective of the paper is to determine whether U.S. Environmental Protection Agency (EPA) Energy Star Certification — certification that a building operates in the top quartile of energy efficiency in the U.S. — affects transaction

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[1] Two reports by the International Energy Agency (IEA 2009, 2008) provide comparisons of residential energy use in the U.S. and Europe, corrected for climate and measured per unit of GDP or per capita. McKinsey (2007) also shows substantially higher energy consumption in the U.S. than in Europe, after controlling for GDP and population. Ries et al. (2009) compare energy use in the U.S., Australia and the European Union.

[2] Bureau of Labor Statistics, Employment Hours and Earnings, State and Metro Area, http://www.bls.gov/sae/data.htm.

[3] These are sales between unrelated parties.

values. To meet this objective, we obtained information on the population of Energy Star rated buildings from the EPA. The EPA list includes the exact location of the building, the numeric Energy Star rating, and the date at which the rating was granted. We merged these data with the CoStar transaction data so that we can identify all buildings that had an Energy Star rating prior to their sale date. Finally, for a subset of the transactions we have complete information on each building's total operating expenses, gross and net operating income, and capitalization rate at the sale date, along with information on the first- and second-mortgage debt structure.

A final objective of the paper is to consider the effects of the lease contracting structure on the energy certification and transaction prices of office buildings. We consider the effects of potential split incentive problems that may arise between landlords and tenants due to commonly used leasing contracts such as triple-net leases, where tenants bear the entire risk of energy cost uncertainty because utility charges are fully passed through to tenants, versus modified-gross or full-service leases, where landlords bear some or all of the energy cost uncertainty associated with the operation of buildings. Although net leases are commonly judged to be the most conducive for the alignment of tenants to energy efficiency objectives, net leases also potentially limit the incentive of landlords to carry out energy efficient building improvements, as the benefits of lower energy costs would then accrue, at least initially, to the current tenants. Thus, Energy Star certification and transaction prices are likely to be importantly associated with the leasing structures used in properties. For this part of our analysis, we rely on unique information obtained from CoStar on the dominant type of lease contracts in use in each of our sampled buildings. We find that leases are indeed important in aligning energy certification and building value.

The paper is in seven sections. In "Commercial Office Building Market Value" we discuss empirical representations for the value of commercial real estate. In "The CoStar Data" we provide details on the construction of our data sets. In "The Investor's Energy Star Rating Decision" we conduct an empirical investigation of the Energy Star rating decision of investors in commercial real estate in the U.S. "Empirical Results with Transactions Prices" presents empirical results for tests on the relation between real estate transaction prices, operating expenses, net operating income, the capitalization rate, and Energy Star labels. Section "Leases" considers the role of leasing structure on the pricing of commercial real estate assets and the contractual management of energy price passthroughs to tenants. Section "Conclusions" concludes.

Commercial Office Building Market Value

The canonical representation for the market value of a commercial real estate asset is as the discounted present value of the asset's future net operating income. The market price of a commercial office building at the investor's purchase date (P_0) can be written as

$$P_0 = \sum_{t=1}^{\infty} \frac{R_t}{(1+i_t)^t}, \tag{1}$$

where R_t is the net operating income at period t. The forward path of the net operating income is defined as the forward path of gross effective income (rent per square foot times the square footage rented minus the vacancy rate) minus the forward path of total operating expenses. The market interest rate at period t, i_t, is defined as the riskless rate plus a risk premium. Because there is rarely sufficient information about the future path of net operating income for these assets, often the current net operating income is used as a sufficient statistic for future net income, given an assumption about its future growth rate. Assuming a flat term structure, the value of a commercial real estate asset can be written as

$$P_0 = \sum_{t=1}^{\infty} \frac{R(1+g)^t}{(1+i)^t} = \frac{R}{(i-g)}, \tag{2}$$

where g is the market growth rate for net operating income and $(i-g)$ is known in the real estate industry as the "market capitalization rate."

Plazzi et al. (2010) find that metropolitan-level macroeconomic conditions appear to significantly impact the dynamics of observed growth rates in net operating income across regional markets. In addition to these growth rate dynamics, macro-economic shocks to factor input prices, such as energy and labor costs, are also likely to affect the level of net operating income, and thus the level of asset prices, through total operating expenses. An important outstanding question is the degree to which shocks to the energy factor can be mitigated by building characteristics such as the energy efficiency of building engineering systems, such as heating, air conditioning and ventilation, or low-energy-use lighting systems. To our knowledge, other than engineering simulation studies, there are no systematic empirical analyses of the relative operating efficiency of office buildings in U.S. metropolitan markets. The primary impediment to such studies is the lack of information on office building transaction prices along with information on building-level total operating expenses, gross/net operating income, capitalization rates, location, energy-use metrics, and physical characteristics of the building.

In an influential recent paper, Eichholtz et al. (2010) measure the economic value of the certification of "green buildings," which have either received an Energy Star rating or a LEED rating. They find that these buildings have asking rents (prices) that are about 3% (16%) higher per square foot than the asking rents (prices) found in otherwise spatially identical buildings. Two other studies by Wiley et al. (2010) and Fuerst and McAllister (2011) also find higher asking rents, prices, and occupancy rates for buildings with green ratings. All three of these studies test for the effects of "green" ratings using a hedonic representation of prices (asking rents) as a function of the characteristics and location of the building, including controls for whether each building was rated by LEED or Energy Star. Following the standard specification found in the hedonic pricing literature for real estate assets (see Rosen 1974), the natural log of prices, p,[4] is characterized by the set of all of its physical attributes,

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[4] The semi-log specification is used to correct for skewness in the distribution of office building prices.

found in the vector, X_i, including an indicator variable for the existence of a green rating, x_{green}, such that

$$p_i = \beta_0 + \beta_i X_i + \beta_{green} x_{green} + \epsilon_i, \tag{3}$$

where the βs are coefficients to be estimated and ϵ_i is a building-specific residual. It is further assumed that the preferences of the commercial real estate investors are solely determined by the corresponding vector of attributes, including the ratings, that define the building. In contrast to Eq. 2, the hedonic specification found in these studies does not control for the operating costs of the buildings, nor does it control for the expected metropolitan-level energy costs for the major fuels used by commercial office buildings—natural gas and electricity. Thus, the introduction of an indicator variable for "green" building ratings is likely to primarily account for the benefit stream associated with the ratings. The benefit stream would be expected to have a positive effect (i.e., positive β_{green}) although the effect on prices might be statistically insignificant. The causal determinants of this benefit, however, would be indeterminate. It could either be associated with real energy efficiency of the building (although this is unmeasured in this specification) or it could be due to the "plaque-in-the-lobby effect" or other labeling related attribute effects (see, for example, the label of an "architect-designed building," as in Vandell and Lane (1989)).

A primary contribution of this paper is to assemble a data set suitable for the empirical estimation of Eq. 2. Because Eq. 2 measures current values as a function of forward measures of fundamentals, our data requirements include forward measures for the metropolitan-level net-income growth rates, as identified by Plazzi et al. (2010), as well as building-level measures of the dynamics of key forward-looking factor-input prices. Any empirical analysis of the highly heterogeneous stock of commercial office properties must also include numerous controls for the physical and utilization characteristics of these buildings, as is typically done in the estimation of hedonic price estimates.

Another focus of our work is to consider the effect of each building's contractual leasing structure on observed total operating expenses, Energy Star ratings, and asset values. Because the contractual structure of leases stipulates the way in which utility costs (primarily gas, electricity, water and taxes) are allocated to tenants and the degree of control tenants have on these costs, we develop measures for these leasing structures and consider several different empirical specifications for the factors that are associated with the adoption of one leasing structure versus another. Finally, we consider the relation between the capital structure of commercial office buildings and their energy risk characteristics.

The CoStar Data

CoStar Group data used in our analysis consists of two separate components: the Properties data and the Comparable Transactions data. The Properties data includes information on subletting, direct, or relet space that is currently available for a large sample of office buildings in the United States. CoStar reports the "Weighted Average Rent," if there is rentable space available in the building; otherwise the

Weighted Average Rent measure appears as missing. The Weighted Average Rent is measured as the weighted average "asking rent" for the available sublet, direct, or relet office space in each building at the time the data are downloaded (in our case, August/September 2010). The property data file also includes detailed information concerning the characteristics of the available space, including the location of the building, the dominant lease contract structure in the building, the amount of leasable square footage available at the download date, an undated indicator variable for whether the building has been Energy Star rated at any time between 1999 and 2010, and the most recent sale transaction information (date of sale and sales price) if there have been recent transactions. There is also a large amount of brokerage contact information, as these data are intended for use by leasing brokers and tenants seeking to dispose of, or obtain, office space.

There are a number of problems with the use of the CoStar measure of Weighted Average Rent in a statistical analysis of the correlation of building attributes, such as indicators for energy efficiency, and the market values of commercial office buildings. First, because there can be no assurance that the CoStar quoted "asking rent" is ever achieved in any future lease transaction, these rents cannot be viewed as directly equivalent to market prices. At best these asking rents might be viewed as a noisy measure of the landlord's evaluation of the market value of the available space given the available space characteristics. A second problem is that the CoStar measure of the Weighted Average Rent does not correspond to a homogeneous combination of available rental space. Because sublet, relet, and direct space would be expected to have very different quoted and realized rents per square foot, the Weighted Average Rent cannot be readily compared across buildings. For these rents to be comparable, additional information on the amount of each type of available space and the rents for each would be required. Unfortunately, the asking rent per square foot for each type of rental space is not reported in CoStar. A final important limitation is sample-selection bias. Because the Weighted Average Rent appears as a missing value for all buildings that are fully leased, more poorly functioning buildings are likely to be systematically over-represented in the CoStar data.

Given these problems with using the CoStar Weighted Average Rent measure as a proxy for market value, we instead use the CoStar Comparable Transaction data. As previously discussed, we limit our analysis to comparable arms-length and confirmed market transactions.[5] These data again have no information on the actual rents paid by current lessors but they do have information on the actual confirmed transaction price and sale/recording dates for each office building. The data also include information on the overall building characteristics (building and lot square footage, typical floor area square footage, numbers of floors, etc), how many tenants, the location, and quality characteristics of the building, information on the first and second lien amounts, and the lien periodic payment amounts. For a subset of these data, there is

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[5] We eliminate all transactions for which there was a "non-arms-length" condition of sale due to such factors as a 1031 Exchange, a foreclosure, a sale between related entities, or a title transfer, among other conditions. All of these sale conditions would affect prices due to the trading of tax basis in the case of 1031 exchanges or the auction structure in the case of foreclosure. Instead, we focus only on market transactions between unrelated parties.

also information on the annual net operating income at sale, the market-capitalization rate at sale, and the total annual expenses at sale.

