Green Noise or Green Value? Measuring the Price Effects of Environmental Certification in Commercial Buildings

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Abstract

This study investigates the price effects of environmental certification on commercial real estate assets. It is argued that there are likely to be three main drivers of price differences between certified and non-certified buildings linked to additional occupier benefits, lower holding costs for investors and a lower risk premium. Drawing upon the CoStar database of US commercial real estate assets, hedonic regression analysis is used to measure the effect of certification on both rent and price. The results suggest that, compared to buildings in the same metropolitan region, certified buildings have both a rental and sale price premium.

Introduction

Given that buildings are estimated to be responsible for 20% of greenhouse gas emissions, there is growing awareness within the real estate sector of global warming and the role of the real estate in reducing the environmental effects of business (Stern Review, 2007). Whether a purely market-driven approach or mandatory environmental regulations imposed by governments and supranational organizations can be expected to be more effective in reducing carbon emissions from the building stock is a highly contested issue. In the real estate sector, a blend of mandatory government regulation and voluntary industry standards has emerged in response to pressure to reduce the environmental impact of the building stock. As a result, required building standards have tended to become more stringent. Mandatory certification has been introduced. A good example is the introduction of a requirement for buildings to publicly display Energy Performance Certificates following the EU Directive on the Energy Performance of Buildings in 2003. However, additionally, the growth of environmentalism has lead to the emergence of market-based approaches in the form of a range of voluntary, environmental certification systems for buildings such as Green Star (Australia), LEED (USA), Energy Star (USA), Green Globes (USA), and BREEAM (UK).

Price signals are central to the operation of markets providing the information basis for the allocation of resources. For market-based solutions to be successful, the key issue has been "getting the prices right" i.e. ensuring that prices reflect environmental costs and benefits. From the perspective of the real estate investor higher risk-adjusted returns relative to other assets would provide a signal to the real estate market to supply more green buildings. In turn, lower risk-adjusted returns provide a signal to supply less. Although 'green markets' have expanded dramatically in some sectors of the economy in response to pricing signals, there is little empirical evidence that commercial real estate prices are influenced by their sustainability characteristics despite widely propagated financial and environmental benefits.

This paper investigates the price differentials between LEED/Energy Star certified buildings and non-certified commercial buildings in the US. Given that the literature suggests that certified buildings may offer a bundle of benefits linked to lower operating costs, improved employee productivity and image benefits relative to non-certified buildings, we model the short and long-run occupational price effects of certification using a static partial equilibrium framework. Assuming that the benefits of certification outweigh the costs, the theoretical analysis suggests short-run rental price premium for green buildings due to inward shifts in the demand curve for non-certified buildings. However, in the long-run rental price premiums should reduce as increased market penetration of certified buildings due to decreasing marginal production costs will be associated with decreasing marginal utility for occupiers. The asset price effects of certification are modelled and it is suggested that asset prices premiums should be obtained due to a combination of higher rental incomes, lower holding costs and/or reduced a risk premium.

We measure both the effect of voluntary certification on occupational prices (rents) and on asset prices (sales). In our empirical analysis, the certified buildings are compared to a sample of non-certified buildings which were selected to include properties in the same metropolitan areas as the certified sample. For the whole sample, rents and prices are related to a set of hedonic characteristics of the buildings such as age, location, number of stories *inter alia.* Essentially, our hedonic model is measuring price differences between certified buildings and randomly selected non-certified buildings in the same metropolitan area controlling for differences in age, height, quality, metropolitan etc. However, the model does not control for differences in micro-location. We first estimate the rental regression for a sample of 110 LEED and 433 Energy Star as well as several thousand benchmark buildings. The results suggest that certified buildings have a rental premium and that the more highly rated that buildings are, the greater the rental premium. Furthermore, based on a sample of transaction prices for 292 Energy Star and 30 LEED-certified buildings, we find price premiums of 10% and 31% respectively. It is not established whether the premiums observed are due to the benefits of a better image, higher productivity or lower operating costs. In addition, observed premiums may reflect short-run imbalances in supply relative to demand.

The remainder of this paper is organized as follows. The first section provides background discussion to the topic focusing on the growth in environmental certification, the nature of green buildings and previous research on their costs and benefits. This is followed by a theoretical analysis of the anticipated price effects of environmental certification for commercial real estate assets in both occupier and investment markets. Thirdly, the main empirical section outlines the data and methods used in the study followed by a discussion of the results. Finally conclusions are drawn.

Background

In the wider economy, the market for eco-friendly products has been expanding in response to a willingness-to-pay premium for goods and services which are considered to have reduced environmental costs. This global growth in the market for products with lower environmental costs has stimulated an array of voluntary certification and labeling codes in a range of sectors. Reinforcing this shift is the fact that many certification and labeling codes are viewed as contributing to a price-based solution to promote, what is essentially, private provision of environmental public goods (Kotchen, 2006). The LEED Green Building Rating System and the Environmental Protection Agency's Energy Star are two schemes that have been developed for the commercial real estate sector in the US.

The LEED Green Building Rating System, developed by the U.S. Green Building Council, consists of set of standards for the assessment of environmentally sustainable construction. The rates of growth in numbers of 'green' buildings have been rapid with numbers doubling nearly every two years. Although the numbers are constantly changing and discussed in more detail below, latest data from the CoStar database indicate that there are 326 LEED rated buildings and 1027 Energy Star rated commercial buildings. In common with the major regional certification such as Green Star and BREEAM, the rating system focuses on six broad categories related to: sustainability of location, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality and innovation and design process.

There are different levels of LEED accreditation based upon a scoring founded upon the six major categories listed above. In LEED v2.2 for new construction and major renovations for commercial premises, buildings may qualify for four levels of certification.

- Certified: 26-32 points
- Silver: 33-38 points
- Gold: 39-51 points
- Platinum: 52-69 points

For existing buildings, the Energy Star scheme tends to be more popular. The Energy Star scheme involves an assessment of buildings' energy performance. Buildings are awarded a score out of 100. Only buildings that are in the top quartile are eligible for Energy Star accreditation. Office properties tend to dominate both the LEED and Energy Star in terms of space and numbers (Nelson, 2007).

There is a large body of work on the attractions of and case for green buildings. Most empirical studies identify a cost premium associated with LEED rated new buildings and that the higher rated buildings tend to have a higher cost premium (see Morrison Hershfield, 2005). However, the cost premium is typically found to be relatively low ranging from 2% to 10% depending on the level of rating. In return, a range of benefits are attributed to green buildings or associated with features common in green buildings; reduced operating costs, improved productivity, improved image for occupiers and owners and reduced operating and regulatory risks. *Ex ante*, micro-level studies have found that the present value of the reduced operating costs alone is sufficient to cover the construction cost premium (see Kats, 2003, ECOFYS, 2003). In turn, surveys of willingness-to-pay have found that occupiers have stated that they are prepared to compensate owners for the additional costs of green buildings through higher rents (see GVA Grimley, 2007 and McGraw Hill Construction, 2006 for examples). However, the value of such stated preference studies is limited by the 'cheap talk' problem and there is little empirical evidence to suggest that occupiers and investors pay a price premium for certified buildings.