Because the Comparables, or Transaction data, represent a subset of the Properties data, or asking-rent data, in CoStar, we merge the two data sets together by building name and address to obtain leasing characteristic information for the subset of office buildings that are in both data sets. The merged set of Transactions and Property data included 15,133 office buildings with complete records on all important covariates such as building square footage or the number of tenants. We also analyze a smaller data set that includes information on the leasing structure, annual net operating income at sale, the actual cap rate at sale, and the total annual expenses at sale.

Energy Star Matching

We merged the CoStar sample of 15,133 buildings with a data set obtained from the U.S. Environmental Protection Agency (EPA) that includes every building in the U.S. that has obtained an Energy Star rating.[6] The Energy Star rating program was designed by the EPA and the U.S. Department of Energy in 1999 to promote energy efficiency in the U.S. commercial real estate sector, and thereby reduce greenhouse gas emissions. The Energy Star rating is based on comparative national data, obtained from the Commercial Building Energy Consumption Survey, which set the annual benchmarks for energy usage levels across property types. A building's energy efficiency is measured as the residual between the actual and predicted energy usage of the building using actual utility bills. To receive an Energy Star label, a building must score in the top quartile of the EPA's energy performance rating system and must meet designated indoor air-quality standards.

For each building, we obtained information on when the Energy Star rating was obtained and the level of the rating the building received.[7] The merged data sets led to 545 matches for Energy Star rated buildings. However, many of these matches were for Energy Star ratings that post-dated the actual observed transaction date.[8] Using data on the actual date of each Energy Star grant, we matched 141 buildings that had an Energy Star rating by the time of sale.

Local Weather Data Matching

The weather data were obtained from Wolfram Schlenker at Columbia University.[9] The weather station data are based on a rectangular grid system, called PRISM, that

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[6] Many buildings in this sample were Energy Star rated multiple times and these ratings are often non-monotonic in time (sometimes lower ratings are obtained at later dates). This non-monotonicity may arise because the Energy Star rating is relative to the population mean performance of office buildings. Thus, if an office building simply maintained its energy consumption profile, its ranking might fall if the overall population of U.S. buildings increases its energy efficiency.

[7] These rating vary between 75 and 100.

[8] CoStar does not account for the date the Energy Star rating was received.

[9] See http://www.columbia.edu/~ws2162/

was developed at Oregon State University and covers the contiguous United States.[10] The weather data include 471,159 grid points representing 2.5 mile squares with non-missing data. The data include the minimum and maximum temperature (Celsius) and the total precipitation (cm) for each day of a year for all of the 471,159 grids in the United States from 1950 through 2010. These data are interpolated from PRISMs monthly weather station averages to daily data and we aggregate them back into monthly data for our analysis. We associate the past twelve months of weather data for each building in the CoStar data with the weather data associated with the nearest grid point in the Schlenker data. Further details concerning the structure of the weather data are reported in Appendix B.

Energy Auction Data Matching

Incorporating information on the energy factor inputs for U.S. office building exposure requires a careful accounting for the institutional and contractual details of the regional and sub-regional gas and electricity markets in the U.S. We use data purchased from Platts (the data vendor) and compute a daily forward curve for power purchased on-peak and off-peak for all the trading hubs represented in our metropolitan areas. Platts gathers information on the power forward market from active brokers and traders and through the non-commercial departments (back offices) of companies. Since October 2007, this information has been augmented with auction prices from the Intercontinental Exchange (ICE) to form Platts forward market power daily assessment. Because more liquid locations and shorter term packages trade more frequently on ICE, while less liquid locations and longer term packages trade more frequently over-the-counter (OTC), Platts is able to combine these sources to build a comprehensive picture of the forward market. Details of the methodology are described in Appendix C.

The raw data from Platts was formatted with single entries for each forward package. For a given trading date, a power hub, and a type of contract — on- and off-peak — there are single entries for the mark-to-market price for each forward package. This scheme characterizes the term-structure of power prices for a given trading date for contracts of varying maturities. Because the hub markets are defined geographically we then develop two measures for each building: 1) the 1–12 month daily average forward price per month (a measure of the short term contract forward price) that is measured contemporaneously, with a six-month lag and with a twelve-month lag; 2) the shape of the forward curve measured as the difference between the daily average for 1–12 month and 25–36 month contracts, standardized by the number of months in the curve, that is also measured contemporaneously, with a six-month lag and with a twelve-month lag. These measures were then matched to each building according to the electricity forward market hub that serves the building's location and were matched to the observed month of the building's sale date. The electricity prices are quoted as $\$/MWh$ (Mega Watts x hour) and Platts publishes these prices as of the delivery, or flow date, of the contract. Our use of delivery prices

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[10] See http://www.prism.oregonstate.edu/

justifies our contemporaneous merges between electricity forward delivery price and the contemporaneous sale date of the building.

The resource costs (wholesale) price dynamics for natural gas are measured similarly to those of the electricity hubs. One important difference is that the natural gas market is benchmarked to a single auction at the Henry Hub. Following our strategy for the electricity prices and slopes, we measure the 1–12 month forward prices and the slopes for the Henry Hub. After the deregulation of the wholesale market for natural gas in the mid 1990s, the New York Mercantile Exchange (NYMEX) launched trading for monthly futures contracts with similar characteristics to those of crude oil. The standard NYMEX natural gas futures contract specifies physical delivery of 10,000 MMBtu (millions of British thermal unit) ratably delivered into Henry Hub - Louisiana. Until the early 2000s NYMEX provided monthly contracts covering maturities of about 36 months out. After that the range of maturities was extended and it currently covers more then six years (72 months) out on a monthly basis. The NYMEX website provides more details on how the contracts are traded and the rules for settlement.

There is also an extensive network of natural gas pipelines connecting the production basins to large consumption areas (mainly large populated urban centers) and wholesale physical natural gas trading occurs in different hubs distributed in the continental U.S. These hubs are key points in the pipeline grid characterized by either being interconnections between major pipelines and/or access points to public utility gas companies. Of all those hubs, Henry Hub is the benchmark for price quotation. Henry Hub's importance comes from its location as an interconnecting point for multiple pipelines and because it is the most liquid hub for trading spot and futures contracts. Prices for other hubs (spot and OTC forwards) are typically quoted as a basis to Henry Hub. These basis quotes are, most of the time, a very small fraction of the full benchmark quote. We follow the market conventions and compute the near natural gas price as the Henry Hub monthly average of daily 1–12 month forward prices and measure the slope as the difference between the near price and the 60–72 month forward prices. We again compute these value contemporaneously, with a six-month lag and with a 12-month lag for each date. We then merge these time series data to the date of the observed sales transactions for each office building. Other specifics of our natural gas measurement are described in Appendix C.

Summary Statistics for the CoStar Transaction Data

As previously discussed, we focus on the 43 metropolitan "office" market areas that account for the highest levels of employment in the category of *Information, Finance, and Professional and Business Services*, as measured by the Bureau of Labor Statistics in 2010.[11] We represent the office market location of the building using market area designations developed by CoStar. In Table 1, we report the frequency of office building arms-length transactions that occurred from 2001 through 2010 for which

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[11] Bureau of Labor Statistics, Employment Hours and Earnings, State and Metro Area, http://www.bls.gov/sae/data.htm.

Table 1 Market location of CoStar transaction data

CoStar market area	Number of sales	Percentage of total	Cumulative frequency	Cumulative percentage
Atlanta	915	6.05	915	6.05
Austin	93	0.61	1008	6.66
Baltimore	370	2.44	1378	9.11
Boston	510	3.37	1888	12.48
Charlotte	102	0.67	1990	13.15
Chicago	909	6.01	2899	19.16
Cincinnati/Dayton	156	1.03	3055	20.19
Cleveland	154	1.02	3209	21.21
Dallas/Fort Worth	306	2.02	3515	23.23
Denver	617	4.08	4132	27.3
Detroit	166	1.1	4298	28.4
East Bay/Oakland	188	1.24	4486	29.64
Hartford	48	0.32	4534	29.96
Houston	218	1.44	4752	31.4
Indianapolis	47	0.31	4799	31.71
Inland Empire (California)	380	2.51	5179	34.22
Kansas City	161	1.06	5340	35.29
Las Vegas	528	3.49	5868	38.78
Long Island (New York)	283	1.87	6151	40.65
Los Angeles	799	5.28	6950	45.93
Marin/Sonoma	33	0.22	6983	46.14
Milwaukee/Madison	30	0.2	7013	46.34
Minneapolis/St Paul	184	1.22	7197	47.56
Nashville	52	0.34	7249	47.9
New York City	243	1.61	7492	49.51
Northern New Jersey	637	4.21	8129	53.72
Orange (California)	464	3.07	8593	56.78
Orlando	323	2.13	8916	58.92
Philadelphia	762	5.04	9678	63.95
Phoenix	1351	8.93	11029	72.88
Pittsburgh	92	0.61	11121	73.49
Portland	179	1.18	11300	74.67
Sacramento	307	2.03	11607	76.7
San Antonio	47	0.31	11654	77.01
San Diego	292	1.93	11946	78.94
San Francisco	185	1.22	12131	80.16
Seattle/Puget Sound	410	2.71	12541	82.87

Table 1 (continued)

CoStar market area	Number of sales	Percentage of total	Cumulative frequency	Cumulative percentage
South Bay/San Jose	161	1.06	12702	83.94
South Florida	707	4.67	13409	88.61
St. Louis	119	0.79	13528	89.39
Tampa/St Petersburg	527	3.48	14055	92.88
Washington DC	1022	6.75	15077	99.63
Westchester/So Connecticut	56	0.37	15133	100

This table presents the sample of office buildings that traded in arms-length transactions between 2001 and 2010 for which we have sales price, sales date, and information on the square footage of the building. The data were obtained from the CoStar transactions data base

we have complete price and characteristic information. As shown in the table, we have good transaction coverage for all of the large U.S. office markets identified by the Bureau of Labor Statistics. Our total sample size is 15,133 office properties.

Table 2 presents the distribution of transaction dates of sale for buildings that traded in our sample. The heavy trading volumes in the years 2005 through 2007 reflect the growth of the Commercial Mortgage Backed Securities market (an important source of mortgage lending for office transactions) during this period and the transaction boom fueled by the availability of cheap credit.

Table 3 presents the distribution of office buildings in the sample that had obtained at least one Energy Star rating by 2010. As shown, we were able to match to 547 Energy Star rated buildings in the U.S. EPA Energy Star ratings reports. When we

Table 2 Transaction dates for the arms-length office building CoStar transactions

Sale year	Number of sales	Percentage of total	Cumulative frequency	Cumulative percentage
2001	10	0.07	10	0.07
2002	227	1.5	237	1.57
2003	1806	11.93	2043	13.5
2004	2457	16.24	4500	29.74
2005	2534	16.74	7034	46.48
2006	2570	16.98	9604	63.46
2007	2641	17.45	12245	80.92
2008	1757	11.61	14002	92.53
2009	935	6.18	14937	98.7
2010	196	1.3	15133	100

This table presents the frequency of trades for the office buildings in our sample. Our sample of buildings are office properties that traded in arms-length transactions between 2001 and 2010 for which we have sales price, sales date, and information on the square footage of the building. The data were obtained from the CoStar transactions data base

Table 3 Energy Star ratings frequencies between 2001 and 2010

Energy Star Status	Number of Sales	Percentage of Total	Cumulative Frequency	Cumulative Percentage
Never Energy Star rated in period	14586	96.39	14586	96.39
Energy Star rated in period	547	3.61	15133	100
Never Energy Star rated by time of Sale	14992	99.07	14992	99.07
Energy Star rated by time of Sale	141	0.93	15133	100
Total Energy Star annual ratings (1999–2010)	1222			

The upper panel of the table presents the numbers of office buildings that even received at least one Energy Star rating between 2001 and 2010. The lower panel of the table reports the number of office buildings in the sample that had an Energy Star rating by the time of their sale

further narrow the definition of the Energy Star rated buildings to buildings that were Energy Star rated at the time of their sale, we have only 141 Energy Star Ratings at the time of sale. This feature of the data arises because the incidence of Energy Star rated buildings has been growing. However, most buildings rated by Energy Star received their ratings at the end of the sample in 2008, 2009 and 2010, and typically these rating dates are several years after the properties actually sold.

In Appendix A, we map the location of the Energy Star rated buildings in the Los Angeles and San Franciso markets. The maps highlight the important geographic structure of the Energy Star rated building locations. For the most part, the Energy Star rated office buildings are located in more central locations, the Central Business District or the Sub-Regional Business District, within the CoStar Markets. A further geographic detail, which is not obvious from Table 3, is that the preponderance of these Energy Star certified buildings are located in the states of California, Florida, Texas, New York/New Jersey, and Washington DC/Maryland. Several markets have only one or two Energy Star rated buildings.

Table 4 provides summary statistics for other important characteristics of the office building transaction data. In the top panel of the table, we report summary statistics for the 1–12 month power and natural gas forward prices that were observed at the time the building traded. We also report the values for the slope of the forward curve for power and natural gas on the sale date. As reported, the average electricity forward price (in \$/MWh), that is observed at the sale date for the traded office buildings is \$68.65/MWh, the standard deviation is \$19.23/MWh, and there is considerable variability, with a high of \$161.71/MWh and a low of \$30.78/MWh. Although not shown, there is also considerable variability in these prices across hub regions, so office buildings in different hubs at the same time period experienced different prices. The average slope of the power forward curve is slightly downward sloping per month \$−0.819. However, here again there is considerable time-series and hub variation, with observations with very steep forward curves indicating expectations that power prices/MWh were expected to rise, \$13.67/MWh/month, and very steeply downward sloping forward price curves, \$−21.74/MWh/month.

Table 4 Summary statistics for office buildings sold in arms-length transactions between 2001 and 2010

Variable	N	Mean	Std. Dev.	Minimum	Maximum
Market characteristics					
Average price of the 1–12 month power forward contract by transaction hub ($\$/MWh$)	15133	68.652	19.237	30.778	161.717
Slope of the power forward curve by transaction hub ($\$/MWh/month$	15133	– 0.819	3.172	– 21.744	13.671
Average price of the 1–12 month natural gas forward contract - Henry Hub ($\$/MMBtu$)	15133	7.381	2.047	2.501	12.721
Slope of the natural gas forward curve - Henry Hub ($\$MMBtu/month$)	15133	– 0.181	0.486	– 1.657	1.005
Standard deviation of the maximum temperature (Fahrenheit)	15133	69.135	39.506	2.223	161.269
Standard deviation of the minimum temperature (Fahrenheit)	15133	58.493	32.235	1.914	133.617
Standard deviation of precipitation (Centimeters)	15133	0.045	0.039	0.000	0.366
Maximum weekly temperature over last fifty two weeks (Fahrenheit)	15133	70.021	41.223	50.299	90.860
Minimum weekly temperature over last fifty two weeks (Fahrenheit)	15133	49.320	40.008	30.954	70.363
Building characteristics					
Transaction price ($\$/sqft$)	15133	183.889	108.729	20.000	798.460
Number of floors	15133	3.437	5.201	1.000	110.000
Age of the Building (years)	15133	30.784	28.616	1.000	198.000
Typical floor area square footage	15133	14058.730	18890.540	1000.000	455304.000
Building size (Square Feet)	15133	54747.950	122254.480	360.000	3781045.000
Indicator Variable for Multi-Tenant Building	15133	0.436	0.496	0.000	1.000
Indicator variable for class A buildings	15133	0.123	0.328	0.000	1.000
Indicator variable for renovation prior to year of sale	15133	0.013	0.114	0.000	1.000
Total expenses per square foot at year of sale ($\$/sqft$)	1470	6.843	4.083	2.040	73.105
Net operating income per square foot at year of sale ($\$/sqft$)	1527	11.910	6.977	4.034	71.489
Market capitalization rate at year of sale (%)	2322	7.733	1.563	2.800	13.140

This table presents the summary statistics for buildings that sold in arms-length transactions between 2001 and 2010. The transactions data were obtained from the CoStar Transactions data base. The energy factor price data were obtained from Platts. The weather and precipitation data were obtained from Wolfram Schlenker

As previously discussed, the natural gas forward prices only vary in the time series, as we measure all buildings at the Henry Hub benchmark forward price following industry convention. As shown in Table 4, the average forward price (in \$/MMBtu) is \$7.38 with a standard deviation of \$2.047. The maximum price was less that twice the average price. The observed slope of the forward curve at the transaction date was slightly negative at $\$-0.18$ MMBtu/month and, similar to the power markets, the minimum and maximum values vary between positively and negatively sloped forward price curves.

The upper panel of Table 4 provides summary statistics for the local weather and energy markets for the twelve months prior to the sale date of the property. We report the average standard deviation of weather data for the minimum temperature, maximum temperature, and the precipitation over the prior twelve months for each building. As shown, the average standard deviation for the maximum temperatures was 69.14 degrees Fahrenheit and was 58.49 degrees Fahrenheit for the minimum temperatures. The precipitation standard deviations are significantly smaller at .045. We also develop two other weather measures: i) the maximum of the weekly median temperatures over the last fifty two weeks and ii) the minimum of the weekly median temperatures over the past fifty two weeks. These measures are intended to control for the effects on the building of extremes in weather exposure in the year prior to the building sale date. As shown in Table 4, there is considerable heterogeneity in these variables across locations and years.

In the lower panel of Table 4, we report summary statistics for the trading price and the building characteristics of the arms-length transactions. The average observed price per square foot was \$183.89, with a standard deviation of \$108.72 per square foot, and the average building size was 54,747.95 square feet with a standard deviation of 122,254.48 square feet. The average number of floors was 3.44 and the largest building had 110 floors. The typical rented square footage per tenant was 14,058.73 square feet in these buildings and the standard deviation was 18,890.54. 44% of the buildings in the transaction data are multi-tenant buildings and 12% of the buildings are class A buildings. Only 1.3% of the buildings in the sample were renovated prior to the sale.

For a subset of the transaction data, we have information on the net operating income, total operating expenses, and observed capitalization rate at the time of sale.[12] As reported in the bottom panel of Table 4, for the sub-sample of sales, the average net operating income per square foot at the time of sale was \$11.91 and the standard deviation was \$6.98. The total expenses per square foot at the time of sale was \$6.84 and the standard deviation was \$4.08. Finally, the observed capitalization rate at the time of sale was 7.73% with a minimum value of 2.8% and 13.14% over the period 2001 to 2010.

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[12] The capitalization rate is the discount rate that translates the observed net operating income into the observed transaction price at the time of sale, assuming an infinite investment horizon,

$$\sum_{t=1}^{\infty} \frac{\text{NOI}}{\text{capitalization rate}} = \text{Sales Price.}$$

The Investor's Energy Star Rating Decision

We first consider the exogenous factors that may lead a building owner to apply for and successfully achieve an Energy Star rating for a commercial office building. As previously discussed, applying for an Energy Star rating involves significant costs in the form of the time and effort required for engineers to verify utility bills and certify the level of air quality in the building. There may also be costs associated with retrofitting the building, if the current operating performance is below the top quartile of performance. Following the logic of standard investment rules, we would expect the investor to undertake the Energy Star application process and, if need be, retrofit the building to successfully achieve an Energy Star rating if the present value of the benefits from that investment exceeds its costs.[13] As is clear from the previous discussion of Eq. 2, the increment to the asset price could arise from an increase in gross income, a decrease in vacancy rates, a decrease in total operating costs, an increase in the net operating income growth rate, or a decrease in the risk of the asset due to reductions in the volatility of the building's cash flows. Whatever the source of the benefits from the rating, however, the increment to the asset's value after the successful Energy Star rating must exceed the cost of obtaining the rating, given the investor's opportunity costs.

An additional dilemma for the econometrician is that the underlying fundamental factors in Eq. 2 are unobserved. Instead, the econometrician observes only an outcome variable equal to 1 if the decision to obtain an Energy Star rating meets the investment threshold for the investor. Future observations on the price of the asset are, of course, conditioned on the prior decision to obtain, or not to obtain, the Energy Star rating, and this decision could affect the level and dynamics of asset prices in important ways. A further problem is that the Energy Star decision is often a dynamic contracting problem, which is solved contemporaneously with leasing and debt-contracting decisions. The Energy Star decision may thus be co-determined with these other contracting decisions.

In its simplest form, the utility an investor derives from obtaining an Energy Star rating in a given period can be associated with a linear function of building characteristics and other exogenous market variables, v_{it}, affecting costs and building value,

$$U_{it} = \gamma v_{it} + \mu_{it}, \tag{4}$$

where μ_{it} is a residual. Utility is an unobserved latent variable. However, we do observe the choice made by the investor each period. Obtaining an Energy Star rating thus corresponds to a response variable, y_{it}, with value 1. If the Energy Star rating is achieved, this implies that latent utility is positive,

$$y_{it} = 1 \Rightarrow U_{it} > 0. \tag{5}$$

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[13] Of course, real options considerations might also enter this calculus, leading to consideration of the second moments of fundamental factors (Grenadier 2005).