Given the apparent benefits of certified relative to non-certified buildings, there is a clear conundrum given the slow rate of adoption. This may be attributed to market failure - when allocations resulting from rational agents operating in decentralized markets are sub-optimal. This is widely implied in the literature and research to date (for examples, see RICS, 2005; Guy, 1998; UNEP, 2007 and Upstream, 2004). The lack of adoption of sustainable features is linked with the lack of an appropriate investment return through the pricing process. This has been explained by imperfect information, split incentives, risk aversion, high discount rates and skills shortages *inter alia*. In addition, there may be other reasons that, despite its importance, sustainability may not be reflected in the prices of buildings. The pricing process may be dominated by the weight placed by market participants on a number of overriding attributes e.g. location, appearance. Further, the heterogeneity of real estate may also be hindering the measurement of price impacts.

An alternative perspective that must be considered is that there is no market failure and that firms are not systematically making non-trivial mistakes in their evaluation of investments in environmental beneficial investments. It has been found that the high discount rates applied by businesses to investments in energy saving technologies and investment opportunities are not unique to energy (Anderson and Newell, 2004). Sanstad, Hanemann and Auffhammer (2006) point out that many of the barriers identified above are normal features of markets. They examine the suggestion that what seems to be evidence of irrational underinvestment may therefore reflect measurement error, the omission of relevant costs and other analytical failures.

Much of the research of the pricing effect of sustainable features in commercial property assets has been normative i.e. analyzing what the price effect should be; rather than positive i.e. what the price effect actually has been. Studies have focused on quantifying expected price effects of sustainable features in commercial real assets rather than measuring observed effects (see Ellison *et al*, 2007). In many cases, it is clear that the researchers are frustrated and disappointed at the absence of empirical evidence to validate their deductive reasoning on price effects (see RICS, 2005).

Additionally, whilst it is indisputable that some attributes of buildings have clear effects on their market price, it is not always clear that increased cost due to higher specification leads to increased value. In order to 'compensate' for the additional costs of construction of certified buildings, rational investors will require a combination of higher income and/or reduced risk. In research on the pricing of variations in lease terms, the standard assumption of lease pricing models is that real estate investors will extract the same value from the property regardless of leases structure (see Grenadier, 1995, Booth and Walsh, 2001, Ambrose, Hendershott and Klosek, 2002). In short, investors are assumed to be fully compensated for the costs of providing attributes that occupiers demand. However, in practice, institutional features of the rent determination process may prevent the transmission of expected price effects to actual prices. For instance, researchers have been unable to identify empirically an expected term structure of rents (see Bond, Loizou and McAllister, forthcoming, Englund, Gunnelin, Hoesli and Söderberg, 2003).

It is clear from the discussion above that real estate investors may be rewarded for the additional costs of providing certified buildings in three main ways: higher rents, lower holding costs and/or lower risk. This suggests that failure to observe rental premiums *per se* for certified buildings will not imply market imperfection. Effects may be identified in either the occupier and/or the investment market. However, assuming a well-functioning market, such effects should be observable in capital values and/or transaction prices. Failure to observe price premiums in certified buildings would provide an economic disincentive to real estate investors to supply certified buildings given the additional costs of certification.

Anticipated Price Effects – Theoretical Considerations

Before proceeding to our empirical analysis, we look at the anticipated price effects in more depth. We are interested in two prices in commercial real estate markets. The first is the rental price that businesses are prepared to pay to occupy commercial space. The second is the asset price that investors are prepared to pay to receive the rents generated by the occupational leases.

The Occupier Market – Rental Pricing

In order to link the studies on stated preferences of market agents in the real estate market to the rental price, we first need to establish the general relationship between willingness-to pay (WTP) and observed rental market price. We assume that consumers i.e. occupiers will express their preference for certified buildings as a willingness-to-pay (WTP) in excess of the price of non-certified buildings. The relationship between individual WTP functions and the aggregate market price is not straightforward, however, since the total benefit received may be higher than the market price for some consumers. As Figure 1 shows, some consumers may be willing to pay above market prices (for example P_1 and P_2) to obtain the certified product. The excess utility derived from the difference between the observed market price and the hypothetical WTP is a consumer surplus.

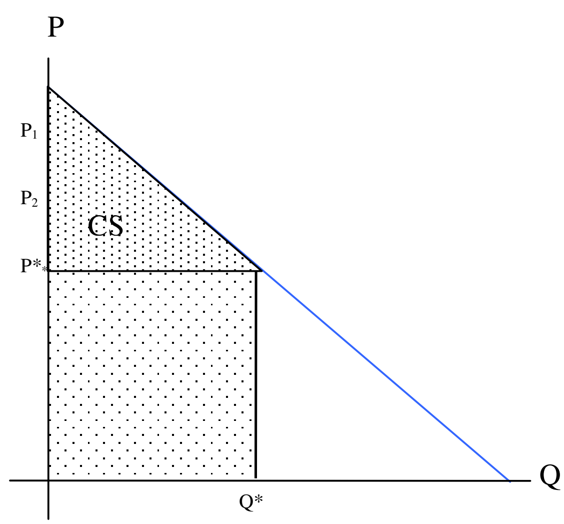

Figure 1: Demand curve for building certification with heterogeneous benefits

NOTE: This figure illustrates the composition of the WTP function with a positive consumer surplus (area labeled CS) in relation to the equilibrium price (P*).

Total WTP is thus defined as market price (P*) plus consumer surplus (CS). Since there is a single market price, it will only partially reflect the total WTP of all market participants. The CS depends on individual cost saving profiles and the importance of following corporate sustainability guidelines to a company and its customers as this is expected to generate additional revenues. The difference between WTP and observed price is crucial for understanding the seemingly paradoxical fact that observed price premia may in fact be lower than the combined utility of cost savings, image benefits, productivity enhancements etc. The magnitude of the consumer surplus is also a function of market penetration of certified buildings, which are discussed in more detail below.

To demonstrate that the diverse price effects of providing environmental certification for a product, we model the short-run price effects of certification using a static partial equilibrium framework in the next step (see Sedjo and Swallow, 2002). Whether certified products will actually incur a price premium depends on a number of factors such as the presence and size of a group of eco-consumers, their utility function relative to that of all consumers and the level of the additional costs of certification. The key issue is that when certification is introduced, supply and demand functions will differ for certified and non-certified buildings.

In Figure 2, the rental supply and demand curves for space are plotted starting with a situation where no certification is initially available. As the market clears, Q^O is supplied and P^0 is the equilibrium price. When (compulsory or voluntary) certification is introduced, it is assumed to generate new demand and supply curves. Assuming increased costs associated with certification, supply becomes more inelastic as developers require increased prices to offset these costs ($SC^0 \rightarrow SC^{cb}$). In addition, the demand curve for certified buildings is assumed to shift outwards as occupiers are prepared to pay more for certified products ($DC^0 \rightarrow DC^{cb}$). The marginal willingness to pay a premium by eco-consumers diminishes however. This means that when large quantities are consumed at a low price the premium evaporates as illustrated by the converging demand curves. The corollary of this is that the proportion of the premium is likely to be higher in the Class A segment of the market and – somewhat counter-intuitively - that suppliers increase the premium by raising costs and restricting supply.

A new equilibrium price and quantity are produced (Q^{cb}, P^{cb}) generating higher prices for certified buildings. Manifestly, the key variables are the additional costs associated with certification and the willingness of occupiers to pay an additional sum for certified buildings.

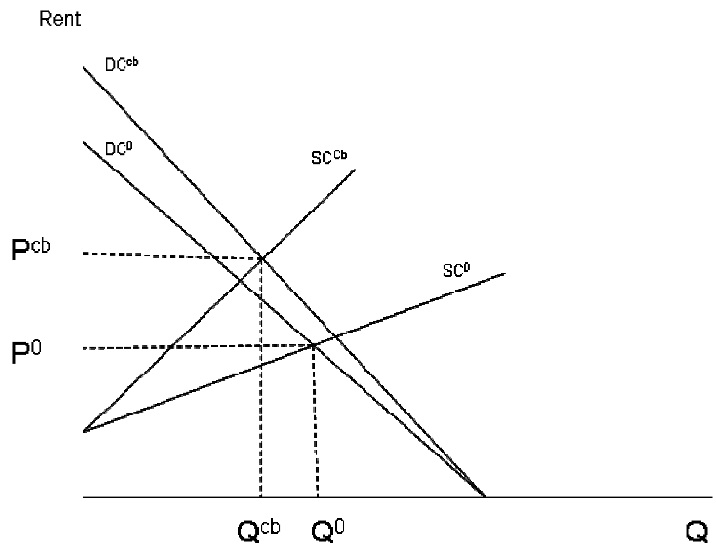

Figure 2: Short-run effect of introducing certification into the market

NOTE: This figure shows the shift in aggregate demand and supply curves caused by the introduction of environmental certification standards into the real estate market. Since certification increases production costs, supply becomes more inelastic ($SC^0 \rightarrow SC^{cb}$). The demand curve for certified buildings shifts outwards to reflect increased WTP for certified products ($DC^0 \rightarrow DC^{cb}$). Thus, new partial equilibrium quantities and prices are established (Q^{cb}, P^{cb}).

Expanding this analysis further to show differential price effects on both certified and non-certified buildings, Figure 3 assumes an inward shift in the demand curve for non-certified buildings (D^{ncb}). With the introduction of certification, it is expected that occupiers will be prepared to pay less per unit of supply of non-certified buildings at the aggregate level reflecting a generally decreased WTP in the presence of a superior product. Supply of non-certified space is more elastic (S^{ncb}), however, since it is comparatively less costly and time-consuming to provide space in this segment. In the short run, we therefore expect that certified space achieves higher rents ($P^{cb} > P^{ncb}$) but a larger quantity supplied in the non-certified market segment ($Q^{ncb} > Q^{cb}$).

In the medium- and long-run, a different pattern is likely to emerge (Figure 4). Under the assumption that certified products become the norm their supply function will coincide with that of non-certified, eventually yielding a single supply curve ($S^{cb,ncb}$). Differences in demand for both types of products will persist, however. In fact, the discount on non-certified space is expected to increase further as certified space becomes more widespread. Regardless of this, the price premium on certified space will erode over time, mainly because of the change in the supply function. A further consequence of this is that the relationship between quantities supplied in each segment will reverse as the marginal cost of certification decreases ($Q^{cb} > Q^{ncb}$).

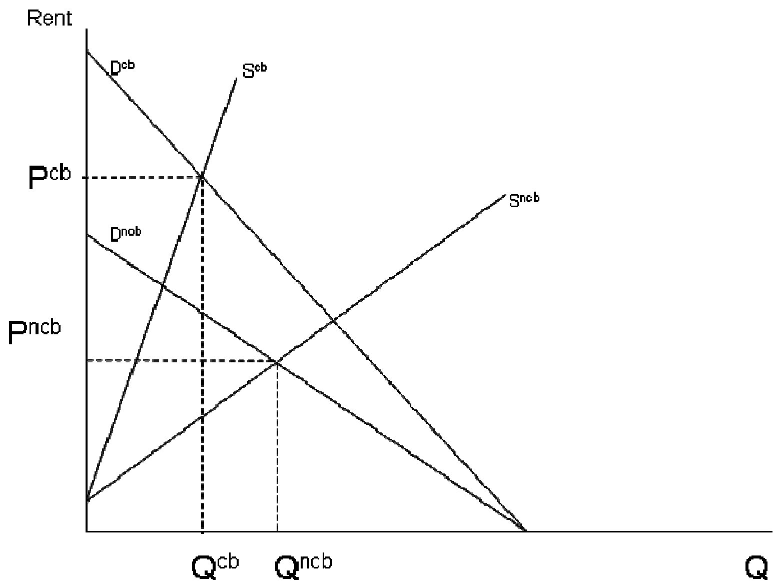

Figure 3: Short-run equilibrium prices for certified and non-certified market segments

NOTE: The demand curve for non-certified buildings (D^{ncb}) shifts further inward as certified buildings achieve higher market penetration rates. Supply of non-certified space becomes more elastic (S^{ncb}). In equilibrium, certified space achieves both higher rents ($P^{cb} > P^{ncb}$) while a larger quantity is supplied in the non-certified market segment ($Q^{ncb} > Q^{cb}$).

An important caveat is in order, however. The extent of the change is conditional upon the extent to which certified buildings become a commonly accepted industry standard. If certified buildings are only considered a niche market and fail to grow considerably, a different outcome may be expected. Instead, the short-run situation illustrated in Figure 3 may persist as eco-consumers with a higher WTP pay a premium to occupy certified space in the niche segment.

Dynamic pricing aspects

The previous section has identified possible market outcomes under various constellations in the framework of a static partial equilibrium analysis. We now explore the dynamic aspects of market entry and diffusion pertaining to price effects in more depth, by outlining an approach that merges product life cycle (PLC) theory with environmental equilibrium analysis.

As stated above, economies of scale in building production will tend to emerge in the medium term. A common assumption is that certification increases construction costs, at least initially. It is further assumed that complying with certification standards requires additional know-how and resources which specialized service providers in the construction and consulting industries possess and seek to exploit. This comparably more advanced production technology is expected to command a price premium that varies depending on the market share and phase in the product life cycle.