Under the assumption that the residual follows an i.i.d. extreme-value distribution, the probability of obtaining an Energy Star rating is given by the logistic function,

$$Pr(y_{it}=1)=Pr(\gamma v_{it}+\mu_{it}>0)=Pr(\mu_{it}>-\gamma v_{it})=\frac{1}{(1+\exp(\gamma v_{it})}. \quad (6)$$

The coefficients of this choice behavior can be estimated using maximum likelihood. The likelihood function is calculated by aggregating the probability of the observed choice stream for each building,

$$\log L(\theta; v)=\sum_{i=1}^{N}\sum_{t=1}^{T_i}\left\{\log\left[Pr(y_{it}=1)1_{y_{it}=1}\right]+\log\left[(1-Pr(y_{it}=1))\,1_{y_{it}=0}\right]\right\}. \quad (7)$$

We report the results of maximum-likelihood estimation for the Energy Star choice in Table 5. Because we only observe the year of the Energy Star rating, we compute the annualized average near contract prices and the annualized value of the slope for power and gas for each building. We also have measures for the quality of the building, the age and the square footage at the Energy Star grant date and the quality level of the building. Many of the Energy Star rated buildings in the sample are rated multiple times over the period 1999 through 2010. For every building in the sample, we construct a panel of annual observations on market and building characteristics, including an indicator for whether the building became Energy Star rated in that year. Our estimator accounts for the path-dependence of these decisions, as a sub-sample of the buildings were Energy Star rated every year, some buildings were Energy Star rated more than once but not every year, some were Energy Star rated only once in the sample period, and some buildings were never Energy Star rated over the period. We merge the building-level characteristics with time-varying market characteristics for energy forward prices and weather variables, measured year by year from the building's transaction date.

As shown in columns two and three of Table 5, the investor's decision to obtain an Energy Star rating for a building is associated with the energy factor prices in markets. Obtaining an Energy Star rating is positively associated with both the six-month lagged price level of the one- to twelve-month electricity contract and a higher slope of the electricity forward curve, indicating expectations for electricity prices to rise. Changes in the level of Henry Hub natural gas prices have a statistically significant effect on the likelihood that an Energy Star rating is achieved and expectations that natural gas prices are expected to rise also have a statistically positive effect on the probability of achieving an Energy Star rating. A higher standard deviation in the maximum temperature is statistically significantly and positively related to the decision to obtain an Energy Star rating in a given year, whereas increased standard deviation in the minimum temperatures has an offsetting negative association with obtaining an Energy Star rating. The maximum weekly median temperature over the past fifty two weeks has a significant negative association with the likelihood of obtaining an Energy Star score, whereas the minimum weekly median temperature over the past fifty two weeks has a larger and positive effect. These results suggest that energy cost drivers are strongly associated with obtaining Energy Star rating

Table 5 Logit estimation of the Energy Star rating choice and two-step heckman estimator for sample selection bias

	Logit estimates		Heckman Two step estimation			
	Probability of Annual Energy Star rating		Probability of Energy Star Rating prior to sale		Log building price per square foot	
Variable	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Intercept	3.576***	0.476	−2.940***	0.407	2.454*	1.059
Annual average of the six month lag price of the 1–12 month forward contract at sale by transaction hub	0.008***	0.001	0.013**	0.002		
Annual average of the six month lag slope of the power forward curve	0.024*	0.010	0.034*	0.012		
Annual average of the six month lag price of the 1–12 month natural gas forward contract	0.056*	0.021	0.021	0.035		
Annual average of the six month lag slope of the natural gas forward curve	0.224**	0.102	−0.137	0.167		
Standard deviation of 12 month maximum temperature	0.015***	0.004	−0.010**	0.004		
Standard deviation of 12 month minimum temperature	-0.019***	0.005	0.002	0.005		
Standard deviation of 12 month precipitation	−1.255	0.952	−3.579*	1.477		
Maximum temperature over past fifty two weeks	−0.070***	0.022	0.031	0.017		
Minimum temperature over past fifty two weeks	0.100**	0.036	−0.057**	0.018		
Age of the building	0.001	0.001	0.001	0.002	−0.010***	0.003
Indicator variable for multi-tenant building	0.813***	0.077	0.742***	0.130	0.646***	0.105
Indicator variable for class A buildings	1.200***	0.058	1.273***	0.094	0.987***	0.049

Table 5 (continued)

	Logit estimates		Heckman Two step estimation			
	Probability of Annual Energy Star rating		Probability of Energy Star Rating prior to sale		Log building price per square foot	
Variable	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Typical floor area square footage	−0.024*	0.001	0.021	0.018	0.824	0.536
Number of floors					−0.001	0.006
Building size (square feet)					0.001	0.003
Inverse mills ratio					−0.124	0.086
Market fixed effects	Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes	
Likelihood Ratio Test (χ^2)	−1487.250***					
Wald test (χ^2)			104.87***			
Number of observations	173,640		15133		15133	
	$*p < 0.05$, $**p < 0.01$, $***p < 0.001$					

Columns two and three present the maximum likelihood estimates for the probability that a building sucessfully received an Energy Star rating in a given year as a function of local energy-market and weather characteristics and building and market characteristics. Columns four through seven present a two step Heckman estimator for sample selection bias. The coefficients for the choice equation, the probability that a building successfully received an Energy Star rating, is reported in the fourth and fifth columns. The sixth and seventh columns report coefficient estimates for the log price per square foot for buildings conditioned on the choice equation and other value related covariates. The Energy Star rating indicator for each building was obtained from the U.S. Environmental Protection Agency, the office building data were obtained from CoStar, the electricity forward curve was estimated using data from Platts, the natural gas data were obtained from NYMEX, and the weather data were obtained from Wolfram Schlenker. The reported test statistics are z scores decisions. In addition, Class A buildings are more likely to obtain an Energy Star rating, as are larger and newer multi-tenant buildings.

As a further robustness check, we also report in Table 5 the results of a two step Heckman test (see Heckman 1979) for sample-selection bias in transaction prices given the investor's choice of obtaining an Energy Star rating prior to the sale transactions. These results are intended to address the two concerns identified above: 1) we only observe the Energy Star rating if the investor determines that obtaining the rating is NPV-positive; 2) the observed transactions prices of building are always conditioned on the prior decision to obtain, or not to obtain, the Energy Star rating. Because we only observe the year of the Energy Star rating, we compute the annualized average near contract prices and the annualized value of the slope for power and gas for each building in the year prior to the transaction date. If the building does not have an Energy Star rating at or before the transaction data, we set the indicator variable for Energy Star score to zero. We merge the building level transaction data with market characteristics for the energy forward prices and the weather variables are measured relative to the building's transaction date. We then test whether there is sample selection bias in the distribution of observed realized transaction prices, given the Energy Star rating choice based upon the coefficient estimate on the inverse Mills ratio reported in Table 5. As shown in column six of the table, the coefficient on the inverse Mills ratio is positive but not significantly different from zero, so there is no strong evidence that the observed transaction cost distribution is censored by the Energy Star choices. This suggests that there is no evidence for sample-selection bias in the transaction prices of certified properties that are sold.

The first-stage estimates of the probability of obtaining an Energy Star rating prior to the sale of a building are reported in columns four and five of Table 5. Here again, the decision to obtain an Energy Star rating appears to be associated with the level of the electricity forward prices and with the shape of the forward curve for electricity. Higher electricity prices make it more likely that a building will obtain an Energy Star rating prior to the sale date, as do steeper forward curves. In contrast, neither changes in the level of Henry Hub natural gas prices nor the slope of the slope of the futures curve have a statistically significant effect on the likelihood that an Energy Star rating is achieved prior to sale. MSAs with higher variance in maximum temperatures, higher levels of precipitation, and higher minimum weekly temperatures over the past fifty two weeks all have a statistically significant negative effects on the probability on the likelihood that an Energy Star rating is obtained by building investors prior to sale. These results suggest that it is the level of electricity prices, the primary fuel in office buildings, that is the driver of Energy Star rating decisions prior to building transactions. As expected, the results show that Class A buildings are more likely to obtain an Energy Star rating, as are larger multi-tenant buildings.

Of course, an important caveat with these results is that we have no additional controls for whether the buildings in the CoStar sample are actually energy efficient, whether or not they have an Energy Star rating. Thus, our specification only represents decisions whereby the labeling decision was NPV-positive, not whether overall objective energy-efficiency measures lead buildings, on average, to obtain an Energy Star rating. In the next sections of the paper, we will further explore the operating expense and net operating income characteristics of buildings to better understand the relation between the Energy Star label and relative building operating performance.

Empirical Results with Transactions Prices

As previously discussed, due to data limitations, all previous studies of the effects of energy metrics or environmental and architectural factors on commercial office building values have applied hedonic approaches similar to Eq. 3 (for examples, see, among others, Vandell and Lane (1989), Wheaton and Torto (1994), Kotchen (2006), Eichholtz et al. (2010), Fuerst and McAllister (2011), and Wiley et al. (2010)). These studies usually find that the benefits of energy certification or the environmental/architectural attributes of buildings are positive factors leading to a premium on buildings with these attributes. These results, however, say nothing about whether the investment in the certificate or the environmental or architectural attributes are NPV-positive or whether, in the case of energy certification, the buildings are actually energy saving. To do so requires a specification closer to Eq. 2, which controls for costs and expected energy-related factor input prices.

Table 6 reports the results of two specifications: columns two through five report results for the hedonic specification (for the full sample and for a subsample of buildings for which we have income and expense data); columns six and seven report results for the forward-looking asset-pricing specification in Eq. 2 for the same subsample. As shown in the Table, the hedonic specification indicates that higher building values are associated with higher near-term power forward prices and a more steeply sloped forward curve, even after controlling for market fixed effects. Thus, the level of net operating income or its growth rate appears to more than compensate for exposure to increased electricity costs, which is the primary energy exposure for commercial office buildings. Higher prices for natural gas near-term futures contracts have a significant negative association with building prices per square foot, indicating that the cost effect of this factor input is not compensated by rents. The standard deviation of the twelve-month maximum temperature has a significant negative effect on price, and the standard deviation of the minimum temperature has an offsetting positive effect. As shown, larger class-A buildings and those buildings that were Energy Star rated prior to sale have significantly higher transaction prices. The statistically significant and positive coefficient estimate for the presence of an Energy Star rating is similar to results from the hedonic specifications in prior papers. Building attributes that negatively affect building value include age, multi-tenant buildings, and large rentable floor areas.

In columns 4 and 5 of Table 6, we re-estimate the hedonic regression for a subsample of buildings for which we have the data required to estimate the forward-looking asset pricing specification in Eq. 2. As shown, the results are nearly identical to those for the larger sample, although statistical significance is lessened due to the smaller sample size. The Energy Star rating, which is based on quantitative measures of energy efficiency of commercial office buildings, has a positive association with the transaction prices of these buildings, however, it is only statistically significant at $p < .10$.