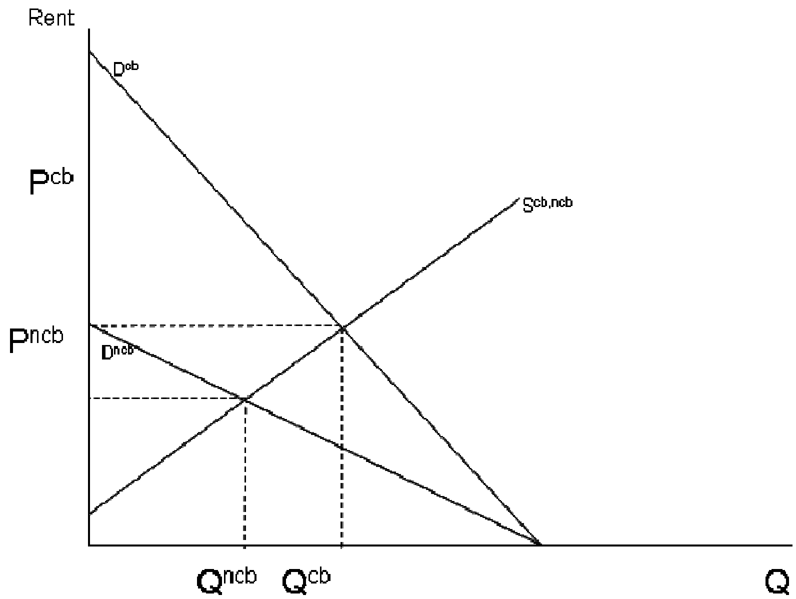

Figure 4: Medium to long-run equilibrium prices for certified and non-certified market segments

NOTE: The supply functions of certified and non-certified products converges, eventually yielding a single supply curve ($S^{cb},^{ncb}$). As certified space becomes more widespread, the absolute levels of the price premium will erode mainly because of the change in the supply function and the quantities supplied in each segment will reverse as the marginal cost of certification decreases ($Q^{cb} > Q^{ncb}$).

Figure 5 shows the dynamic interaction of the marginal cost function (*mc*) with the marginal utility (*mu*) of certified buildings. In this context, marginal utility is composed of operational cost savings associated with implementing energy-efficient standards and practices (*csv*) and the additional image-productivity premium (*ip*) paid by consumers (occupiers) to rent certified space so that

$$mu = \int_0^1 f(ip, csv)dx \qquad (1)$$

While we assume the marginal *csv* to remain constant, the *ip* that initially arose due to product differentiation benefits will diminish over time. In the initial phase, costs outweigh the tangible and intangible savings as producers seek to recoup development and introduction costs. At this point, the production capacity of certified buildings is low because of the low degree of standardization. As the market share of certified buildings increases (by voluntary or compulsory certification or a combination of both as outlined in the previous section), certification costs decrease gradually and production costs will reduce due to increasing returns to scale in the production process of certifiable buildings. *BE 1* denotes the break-even point where *mc*=*csv*. Moving along the *mc* line, investment in building certification is justified in the area between *BE 1* and *BE 2* by the combination of cost savings and image gains due to being perceived as eco-friendly and in compliance with internal or external environmental policies although energy cost savings alone outweigh the additional cost. In the rental market, it is expected that cost savings positively impact the WTP of occupiers since their total occupancy cost is *ceteris paribus* decreasing with certification. A consumer surplus arises as defined above with

$$CS = \int_0^1 (ip, csv) - \int_0^1 f(c)dx \qquad (2)$$

As the cost of certification declines further with increasing market penetration, the consumer surplus increases and investment in certification is feasible even in the absence of an image premium simply due to cost savings. As certified buildings become the norm in the market, production constraints and the higher marginal cost of certifying buildings with low environmental performance may cause the *mc* to increase again, eventually exceeding both *csv* and *mu*. *BE3* marks the transition from the feasible certification space to a situation where the cost of investing in the certification of the *n*th building outweighs *mu*. In essence, as market penetration grows rental premiums should decrease as shown before in Figure 4.

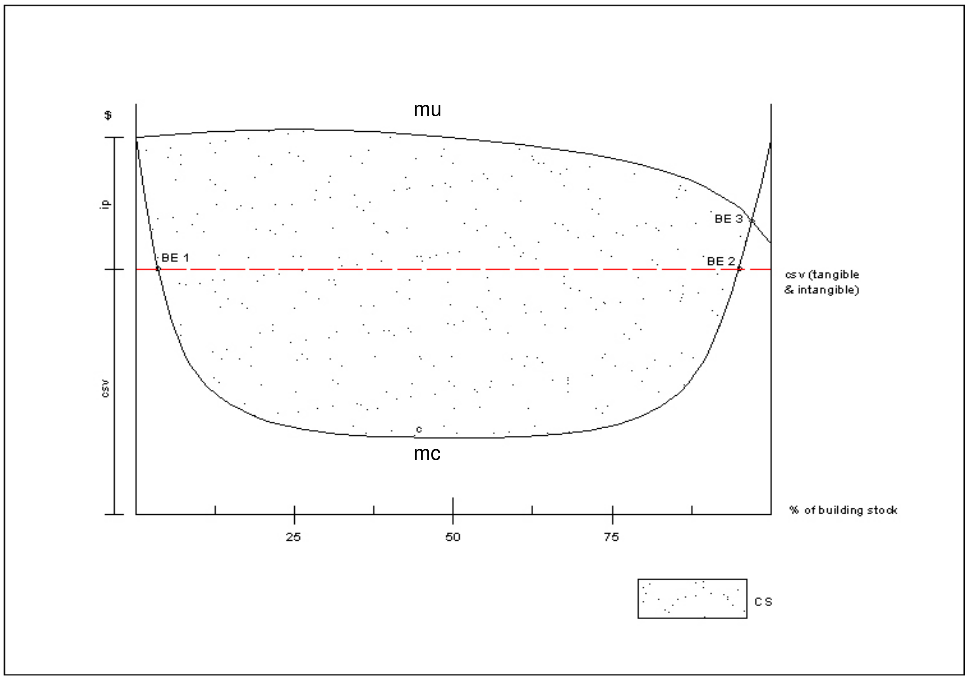

Figure 5: Marginal utility and marginal cost as a function of market penetration of the certified product

NOTE: .This figure depicts the dynamic interaction of the marginal cost function (*mc*) with the marginal utility (*mu*) of certified buildings. Hence, *mu* is composed of operational cost savings (*csv*) and the additional image and productivity premium (*ip*) paid by consumers (occupiers) to rent certified space. BE 1,2 and 3 denote the break-even points of *mc* and *mu*.

Asset Pricing

Potential price effects of sustainable features in certified buildings can be transmitted to asset prices through a number of channels. In standard real estate appraisal models, asset value represents the discounted sum all future net incomes. Assuming constant growth, the value (V) can be expressed as

$$V = \sum_{t=0}^{T} \frac{(R_t - C_t)(1+g)^t}{(1+i)^t} \qquad (3)$$

where V is the current value, R_t is rent, C_t is the periodic costs of owning the unit, management, vacancy, refurbishment etc (so that R_t – C_t = Net Operating Income), g is a constant growth rate, i is the target rate of return (composed of the risk-free rate of return plus a risk premium), and t is the life of the asset. When taken as a perpetuity, this approximates to

$$V = \frac{NOI}{i - g} \qquad (4)$$

where $i - g$ is a capitalization rate. As indicated above, the attributes of green buildings have the potential to affect many of the variables in the appraisal model:

$\boldsymbol{R_t}$ Assuming a well-functioning market and that the positive attributes outweigh negative attributes associated with certified buildings, occupiers should be willing to pay higher rents due to expected lower total occupancy costs and the benefits to occupiers of improved image and business performance.

$\boldsymbol{C_t}$ It is also expected that the increased attractiveness to occupiers should reduce the costs of ownership due to reduced vacancies and potentially reduced capital expenditure.

$\boldsymbol{i - g}$ The risk premium (and, therefore, capitalization rate) may also be affected. Whilst speculative, it has been claimed that the reductions in regulatory risk associated with certified buildings feature and the (implied) reductions in uncertainty of income may mean that investors apply a lower risk premium. However, on the other hand, there is the possibility that the less established technologies associated with green buildings may attract counteracting increases in risk premium.

Actual Price Effects – Empirical Research

There have been few studies have attempted to measure the price effects of green building rating. Studies that have identified higher rents and improved returns based on the views and experiences of expert professions still require empirical verification. Whilst recognizing the centrality of pricing to adoption, recent reviews of the literature have found little convincing research that identified a certification premium (see Berry, 2007). Nelson (2007) examined the performance differences between certified and non-certified buildings using a number of criteria. Drawing upon the CoStar database, the study compared LEED rated buildings and Energy Star buildings with a vastly larger sample of non-certified buildings in the CoStar database. Whilst acknowledging the significant differences between the sample and the wider population, it found that certified buildings tended to be newer, owner-occupied or single tenanted, concentrated geographically and sectorally (in the office sector). Recognizing that it did not control for these differences, the study identified lower vacancy rates and higher rents in LEED-rated buildings. These broad results have been confirmed by Miller, Spivey and Florance (2008) and Eichholtz, Kok and Quigley (2008). Both of these studies also drew upon the CoStar database to identify the effect of environmental certification on sale prices and rents respectively. To control for differences between their sample of certified buildings (927 buildings) and a much larger sample of non-certified buildings, Miller et al include a number of control variables such as size, location and age in their hedonic regression framework. They find that dummy variables for Energy Star and LEED ratings show the expected positive sign but tests show that these results are not significant at the 10 percent level. Eichholtz et al use a similar hedonic framework to test for the effect of certification on the contract rents of 694 office buildings. Using GIS techniques, they identify other office buildings in the CoStar database within a radius of 0.25 miles of each certified building. They identify a rent premium on the contract rents per square foot of 2.8 % for Energy Star and 0.3% for LEED-certified buildings. However, when they adjusted the rents to reflect lower vacancy rates in certified buildings the premium increases to 8.9% and 4.4% for Energy Star and LEED-certified buildings respectively. The results for LEED-certified buildings have to be interpreted with caution, however, as they fail to be significant at the 10% level.

Whilst there are clearly plausible *a priori* reasons to expect price differences between certified and non-certified buildings, this is not necessarily certain. As noted below, previous research has shown that not all variations in asset attributes are necessarily reflected in asset prices (see, for example, Wheaton, 1984 below).

The Empirical Model

Rent determination is central to the revelation of WTP by occupiers. There is a long established literature on the determinants of office rents that investigates the effect on rental levels of locational, physical and lease characteristics of commercial property assets. Rosen (1974) first used the hedonic pricing framework commonly used in rental determination research. He generalized that the hedonic price function covering any good or service consisted of a variety of utility-bearing characteristics. In office rent determination literature, the use of hedonic modeling typically involves the use that structural, locational and lease characteristics be used as the independent variables determining value.

Hedonic analysis

Hedonic regression modeling is the standard methodology for examining price determinants in real estate research. We use this method in our study primarily to isolate the effect of LEED and Energy Star certification. As described in the literature review section of this paper, higher rents or transaction prices may simply be due to the fact that certified buildings are newer, higher or located in more attractive locations or markets. The quintessential log-linear hedonic rent model takes the following form:

$$\ln R_i = \alpha_i + \beta x_i + \phi Z_i + \varepsilon_i \tag{1}$$

Where R_i is the natural log of average rent per square foot in a given building, x_i is a vector of the natural log of several explanatory locational and physical characteristics[1], β and ϕ are the respective vectors of parameters to be estimated. Z_i is a vector of time-related variables and ε_i is a random error and stochastic disturbance term that is expected to take the form of a normal distribution with a mean of zero and a variance of σ^2_ε. The hedonic weights assigned to each variable are equivalent to this characteristic's overall contribution to the rental price (Rosen 1974).

For the purpose of this study, we specify two hedonic models. The first model explains rents and the second explains price per square foot in sales transactions.

Rent Model

$$\ln R_i = \beta_0 + \beta_1 \ln Y_i + \beta_2 \ln O_i + \beta_3 \ln S_i + \beta_4 \ln L_i + \beta_5 \ln F_i + GR_i + \varepsilon_{it} \tag{2}$$

In this model, Y_i represents the year of construction or major refurbishment (whichever occurred more recently), O_i is the occupancy rate of the property, S_i is the number of stories of the property, L_i is the land area, F_i is the size of a typical floor in the building and ε_i is the

[1] We acknowledge the body of literature on the rental effects of age, vacancy levels, size and number of stories (for vacancy rates see Sirmans, Sirmans and Benjamin, 1989; Sirmans and Guidry, 1993; Clapp, 1993; Mills, 1992; for floor area see Clapp, 1980; Gat, 1998; Bollinger, Ihlanfeldt and Bowes, 1998; for age see Bollinger, Ihlanfeldt and Bowes, 1998; Slade, 2000, Dunse *et al*, 2003; for height see Shilton and Zaccaria, 1994). However, we do not discuss this body of work in this context.

error term which is assumed to be normally distributed with constant variance and a mean of zero. A rent premium for LEED and/or Energy Star rated buildings is captured by the GR_i term, a dichotomous variable that takes the value of 1 for certified buildings and a value of 0 otherwise.

Similarly, the regression for estimating price per square foot in sales transactions is estimated in the following way:

Transaction Price Model:

$$\ln P_i = \beta_0 + \beta_1 \ln YS_i + \beta_2 \ln Y_i + \beta_3 \ln O_i + \beta_4 \ln S_i + \beta_5 \ln L_i + \beta_6 \ln F_i + \beta_7 \ln W_i + \varepsilon_{it} \tag{3}$$

where YS_i is the year of the sales transaction and W_i is a vector of proxy variables of unobserved locational traits (e.g. x and y coordinates). All other variables are the same as in Rent Model.