Table 6 Regression results for office buildings that sold in 2001 through 2010. This table presents the regression results for buildings that sold in arms-length transactions between 2001 and 2010. The dependent variable is the log of the price per square foot of the building at sale. These data were obtained from the CoStar Transactions data base. The Energy Star rating indicator for each building was obtained from the U.S. Environmental Protection Agency, the office building data were obtained from CoStar, the electricity forward curve was estimated using data from Platts, the natural gas forward curve was estimated using data from NYMEX, and the weather data were obtained from Wolfram Schlenker

	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Intercept	4.971***	0.146	5.156	0.298	5.404***	0.301
Annual average of the six month lag price of the 1–12 month forward contract at sale by transaction hub	0.006***	0.001	0.002	0.002	0.001	0.002
Annual average of the six month lag slope of the power forward curve	0.016***	0.003	0.013*	0.008	0.019**	0.007
Annual average of the six month lag price of the 1–12 month natural gas forward contract	−0.023***	0.005	0.004	0.016	−0.011	0.014
Annual average of the six month lag slope of the natural gas forward curve	−0.025	0.022	−0.031	0.071	−0.128	0.065
Standard Deviation of 12 Month Maximum Temperature	−0.008***	0.001	−0.011**	0.003	−0.007**	0.003
Standard Deviation of 12 Month Minimum Temperature	0.008***	0.001	0.010**	0.003	0.007**	0.002
Standard Deviation of 12 Month Precipitation	0.812**	0.269	−0.215	0.662	−0.255	0.505
Maximum temperature over past fifty two weeks	−0.030**	0.01	−0.030	0.016	−0.022	0.014

Table 6 (continued)

	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Minimum temperature over past fifty two weeks	0.098***	0.016	0.100***	0.026	0.067**	0.022
Age of the building	−0.001**	0.000	−0.003**	0.001	−0.003***	0.001
Indicator variable for multi-tenant building	−0.053***	0.012	−0.091*	0.043	−0.033	0.038
Indicator variable for renovation prior to sale	−0.072	0.043	0.112	0.138	0.093	0.118
Indicator variable for class A buildings	0.201***	0.023	0.227***	0.041	0.175***	0.034
Typical floor area square footage	−0.045***	0.004	−0.005	0.009	0.001	0.008
Number of floors	0.004*	0.001	0.002	0.004	0.003	0.003
Building size (square feet)	0.002***	0.000	0.001	0.001	0.000	0.001
Market capitalization rate at time of sale					−0.104***	0.001
Log net operating income at time of sale					0.467***	0.047
Log total operating expenses at time of sale					−0.189***	0.043
Indicator variable for Energy Star rating by time of sale	0.142***	0.037	0.123	0.064	0.094	0.086
Market Fixed Effects	Yes		Yes		Yes	
Year Fixed Effects	Yes		Yes		Yes	
Clustered standard errors (Sale year and Market)	Yes		Yes		Yes	
R^2	0.4936		0.5012		0.6123	
Number of Observations	15133		1479		1479	

t tests of statistical significance: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

In columns 6 and 7 of Table 6, we control for total expenses, market capitalization rate (capturing the expected growth rate in rents), and net operating income at the time of sale. In this specification, we find that the slope of the electricity forward curve is positively associated with the log of building price per square foot suggesting that auction-market bets that energy prices will rise are associated with higher expenses per square foot and thus lower prices. The standard deviation of minimum temperature also has a significant positive effect on log price as does the minimum weekly median temperature over the past fifty two weeks prior to the sale. These results appear to suggest that the primary driver of higher weather-related costs is heating costs in the winter. Total expenses, the capitalization rate, and net operating income are all economically and statistically significant, with the anticipated signs. Higher total expenses and higher market capitalization rates are associated with lower transaction prices, while buildings with higher net incomes have higher prices. The revealing result is that when we control for operating expenses, factor prices, and interest, the Energy Star rating has an effect on transaction prices that is not significantly different from zero. Of course, our measure of operating expenses includes property taxes, labor costs, and utilities (primarily electricity, gas, and water), so it might be highly correlated with the Energy Star metric, as utilities are on average about 30% of total operating expenses nationally.[14]

To better understand the relation between the Energy Star rating and total operating expenses, net operating income, and the capitalization rates at sale of the office buildings, we report three separate regressions where the right-hand-side variables are the same as in the prior tables and the left-hand-side variables are, respectively: i) net operating income per square foot; ii) operating expenses per square foot; and iii) the capitalization rate. The results of these regressions are reported in Table 7. Overall, the Energy Star rating of the building does not have a significant effect on operating expenses, net operating income, or the capitalization rate. By contrast, the six-month lag in the one- to twelve-month electricity forward prices has a statistically significant positive association with net operating income per square foot and a statistically negative association with the capitalization rate. These results again suggest that rents more than fully compensate electricity prices leading to higher transaction prices. Interestingly, the standard deviation in the maximum twelve month temperature has a statistically significant positive association with log net operating income and a negative significant association with the cap rates, suggesting that high variance in summer temperatures negatively affects transaction prices. The log of operating expenses per square foot are positively associated with the the one- to twelve-month electricity forward prices, the slope of the electricity forward curve, and the level of the Henry Hub natural gas forward prices as expected. The standard deviation of the minimum weather temperature conditions over the twelve months prior to the sale also have a statistically significant positive effect on log operating expenses, but the other weather metrics do not have statistically significant associations with operating costs per square foot. As shown in Table 7, there do not appear to be cost economies

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[14] Computed by the authors using various BOMA publications.

Table 7 Regression results for net operating income per square foot, capitalization rate at sale, total operating expenses per square foot for office buildings that sold 2001 through 2010. This table presents the regression results for regressions of the net operating income per square foot, the capitalization rate at sales, and the total operating expenses per square foot of office buildings that sold in arms-length transactions between 2001 and 2010 on energy costs, temperature variances, building characteristics, and whether the building was Energy Star before the sale. These data were obtained from the CoStar Transactions data base. The energy forward curve was estimated using data from Platts and NYMEX and the weather data were obtained from Wolfram Schlenker

	Log net operating Income per Sq. Ft.		Market capitalization Rate		Log net operating Expenses per Sq. Ft.	
Variable	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Intercept	2.293***	0.239	9.821***	0.551	1.389***	0.227
Annual average of the six month lag price of the 1–12 month forward contract at sale by transaction hub	0.004*	0.002	−0.010*	0.005	0.005*	0.002
Annual average of the six month lag slope of the power forward curve	0.009	0.008	−0.009	0.019	0.021**	0.007
Annual average of the six month lag price of the 1–12 month natural gas forward contract	0.005	0.012	−0.015	0.025	0.023*	0.011
Annual average of the six month lag slope of the natural gas forward curve	0.101	0.066	−0.100	0.145	−0.032	0.053
Standard deviation of 12 month maximum temperature	−0.006**	0.002	0.010*	0.005	−0.005	0.003
Standard deviation of 12 month minimum temperature	0.004	0.003	−0.014*	0.006	0.006*	0.003
Standard deviation of 12 month precipitation	0.058	0.484	−0.023	0.988	0.554	0.557

Table 7 (continued)

Variable	Log net operating Income per Sq. Ft.		Market capitalization Rate		Log net operating Expenses per Sq. Ft.	
	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Maximum temperature over past fifty two weeks	−0.006	0.013	0.063	0.036	0.005	0.013
Minimum temperature over past fifty two weeks	0.035	0.020	−0.176**	0.054	−0.026	0.020
Age of the building	−0.001	0.001	−0.004	0.002	−0.001	0.000
Indicator variable for multi-tenant building	−0.107**	0.037	0.021	0.070	0.212***	0.031
Indicator variable for renovation prior to sale	−0.002	0.080	−0.067	0.200	−0.037	0.085
Indicator variable for class A buildings	0.032	0.034	−0.385***	0.084	0.120**	0.036
Typical floor area square footage	−0.022***	0.006	0.015	0.016	−0.013*	0.006
Number of floors	−0.002	0.004	−0.026**	0.008	0.014***	0.004
Building size (square feet)	0.002	0.001	0.001	0.002	−0.002	0.002
Indicator variable for Energy Star rating by time of sale	0.006	0.077	−0.122	0.200	−0.073	0.066
Market fixed effects	Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes	
Clustered standard errors (Sale year and Market)	Yes		Yes		Yes	
R^2	0.302		0.368		0.334	
Number of observations	1470		1470		1470	

t tests of statistical significance: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

of scale associated with multi-story Class A buildings with multiple tenants, since these buildings appear to have economically and statistically significantly higher log operating expenses per square foot.

Given the results in Table 7, log net operating income and log operating expenses appear themselves to be functions of local supply and demand factors, suggesting that controls should be introduced for the joint endogeneity of net operating income and operating expenses in a specifications such as Eq. 2. Because the market capitalization rate is in large part a function of the interest rate, we assume that it is exogenous. In Table 8, we report the results for a three-stage least squares estimation of endogenous log net operating income and log operating expenses as a function of exogenous factors such as the local energy factor input prices for natural gas and electricity, local weather conditions, building characteristics, local market fixed effects, and year fixed effects and the Eq. 2 specification with the instrumented value of net operating income, the instrumented value of operating expenses, and the market determined capitalization rate.

The three-stage least squares estimation is, again, using the sub-sample of transactions for which we have information on operating expenses, net operating income, and the market capitalization rate at sale. As shown in Table 8, operating expenses per square foot have a statistically significant and positive association with the slope of the natural gas forward curves, implying that the higher the future bets from the auction markets on the cost of this factor input, the higher the expected operating costs of the building. The energy factor inputs appear to have no statistically significant effect on net operating income. A higher standard deviation of the maximum temperature in the local markets has a statistically significant negative association with log net operating income per square foot but this effect is basically offset by a higher standard deviation in the minimum termperatures realized in the last twelve months after controlling for local market fixed effects. Multi-tenant buildings are associated with statistically significantly higher log operating expenses and larger floor areas rented by tenants are associated with lower log net operating income probably due to the discounts afforded to larger block rentals and with higher log operating expenses.

Instrumenting for operating expenses and net operating income in the price equation leads to results that are very similar to those reported in Table 6 (which does not use a three-stage least squares estimator). As expected from Eq. 2, the capitalization rate, the net operating income and the operating expenses are the key determinants of the transaction values of building. We also introduce two indicator values for Energy Star ratings from the earlier period of 2003 through 2005 and Energy Star ratings from the latest period, 2006 through 2009, when it is thought to be more difficult to get into the top 25th percentile of energy efficiency due to the increased competition for these scores among building owners. As shown in the last two rows of the last column of Table 8, once appropriate controls for net operating income, operating expenses, and capitalization rates are introduced into the pricing equation, there appears to be no significant additional effect of obtaining an Energy Star label, even in the most recent period. Similar to Table 6, multi-story class A office buildings with multiple tenants are associated with higher transaction prices.