To detect differences in the weight of parameter estimates across markets, the intercept β_0 is estimated separately for each market. This Least Squares Dummy Variable (LSDV) approach is used to control for unobserved traits across metropolitan markets. The LSDV allows intercepts of the regression to differ across markets while assuming constant variable coefficients. This is important not only because of the difference in price levels across markets but also because it controls for tax and other incentives that several states and cities grant for buildings that are certified including tax credits, reduced permitting fees and property tax abatements (Roberts, 2007).

Data

In the environmental valuation research, different methodological approaches have been taken to the estimation of WTP. This study attempts to measure the revealed preferences of market participants. Garrod and Willis (1999) evaluate the relative advantages and disadvantages stated versus revealed preference methods used in environmental valuation studies. A key issue is the existence and quality of the market data. In order to estimate revealed preferences, this study draws on CoStar's comprehensive national database which includes approximately 42.9 billion square feet of commercial space in 2 million properties making it the largest available real estate database in the United States. In an effort to provide details on the environmental performance of buildings, the CoStar Group began tagging LEED and

Energy Star buildings approximately two years ago in collaboration with the US Green Building Council (USGBC) and the US Environmental Protection Agency (EPA). This enables researchers to identify numbers and types of LEED and Energy Star certified buildings in the database. For the purpose of a rigorous analysis of certified buildings, a key issue is the benchmark against which the sample of certified buildings can be compared. There are currently 326 LEED-certified and 1027 Energy Star certified office and retail properties in the database. Our benchmark sample consists of 3626 commercial buildings in 60 metropolitan markets spread throughout the United States. Only metropolitan markets that contain certified buildings have been selected. This means that our hedonic model is measuring price differences between certified buildings and randomly selected non-certified buildings in the same metropolitan area controlling for differences in age, height, quality, metropolitan etc. However, it does not control for differences in micro-location.

In the first step, we drew details of 543 certified buildings with complete information of which 110 were LEED-NC certified and 433 were Energy Star certified representing 194 million square feet of commercial space. Weighted by the size of the properties, the four largest markets in our sample containing both LEED and Energy Star buildings were Houston (14%), Los Angeles (12%), Chicago (9%) and Denver (6%). Considering only the subsample of LEED certified buildings, the largest markets are Chicago (20%), New York City (10%), Seattle/Puget Sound (7%) and Washington DC (7%). In the second step, buildings were selected in the same metropolitan areas as the certified sample. Although the market weightings may be different between the benchmark and the certified samples, our regression model controls for market-specific effects. Both the certified and the benchmark samples include retail and office buildings with the former making up roughly 20% of the benchmark and 15% of the certified sample. Since this corresponds to less than 20 observations of certified retail properties, we will refrain from analyzing retail properties separately from office buildings. A preliminary analysis of retail property suggests, however, that the results resemble those of the combined analysis to a certain extent. Of the LEED buildings, 24% (n=26) are certification-level, 36% (n=39) are Silver, 36% (n=40) are Gold and 4% (n=5) are Platinum level. It is clear that the Platinum sample is too small to draw any inferences about pricing differences based on level of certification. In total, we have used 3,257 observations of transaction prices and 3,626 (asking) rent observations.

Results

Descriptive Statistics

The descriptive statistics are displayed in Table 1. There are clearly some differences between certified and non-certified buildings. The former tend to be newer. In particular, the median con of LEED certified buildings is 2005. The comparable figure for the benchmark sample is 1988. Whilst there is little difference between buildings with Energy Star certification and the benchmark sample in terms of age, the former tend to be dominated by tall buildings suggesting that they are mainly located in downtown locations. This is supported by the fact that Energy Star buildings tend to have the lowest land area. Without controlling for the differences between the samples, certified buildings have the higher mean asking rents and lower vacancy rates than non-certified buildings.

Table 1: Descriptive statistics of overall sample with LEED and Energy Star sample

Overall	**RENT $ psf**	**PRICE $ psf**	**% LEASED**	**LAND AREA (acres)**	**STORIES**	**YEAR TOTAL**
Mean	24.68	285.44	71.79	6.94	5.54	1985
Median	22.50	205.00	86.06	1.86	2.00	1988
Std. Dev.	12.59	248.73	33.21	85.64	8.34	20.09
Skewness	3.60	1.89	-1.21	59.85	3.46	-1.98
Kurtosis	37.46	6.80	3.10	3.70	19.36	8.04
Observations	3626	3257	3626	3626	3626	3626
LEED	**RENT $ psf**	**PRICE $ psf**	**% LEASED**	**LAND AREA (acres)**	**STORIES**	**YEAR TOTAL**
Mean	27.07	318.38	73.78	15.36	10.57	1997
Median	24.50	312.68	88.40	1.91	6.00	2005
Std. Dev.	11.62	174.35	32.47	68.57	12.29	19.41
Skewness	0.96	0.42	-1.26	7.96	2.01	-3.57
Kurtosis	4.53	2.53	3.31	67.84	6.55	16.18
Observations	110	30	110	110	110	110
Energy Star	**RENT $ psf**	**PRICE $ psf**	**% LEASED**	**LAND AREA (acres)**	**STORIES**	**YEAR TOTAL**
Mean	29.34	346.11	88.40	4.87	18.08	1989
Median	25.50	263.07	92.08	2.36	13.00	1989
Std. Dev.	18.53	243.44	13.15	6.67	14.71	11.27
Skewness	5.48	1.32	-3.01	3.53	1.17	-1.91
Kurtosis	47.32	4.15	17.47	22.72	4.09	11.09
Observations	433	288	433	433	433	433

NOTE: Descriptive statistics of the samples used in this analysis (LEED-certified, Energy Star and all buildings). The values indicate considerable differences among the groups in the distribution of occupancy rates, land area, height and vintage that need to be controlled in the regression analysis.

Aggregate time series sample

In the first step, aggregate time series data of the full set of 350 LEED and 1015 Energy Star buildings was analyzed. Figure 5 illustrates that all types of certified buildings exhibit lower vacancy rates than the benchmark group of Class A and Class B office buildings. It is interesting to note that the vacancy rates of certified buildings exhibit an overall decreasing trend in recent periods while the benchmark group, particularly the Class B type vacancy rate is increasing. Roughly half of the LEED sample buildings and 80% of the Energy Star sample are Class A properties.

Turning to Figure 6, we note that the average nominal rental rate per square foot is consistently higher for LEED Silver and Gold certified properties compared to their overall Class A and B peers. This may be taken as a further indication of the enhanced attractiveness of certified buildings.