Table 8 Three-stage least squares estimates for endogenous net operating income, endogenous total operating expenses, and prices for office buildings that sold 2001 through 2010. This table presents the three-stage least squares estimates for net operating income, total operating expenses per square foot, and prices per square foot for office buildings that sold in arms-length transactions between 2001 and 2010. We instrument net operating income and operating expenses with exogenous energy factor prices, weather effects, time dummies and location dummies. The third stage least squares estimates the price per square foot with instruments for endogenous net operating income and operating expenses

	Log operating Expenses per Sq. Ft.		Log net operating Income per Sq. Ft.		Log price per Sq. Ft.	
Variable	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Intercept	1.615***	0.302	2.506	0.312	4.670***	0.266
Annual average of the six month lag price of the 1–12 month forward contract at sale by transaction hub	0.002	0.002	0.003	0.002		
Annual average of the six month lag slope of the power forward curve	0.005	0.019	-0.002	0.009		
Annual average of the six month lag price of the 1–12 month natural gas forward contract	0.005	0.019	0.003	0.02		
Annual average of the six month lag slope of the natural gas forward curve	0.197*	0.086	0.142	0.089		
Standard deviation of 12 month maximum temperature	−0.005	0.003	−0.011***	0.003		
Standard deviation of 12 month minimum temperature	0.005	0.003	0.010***	0.003		
Standard deviation of 12 month precipitation	0.748	0.609	0.449	0.629		
Maximum temperature over past fifty two weeks	−0.007	0.016	−0.015	0.016		
Minimum temperature over past fifty two weeks	−0.014	0.025	0.029	0.026		
Age of the building	0.001	0.001	−0.001	0.001	−0.001	0.001

Table 8 (continued)

	Log operating Expenses per Sq. Ft.		Log net operating Income per Sq. Ft.		Log price per Sq. Ft.	
Variable	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Indicator variable for multi-tenant building	0.191***	0.042	−0.038	0.044	0.185***	0.056
Indicator variable for class A buildings	0.066	0.045	0.071	0.046	0.150**	0.049
Typical floor area square footage	−0.018*	0.007642	−0.021**	0.007948	0.003207	0.009
Number of floors	0.008	0.004	−0.006	0.004	0.017***	0.005
Building size (square feet)	−0.002	0.002	0.001	0.002	−0.003	0.002
Indicator variable for renovation prior to sale					0.098	0.122
Market capitalization rate at time of sale					−0.124***	0.01
Log net operating income at time of sale					1.373***	0.119
Log total operating expenses at time of sale					−1.146***	0.128
Indicator variable for Energy Star rating by time of sale by time of sale (2003–2005)					0.093	0.287
Indicator variable for Energy Star rating by time of sale by time of sale (2006–2009)					0.261	0.175
Market fixed effects	Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes	
Clustered standard errors (Sale year and Market)	Yes		Yes		Yes	
Number of observations	1470		1470		1470	

t tests of statistical significance: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

These results suggest that the Energy Star rating can only be viewed as having a muted effect on building transactions prices at least through the expense channel. Accounting for the primary determinants of office building asset prices, net rents, expenses, energy factor prices and interest rates appears to leave no further room for either the “plaque-on-the-wall” effect or the incremental savings associated with Energy Star certification. There is, of course, one further control that is missing from these specifications, the cost associated with actually obtaining an Energy Star rating. Given our result that the benefits of the Energy Star certification appear to proxy for important missing factors in office building asset prices, it is unlikely that inclusion of these costs could change our conclusions.

Leases

Important reductions in the energy consumption of U.S. buildings are technologically feasible, but building owners — landlords — often do not receive the proper economic incentives to carry out the required investments. The incentive failures occur in two related markets: the rental market, where lease contracts often inhibit energy efficiency; and the mortgage market, where loan underwriting procedures also inhibit energy-efficiency investments. Lease contracts contain many common basic terms and conditions that set the terms for payments and services received between the tenant and landlord in three dimensions:

1. *Space rent*: The core purpose of a lease is to identify the space provided to the tenant and the rent paid to the landlord. The lease will also typically identify the physical condition of the space and any improvements the landlord will provide.
2. *Building operating expenses*: Building operating costs include energy use, property taxes, building operations and maintenance, and insurance. Lease contracts will identify how the payments for these expenses are to be allocated between the landlord and the tenants. The lease contracts will typically indicate the quality level promised by the landlord for building operations and maintenance.
3. *Building capital expenditures*: Building capital expenditures cover a variety of investments that maintain or improve the building, including investments to improve the building’s energy efficiency. Lease contracts will identify how the amortized costs of these investments are to be shared between the landlord and the tenants.

Lease contracts also indicate the period over which the contract pertains. On longer-term contracts, the lease will indicate how payments in the three categories will change over time, quite possibly including how rising operating costs will be shared between the landlord and the tenants. Lease contracts may also allow a variety of options, such as allowing either the landlord or tenant to break the lease under specified conditions.

Lease contracts for commercial buildings commonly take one of three main formats: full-service leases, net leases, and modified-gross leases. Full-service leases require that the tenant makes a single payment that covers the tenant's responsibility for space rent and operating expenses. The individual components are typically not identified. This allows the landlord freedom to reduce operating expenses, including energy costs, by making efficient capital expenditures (subject to the minimum standard for building services and maintenance specified in the lease contract).

With net leases, the tenant agrees to pay for both space rent and the tenant's actual or allocated share of the specified operating expenses. The operating expenses may include energy, property taxes, and insurance and a lease that includes all three expense categories is call a "triple-net" lease, but other combinations are possible. We focus here on the set of net leases that at least include electricity, which then requires that the tenant's space have direct metering.

Modified-gross lease contracts specify a specific payment for the space rent and stipulate an actual amount to be paid for operating expenses in the first year. For later years, the landlord provides an audit of building expenses, and the tenants pays a prorated share of the realized percentage increase in the building expenses. Modified-gross and net leases share the feature that the tenant pays a share of the building's operating expenses, but on modified-gross leases, the tenant pays a prorated share of the building's total expenses, which are thus independent of the tenant's actual energy usage. For this reason, modified-gross leases are commonly used in buildings where energy metering of each tenant's space is not available.

Lease Contracts and Energy Efficiency: Economic Theory

Contract theory is the part of economics that studies the incentives received by contract participants to take various actions. The specific implications depend critically on the environment in which the contracting process is assumed to occur. Uncertainty regarding a building's energy usage, including the possibility of asymmetric information between the landlord and the tenants, is critical to understanding the impact of lease contracts on energy efficiency. In particular, if there were complete knowledge concerning the dollar costs of energy usage, then lease contracts would have no impact on energy efficiency.

Lease contracts have an insurance component, with the risk of high energy cost outcomes borne by the landlord under a full-service lease and by the tenant under net and modified-gross leases. Economic theory indicates that the best party to bear the risk — the tenant or the landlord — will be whichever is the more risk tolerant. For example, if the landlord is more risk tolerant, then we would expect the market to adopt full-service leases, thus allowing the tenants to avoid the risk of unexpectedly high energy costs.

Asymmetric information, meaning that either the landlord or tenant has better information concerning likely energy costs, raises additional issues for the desired contracting outcome. For example, if the landlord can estimate the likely energy costs with greater precision than can the tenant, then this creates a further reason for the landlord to bear the risk as under a full-service contract. On the other hand, when the tenant can control the amount of energy use, and would significantly expand the use under a full-service or modified-gross contract, then a net contract may be the preferred outcome. Net-lease contracts are commonly judged to be the most conducive for energy efficiency, because they provide tenants the greatest incentive to limit their energy use.

The preceding discussion has taken as given the building's energy efficiency. Landlords, of course, may carry out capital investments that would improve the building's level of energy efficiency. Their incentive to do so is affected by the building's lease structure. Under full-service leases, all the costs and benefits of energy investments accrue to the landlord alone, so we should expect the optimal level of energy-efficient investment. With net and modified-gross leases, the tenant both receives the benefits of reduced energy costs and pays the amortized costs of the investment. However, the tenant's occupancy horizon may not equal the expected economic life of the capital investment, which can distort incentives to invest, especially if time patterns in the amortized costs differ from those in the energy-saving benefits.

Empirical Tests

One implication of the preceding discussion is that energy use in triple-net buildings should be lower, reflecting the direct incentive for tenants to minimize their energy bills. Although we cannot directly test this hypothesis, we consider two specifications to explore these effects: an estimation of the forward-looking asset pricing specification defined by Eq. 2 with controls introduced for the lease contracting structure of the building; and a re-estimation of the total operating expenses relation, again with controls for the leasing structure.

Income and Expenses

Table 9 tests for the effects of leasing structure on log operating expenses per square foot, log net operating income per square foot, and the ratio of log operating expenses to log net operating income. Columns 2 and 3 report the results of regressing log operating expenses per square foot on market and building characteristics when we introduce controls for the dominant lease contracting structure of the building. As shown, multi-tenant, multi-story and class-A buildings are economically and statistically associated with higher total operating expenses. Interestingly, the controls for the full-service and modified full-service leases do not have statistically significant effects on log operating expenses per square foot, and neither does Energy Star certification.

Table 9 Regression results for log(Operating Expenses), log(Net Operating Income) and log(Operating Expenses)/Log(Net Operating Income). This table presents regression results for office buildings that sold in arms-length transactions between 2001 and 2010. The dependent variable in columns two and three is the log operating expense per square foot at sale. The dependent variable in columns four and five is the log operating income per square foot at sale. The dependent variable in columns six and seven is the ration of the log operating expense per square foot to log net operating income at sale. The regressors are energy price and weather effects, building characteristics, leasing characteristics, and the Energy Star rating status of the building at the time of sale. These data were obtained from the CoStar Transactions data base. The energy forward curve was estimated using data from Platts and NYMEX and the weather data were obtained from Wolfram Schlenker

	Log operating Expenses (psf)		Log net operating Income (psf)		Ratio of log net operating Expenses to log Operating income	
Variable	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Intercept	1.421***	0.277	2.439***	0.29	0.722***	0.141
Annual average of the six month lag price of the 1–12 month forward contract at sale by transaction hub	−0.001	0.003	0.001	0.003	−0.001	0.001
Annual average of the six month lag slope of the power forward curve	0.009	0.007	0.007	0.009	−0.001	0.004
Annual average of the six month lag price of the 1–12 month natural gas forward contract	−0.016	0.013	−0.005	0.012	−0.001	0.006
Annual average of the six month lag slope of the natural gas forward curve	−0.011	0.058	0.021	0.079	−0.006	0.035
Standard deviation of 12 month maximum temperature	−0.007*	0.003	−0.009**	0.003	0.000	0.001
Standard deviation of 12 month minimum temperature	0.009*	0.004	0.006	0.003	0.002	0.001
Standard deviation of 12 month precipitation	0.95	0.525	0.388	0.582	0.351	0.271
Maximum temperature over past fifty two weeks	0.011	0.016	0.008	0.015	0.001	0.007

Table 9 (continued)

Variable	Log operating Expenses (psf)		Log net operating Income (psf)		Ratio of log net operating Expenses to log Operating income	
	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Minimum temperature over past fifty two weeks	−0.026	0.025	0.033	0.023	−0.031*	0.013
Age of the building	0.001	0.001	−0.001	0.001	0.001	0.000
Indicator variable for multi-tenant building	0.262***	0.044	−0.019	0.052	0.097***	0.023
Indicator variable for class A buildings	0.152***	0.036	0.053	0.04	0.038*	0.018
Typical floor area square footage	−0.005	0.006	−0.017*	0.003	0.004	0.003
Number of floors	0.012**	0.004	0.002	0.005	0.003	0.002
Building size (square feet)	−0.003	0.002	−0.002	0.003	−0.001	0.001
Indicator variable for renovation prior to sale	−0.157	0.092	0.035	0.127	−0.034	0.057
Predominant lease structure: full service gross	0.014	0.041	−0.125***	0.038	0.046*	0.021
Predominant lease structure: modified gross	−0.046	0.058	−0.078	0.053	0.010	0.026
Indicator variable for Energy Star rating by time of sale	−0.082	0.071	0.006	0.077	−0.044	0.031
Market fixed effects	Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes	
Clustered standard errors (Sale year and Market)	Yes		Yes		Yes	
R^2	0.4358		0.2885		0.2980	
Number of observations	953		953		953	

t tests of statistical significance: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Columns 4 and 5 regress log net operating income on a full set of controls for energy prices, Energy Star certification, building characteristics, fixed effects, and indicator variables for full-service and modified-gross leases. We find that relative to triple-net leases, full-service leases have a statistically significant negative relationship with log net operating income; modified-gross leases also have a negative relationship, though not significantly so. This result, plus the result that the standard deviation of the 12 month maximum temperature also has a significant negative effect on log net operating income, suggests that full-service and modified-gross leases are associated with lower transaction prices because tenants are willing to pay less for buildings that use these lease types rather than triple-net leases (where the exact utility cost associated with each tenant is passed directly through to the tenant). A possible explanation for this result could be that tenants perceive buildings with full-service and modified-gross leases do not fairly price weather shocks and shared building-level energy usage, which are embedded as averages in their rents.

Columns 6 and 7 report the regression of the ratio of log operating expenses to the log of operating income on indicator variables for the lease contract terms, the Energy Star rating, other energy, weather, and building characteristics along with market and year of sale fixed effect controls. As shown, the relative log operating cost to log operating income is statistically significantly higher for full-service leases, for class A buildings and for multi-tenant buildings. From Appendix A, buildings that are multi-tenant and class A with full service leases tend to be located in the central business districts and tend to be multi-story glass sheathed structures. All else equal, these buildings appear to be more costly to operate relative to their net operating income perhaps because of unmeasured architectural or engineering features of these buildings such as the heating and cooling inefficiencies associated with glass sheathing. Interestingly, a higher minimum weekly median temperature over the past fifty two weeks has a statistically significant negative association with the ratio of log net operating expenses to log net operating income, possibly because relatively lower temperatures moderate the high energy usage costs of hot summer months, which, as discussed above, have a significant negative effect on log net income.

While the small sample size and data limitations make it difficult to draw strong conclusions about the relation between energy related building costs and leasing structure, these results do suggest that leasing structure matters. Unfortunately, our data set does not allow us to breakdown operating expenses into a direct measure of the energy costs per square foot of the building which would allow us to explore the direct channel between energy consumption and leasing structure. Nevertheless, the results in Table 9 do present a consistent result across all three regressions that relative to triple net leases, full-service and modified-gross leases appear to expose building owners to more net-income risk associated with shocks to high temperatures, and the use of full-service and modified-gross leases is associated with a lower willingness to pay on the part of tenants.

Table 10 Regression results for log price per square foot. This table presents regression results for buildings that sold in arms-length transactions between 2001 and 2010. Log price per square foot is regressed on energy price and weather effects, building characteristics, leasing characteristics, and the Energy Star rating status of the building at the time of sale. These data were obtained from the CoStar Transactions data base. The energy forward curve was estimated using data from Platts and NYMEX, and the weather data were obtained from Wolfram Schlenker

Variable	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Intercept	5.373***	0.356	5.374***	0.357
Annual average of the six month lag price of the 1–12 month forward contract at sale by transaction hub	0.003	0.003	0.003	0.003
Annual average of the six month lag slope of the power forward curve	0.016*	0.008	0.016*	0.008
Annual average of the six month lag price of the 1–12 month natural gas forward contract	−0.007	0.013	−0.005	0.013
Annual average of the six month lag slope of the natural gas forward curve	−0.109	0.077	−0.103	0.077
Standard deviation of 12 Month maximum temperature	−0.012**	0.003	−0.011**	0.003
Standard deviation of 12 Month minimum temperature	0.011**	0.003	0.011**	0.003
Standard deviation of 12 Month precipitation	−0.050	0.591	−0.044	0.592
Maximum temperature over past fifty two weeks	−0.013	0.016	−0.014	0.016
Minimum temperature over past fifty two weeks	0.038	0.025	0.040	0.024
Age of the building	−0.004*	0.001	−0.004*	0.001
Indicator variable for multi-tenant building	0.030	0.053	0.031	0.052
Indicator variable for class A buildings	0.200***	0.034	0.195***	0.034
Typical floor area square footage	0.007	0.006	0.007	0.006
Number of floors	−0.001	0.004	−0.001	0.004

Table 10 (continued)

Variable	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Building size (square feet)	0.000	0.001	0.000	0.001
Indicator variable for renovation prior to sale	−0.010	0.146	−0.008	0.146
Market capitalization rate at time of sale	−0.097***	0.016	−0.097***	0.011
Log net operating income at time of sale	0.494***	0.044	0.494***	0.044
Log total operating expenses at time of sale	−0.188***	0.046	−0.187***	0.046
Predominant lease structure: full service gross	−0.160***	0.038	−0.160***	0.038
Predominant lease structure: modified gross	−0.219***	0.056	−0.220***	0.056
Indicator variable for Energy Star rating by time of sale			0.091	0.078
Indicator variable for Energy Star rating by time of sale by time of sale (2003–2005)	0.036	0.285		
Indicator variable for Energy Star rating by time of sale by time of sale (2006–2009)	0.170	0.130		
Market fixed effects	Yes		Yes	
Year fixed effects	Yes		Yes	
Clustered standard errors (Sale year and Market)	Yes		Yes	
R^2	0.6809		0.6811	
Number of observations	584		584	

t tests of statistical significance: $*p < 0.05$, $**p < 0.01$, $***p < 0.001$

Pricing

As shown in Table 10, the results for the valuation expression are very similar to those reported for specifications for Eq. 2, reported in Table 6, which did not include controls for the lease contracting structure of the building. The slope of the power forward curve has a statistically significant and positive effect on the log price per square foot. The other energy factor prices no longer have statistically significant effects on prices. The weather effects retain their strong and statistically significant effects on log price per square foot even after controls for fixed effects, although their effects of standard deviation in minimum and maximum temperatures appear to countervail each other. Again, the importance of the Eq. 2 specification for asset prices is borne out with the results for log net operating income per square foot, the capitalization rate, and log expenses per square foot are all economically and statistically significantly associated with log transaction prices per square foot. Again, the indicator variable for an Energy Star certification at time of sale contributes no additional explanatory power in this regression, nor does a specification that accounts for the period in which the Energy Star certification was received.

The indicator variables for the predominance of full-service and modified full-service leases in the building have a significantly negative effect on transaction prices, relative to the omitted category of triple-net leases. This appears to suggest, as expected from the incentive structure of full-service and modified full-service leases, that contractual inducements for tenants to minimize the utility costs of their space-use do affect building value.

Conclusions

This paper presents an empirical analysis of the relation between energy factor markets, leasing structures and the transaction prices of office buildings in the U.S. We employ a large sample of 15,133 office building transactions between 2001 and 2010. In addition to building characteristics, we also include information on the operating expenses, the net operating income, and the capitalization rates at sale to estimate an asset pricing model for commercial office real estate assets. A further set of important controls in our analysis is the one- to twelve-month forward contract prices and the shape of the forward contract price curve, using auction data from the major electricity trading hubs in the U.S. and from the Henry Hub for natural gas. We also include weather metrics in the form of the standard deviation in the last twelve months of minimum and maximum temperature and precipitation as well as measures of the maximum and minimum weekly median temperatures over the past fifty two weeks from each building's sale date. Our final set of controls includes information on the dominant leasing structures in the buildings. Our empirical results suggest that Energy Star labels do not explain additional variance in property prices, once the key asset pricing factors of expenses, income and capitalization rates are included.

Energy factor market prices, the shape of the energy price curves, and weather metrics are consistently significant determinants of office building transaction prices, suggesting that commercial office building prices are likely to be exposed to shocks in these markets. This finding has important implications for underwriting commercial mortgage default risk.

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Appendix A: Geographic Structure of the Transactions Data

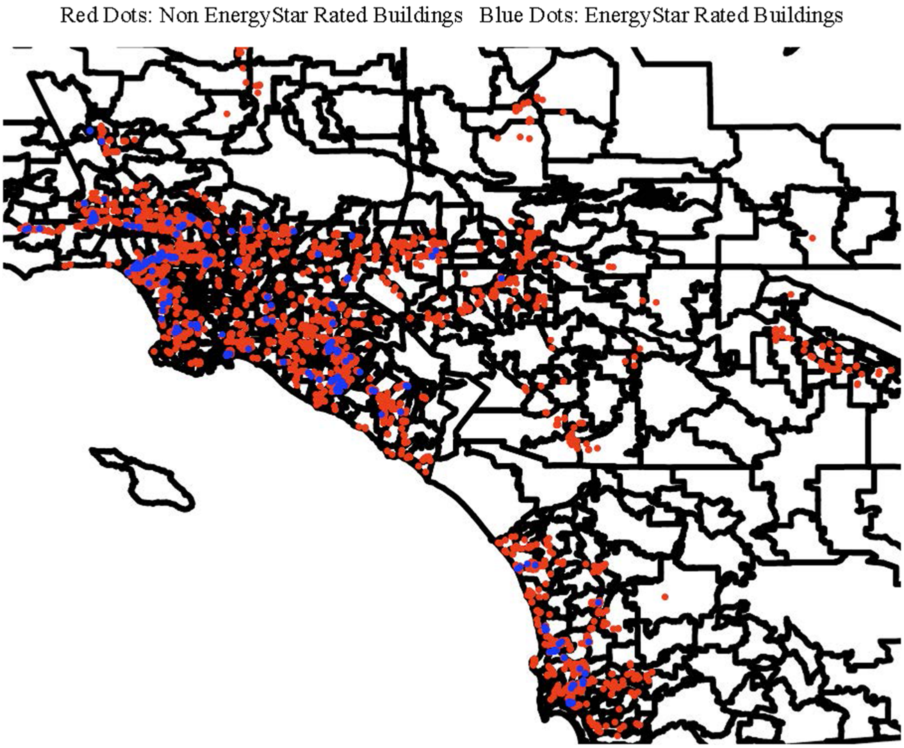

Fig. 1 EPA Energy Star rated buildings in the Los Angeles, Riverside, and San Diego areas