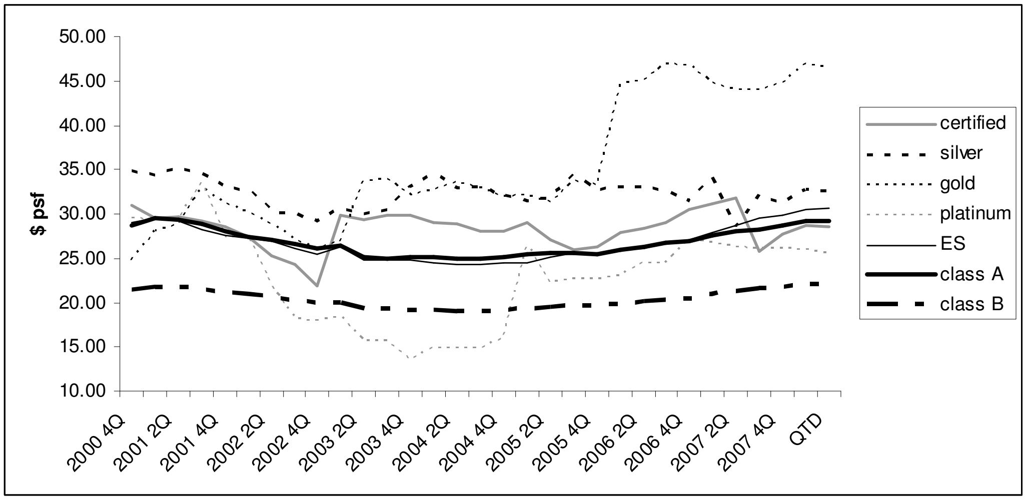

Figure 5: Average Rents: Certified and Non-Certified Buildings Compared

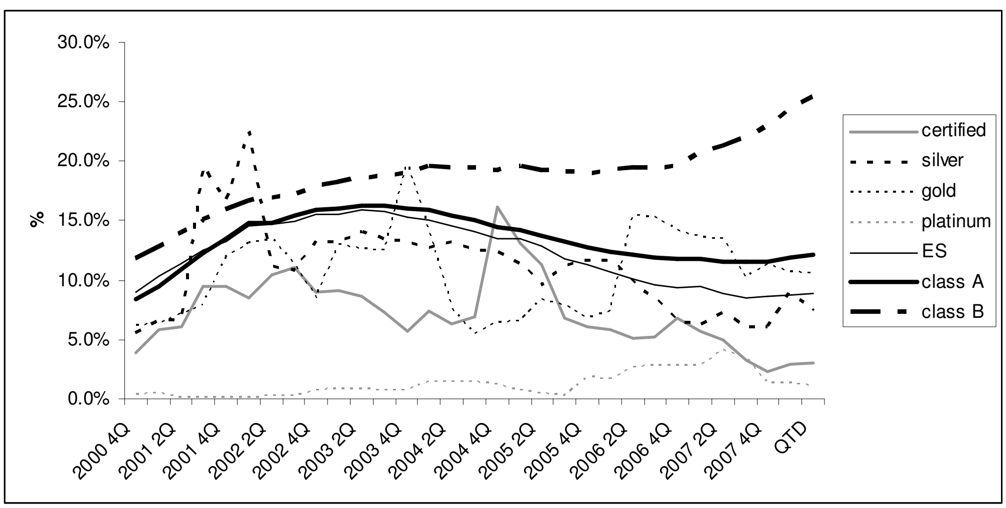

Figure 6: Average Vacancy Rates: Certified and Non-Certified Buildings Compared

NOTE: Plots showing average quarterly rental rates and vacancy rates from Q4 200 until Q1 2008. Compared to average Class A and Class B office buildings, LEED and Energy Star certified buildings exhibit lower vacancy rates and overall higher rental rates (with some exceptions).

Hedonic regression results and the rent premium

Having analyzed the aggregate sample of certified buildings, we now turn to the results derived from the smaller cross-sectional sample described in the data section. To further investigate the hypothesis of a rent and price premium for certified buildings, we estimate hedonic regressions as outlined above.

Two separate regressions are estimated to model rent and transaction price separately. All continuous numeric variables were transformed to log values to (1) reduce non-normality found in initial examinations of the dataset, (2) to reduce heteroskedasticity and (3) to be able to interpret the results as elasticities. The results are summarized in Table 2 (Appendix 1 shows the detailed results of the estimation of the rent model with diagnostics).

When controlling for the most important rent determinants such as age, occupancy rate, height, size and location, we find a significant rent premium of 11.8% in LEED/Energy Star-certified buildings compared to non-certified buildings in the same metropolitan area. The control variables used in the regression show the expected signs although not all of them reach the desired significance levels. This regression explains roughly 55% of the cross-sectional variation in rents in the entire sample.

The White test displayed at the bottom of the results reveals evidence of significant heteroskedasticity in the data. While the estimators can be expected to remain unbiased despite the presence of heteroskedasticity, the t-statistics and significance levels have to be interpreted with caution as they may be inflated. The appendix reports White heteroskedasticity-consistent standard errors and covariance to adjust for this violation of OLS assumptions. A further validity test is the Ramsey Reset test for omitted variables, misspecification and existence of non-linearities. The reported values show that the hypothesis of a faulty functional form is rejected at the 1% level but not at the 5% level.

Since we are primarily interested in the impact of environmental certification, we investigate the coefficient of the certified building variable further by using a Wald test. Under the null hypothesis of this test, the coefficient of green certification is zero. If we are able to reject the hypothesis at the 5 percent level, we can interpret this as evidence of a premium. The results reported in the appendix show that the existence of a "green" rent premium is confirmed at the 5% level.

Table 2 shows the results of the regression with separate dichotomous variables for LEED and Energy Star certification. Both types of certification are found to exert a positive and significant impact on rents. It also becomes evident that the largest part of the rent

Table 2

Summary of hedonic regression results for certified buildings

	Asking Rents						Sale Prices			
	Model 1		Model 2		Model 3		Model 4		Model 5	
Variable	**Coef**	**T-stat**	**Coef**	**T-stat**	**Coef**	**T-stat**	**Coef**	**T-stat**	**Coef**	**T-stat**
Green	0.12***	5.58					0.11***	2.47		
LEED			0.09**	2.07					0.31**	2.42
LEED level					0.03**	1.92				
Energy Star			0.12***	5.32	0.12***	5.07			0.10**	2.21
Year Built	0.38***	19.26	0.38***	18.41	0.38***	12.29	2.28*	1.73	2.16*	1.65
Percent Leased	0.02*	1.73	0.02*	1.69	0.02**	2.16	0.04***	2.87	.04***	2.96
Number of Stories	0.11***	14.21	0.11***	14.01	0.11***	14.46	0.09***	5.93	0.09***	5.81
Land Area	-0.02**'	-2.09	-.01**	-2.02	-0.01**	-1.99	0.06***	4.33	0.06***	4.42
Mean Floor Size	-0.01	-0.91	-.01	-0.94	-0.01	-1.00	-0.13***	-6.58	-0.13***	-6.66
Sale Year							-1.49	-1.14	-1.38	-1.05

NOTE: The dependent vatiable is log asking rent or sale price per sq ft

*** - significant at 1% error level

** - significant at 5% error level

* - significant at 10% error level

Detailed results and diagnostics can be found in Appendices 1-5. The key finding is that the dummy variable for a certified building is significant in all models. Further, the level of LEED rating is also significant.

premium of certified buildings is generated by Energy Star buildings when controlling for other factors. One possible explanation for this disproportionate weight of Energy Star in the premium is that LEED buildings are on average relatively new buildings so a large part of the observed premium *without* the controls may in fact be explained by the characteristics of the buildings (age, occupancy etc.) whereas this may not necessarily be the case for Energy Star buildings. It is also important to keep in mind that the Energy Star sample we used is much larger than the LEED sample which may also affect the results.