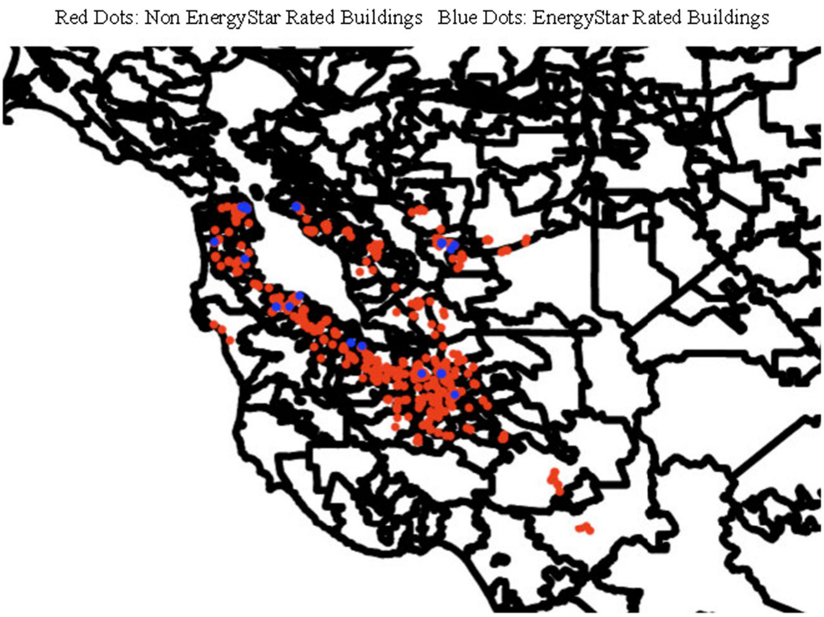

Fig. 2 EPA Energy Star rated buildings in the San Francisco, East Bay, San Jose, and Sacramento areas

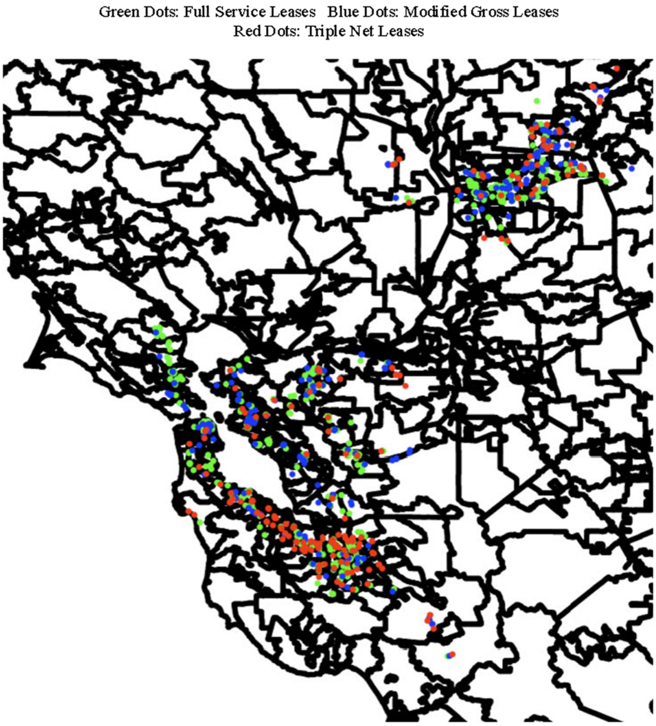

Fig. 3 Lease contract types for buildings in the San Francisco, East Bay, San Jose, and Sacramento areas

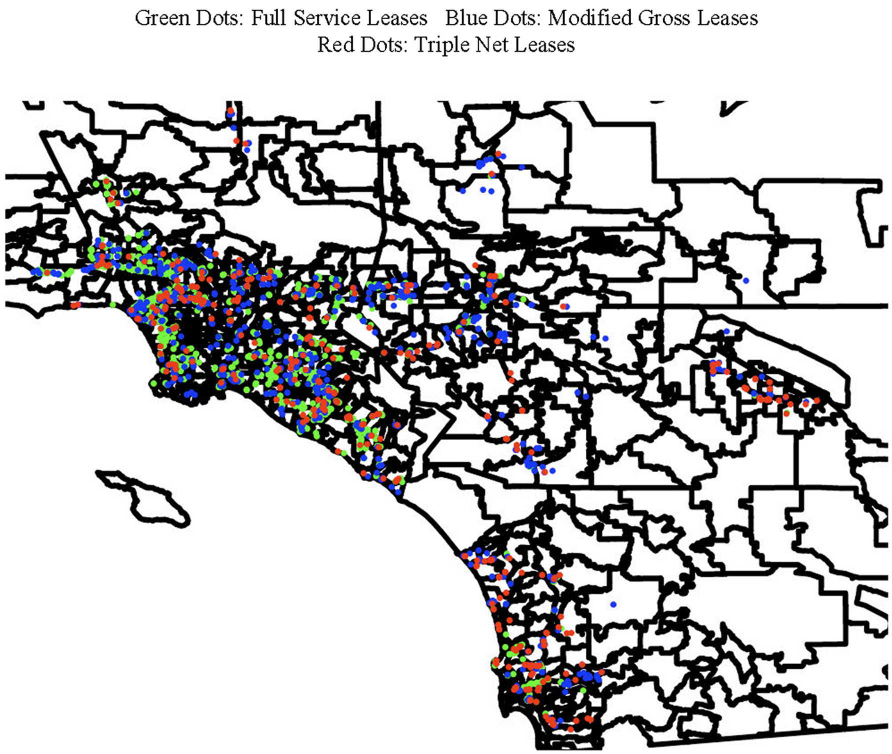

Fig. 4 Lease contract types for buildings in the Los Angeles, Riverside, and San Diego areas

Appendix B: Weather Data Construction

The weather data were obtained from Wolfram Schlenker at Columbia University. These data are based on the same rectangular grid system underlying PRISM that covers the contiguous United States.[15] It consists of 1405 grids in the longitude direction and 621 grids in the latitude dimension, space equidistant 1/24 degree steps (about 2.5 miles). The data are matched to the centroid of each grid point to the fips codes of all counties in the United States. There are 471,159 grid points with non-missing data in the PRISM data where the centroid is matched to lie within a county.

The data include the minimum and maximum temperature (Fahrenheit), and total precipitation (cm) for each day of the year for all of the 471,159 grids in the United States from 1950–2010. These data are interpolated from PRISM's monthly weather station averages to daily data, and we aggregate them back into monthly data for our analysis. We associate the past twelve months of weather data for each building in the CoStar data with the weather data associated with the nearest grip point in the Schlenker data.

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[15] http://www.prism.oregonstate.edu/

Appendix C: Energy Data Construction

We extract the energy forward curve pricing from the forward contract auctions for electricity and from the futures contracts auctions for natural gas. We follow Benth et al. (2007), Benth et al. (2008), Geman and Roncoroni (2006), and Riedhauser (2000), in the construction of these curves.

C.1 Forward Market for Power (Electricity)

The forward market for power is organized around the trading of standard packages covering on-peak and off-peak consumption periods. Trading occurs for delivery hubs located at the Eastern-Central regions and delivery hubs located in the Western region of the continental United States. The Easter-Central standard forward package covers the following markets: New England, New York (several hubs), Ontario, PJM, MISO, ERCOT South, Into Entergy, Into Southern and Into TVA. The Western packages cover NP15 and SP15 among others. Packages for the Eastern-Central hubs differ from those traded for the Western hub on two dimensions: the way on-peak and off-peak are defined and the delivery months of the forward packages.

We compute the standard on-peak forward packages in Eastern and Central markets are 5x16 packages (5 days per week and 16 hours per weekday from 7:00 Am to 22:59 PM), which include power delivered during on-peak hours on weekdays and exclude weekends and holidays .[16] Similarly, on-peak forward packages in Western markets are 6x16 packages, which include power delivered during the 16 on-peak hours each day Monday through Saturday and exclude Sundays and holidays. The off-peak standard packages, the forward market trade 5x8 (5 days per week and 8 hours per day) plus a 2×24 package, this includes power for delivery during the eight off-peak hours each weekday, plus all 24 hours (around the clock) on weekends. The standard off-peak forward package for the Western markets is a 6×8 delivery block plus a 1x24 delivery block, this includes power for delivery during the eight off-peak hours Monday through Saturday plus all 24 hours (around the clock) on Sunday.

For the Eastern-Central markets, on-peak and off-peak contracts are formulated for the prompt month (nearest contract), second month, third month, and balance-of-the-year in seasonal or single month packages, two full years in seasonal or single-month packages and two subsequent calendar year packages. Separate seasonal and single-month packages include the January-February winter package, the March-April spring package, May, June, the July-August summer package, September and the fourth quarter (from October to December).

C.2 Platts-Ice Forward Curve

Using forward contract data from Platts, we construct a daily forward curve for power for on-peak and off-peak consumption. Platts gathers information on the power forward market from active brokers and traders and through the non-commercial

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[16] Power market holidays are defined by the North American Electric Reliability Corp. (NERC).

departments of companies. Since October 2007 this information is complemented with the Intercontinental Exchange (ICE) quotes to form the Platts forward market power daily assessment. Because more liquid locations and shorter term packages trade more on ICE, while less liquid locations and longer term packages trade more over-the-counter (OTC), Platts is able to combine these sources to build a comprehensive picture of the forward market. Details of the methodology are described in the Platts Methodology and Specification Guide - Platts-ICE electricity Forward Curve (North America).

We select a sub-set of electricity hubs based on data availability for options and forward contracts from Platts and by our requirement to account for the power forward prices for all metropolitan areas with 150,000 employees in *Finance, and Professional and Business Services* (the major office categories).[17]

C.3 Futures Market for Natural Gas

There is a very active market for natural gas in the U.S. Following the deregulation of the wholesale market for natural gas in the mid 1990s, the New York Mercantile Exchange (NYMEX) launched the trading of monthly futures contracts with similar characteristics to those of crude oil. The standard NYMEX natural gas futures contracts specify physical delivery of 10,000 MMBtu (millions of British thermal unit) ratably delivered into Henry Hub - Louisiana. Until early 2000 NYMEX provided monthly contracts covering maturities about 36 months out. More recently, the range of maturities has been extended and it now covers more then six years (72 months) on a monthly basis. The NYMEX website provides more details on how the contracts are traded and the rules for settlement.

There is an extensive network of natural gas pipelines connecting the production basins to large consumption areas (mainly large populated urban centers). Wholesale physical natural-gas trading occurs in different hubs distributed in the continental United States. These hubs are key points in the pipeline grid characterized by either being interconnections between major pipelines and/or access points to public utility gas companies. Of all those hubs, Henry Hub is the benchmark for price quotation. Henry Hub's importance stems from both as being an interconnecting point for multiple pipelines and as being the most liquid point for trading spot and futures contracts. Prices for other hubs (spot and OTC forwards) are typically quoted as a basis to Henry Hub. These basis quotes are a very small fraction of the full benchmark quote.

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[17] Bureau of Labor Statistics, Employment Hours and Earnings, State and Metro Area, http://www.bls.gov/sae/data.htm

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