A further common assumption that we set out to test is that the rent premium of LEED buildings is increasing with the level of certification. Model 3 in Table 2 reports the estimation results with a LEED level variable. In this specification, the dichotomous LEED variable is modified to reflect the certification standard, i.e. Certified=1, Silver=2, Gold=3, and Platinum=4. Whilst acknowledging the small number of platinum rated buildings, the linear coefficient indicates an average 3% increase in rent for each increase in certification level.

Hedonic regression results and the transaction price premium

Based on the considerations of the first part of this paper, we expect to detect a premium not only for rents but also for transaction prices of certified buildings. To test this hypothesis, we re-estimate the regression with transaction price per square foot as the dependent variable. Table 2 reports the results of the estimation. The functional form of the price regression differs slightly from the rental equation since it also includes the year of the transaction as a control variable. Similar to our findings for rents, we identify a general certification premium of 11.4%. The diagnostic tests displayed at the bottom of the results reveal again the presence of heteroskedasticity in the residuals but the Ramsey test does not reach the critical significance threshold. Although this potentially merits further investigation, we assume that the model is sufficiently robust for addressing the research question at hand.

Model 5 in Table 2 reports the details of type of certification and its impact on the sale price of a property. Both LEED and Energy Star certification are found to be significant at the 5% level indicating a positive and significant impact on price per square foot. The coefficients suggest a 31% price premium for LEED buildings and a 10% premium for Energy Star. Although high for the LEED buildings, these premiums are consistent with some previously published results and the mean and median values observed for the data set. They may be indicative of a ‘hot’ market generated by the expansion of ‘green funds’ in commercial real estate.

Conclusion and Future Work

Growing global concern about climate change is increasingly transforming the preferences of consumers and investors. In addition, throughout the regulatory hierarchy, international, national and local institutions are expanding the scope of environmental regulation affecting commercial real estate assets. Similar to other product markets, a voluntary environmental certification system for new buildings and refurbishments has emerged in most mature real estate markets. Despite the publicity and promotion, the voluntarily certified sector is miniscule in terms of the current total commercial real estate stock. However, it is likely that certified green buildings will become progressively more important.

Price signals are fundamental to the supply of green buildings. Whilst surveys of the real estate occupiers suggest that they are prepared to pay more for green certified assets, there has been little evidence to support their assertions. Further, *a priori* inference suggests that certified buildings should obtain a rental and an asset price premium. The rental price premium is expected to be largely determined by the level of demand from occupiers for certified buildings. This, in turn, will be a function of the extent of the consumer surplus generated by certified buildings. In addition, the increased costs associated with production of certified buildings will affect the price premium. The supply response is also significant and price premiums should change over time linked to changes in marginal production costs and the extent of market penetration.

From the asset price perspective, it is expected that investors' holding costs should be lower due to attractiveness to occupiers associated with business performance, image and lower running costs. This can lead to a rental premium and/or lower vacancy rates. In turn, investors in certified buildings are likely to be 'future proof' from potential increasing regulatory requirements. The lower risks due to reduced voids and lower regulatory risks may reduce the risk premium that investors require from certified real estate assets relative to non-certified real estate assets.

To date, the relatively small numbers of certified buildings and the fact that they tend to be built for the public sector or for owner-occupation has hindered empirical investigation of the price impacts of certification. Drawing upon the CoStar Group's database, our study provides preliminary support for the price premium hypothesis. The uncontrolled sample suggest the results suggest that certified green buildings obtain higher rents, have lower vacancy rates and sell for more than non-certified buildings. When we control for potential differences between certified buildings and non-certified buildings, the finding of price premium relative to buildings in the same metropolitan area is confirmed. In addition, there is evidence to suggest that the more highly rated that buildings are, the greater the premium.

However, we cannot be sure that the price premiums themselves are sustainable. The finding of high levels of price premiums may be indicative of short-term demand pressure effects from both occupiers and investors in the context of an under-supplied market. As the market for certified buildings matures, it will be necessary to disentangle the short-run and long-run dynamics of the pricing process. Further, it would be interesting to investigate the extent to which observed premiums can be attributed to the benefits of a better image, higher productivity or lower operating costs. This attribution is likely to vary temporally and spatially as the relative importance of energy costs fluctuates along with social and business expectations.

Although the results are plausible and fit with expectations, this is a study of a fairly embryonic sector. A predictable caveat is that the sample needs to be larger. For instance, we identified rent or transaction price information for only four LEED Platinum buildings. Further work is needed on model specification because of the presence of heteroskedasticity in the residuals which potentially distorts significance levels. Initial tests using an alternative Weighted-Least-Squares regression model showed similar results. There is clearly scope for more empirical research in these areas as more data becomes available. It would also be desirable to analyze the premia of various property types, most notably of retail property contingent on a larger sample of this property type.

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Appendix 1

Specification and results of rent regression and the impact of certification (in dollars per sq.ft.)

Dependent Variable: **LOG(RENT)**
Method: Least Squares
Included observations: 2613
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GREEN	0.118	0.02	5.58	0.00
LOG(YEAR BUILT)	0.382	0.02	19.26	0.00
LOG(PERCENT LEASED)	0.020	0.01	1.73	0.08
LOG(STORIES)	0.110	0.01	14.21	0.00
LOG(LAND AREA)	-0.015	0.01	-2.09	0.04
LOG(TYPICAL FLOOR)	-0.010	0.01	-0.91	0.36
MARKET=ATLANTA	-0.087	0.11	-0.79	0.43
MARKET=AUSTIN	-0.026	0.11	-0.24	0.81
MARKET=BALTIMORE	0.183	0.10	1.75	0.08
MARKET=BOSTON	0.181	0.11	1.58	0.11
MARKET=CHARLOTTE	-0.103	0.11	-0.94	0.35
MARKET=CHICAGO	-0.142	0.11	-1.29	0.20
MARKET=CINCINNATI/DAYTON	-0.548	0.12	-4.40	0.00
MARKET=CLEVELAND	-0.451	0.11	-3.99	0.00
MARKET=COLORADO SPRINGS	-0.480	0.11	-4.25	0.00
MARKET=COLUMBUS	-0.466	0.11	-4.12	0.00
MARKET=DALLAS/FT WORTH	-0.232	0.11	-2.15	0.03
MARKET=DENVER	-0.253	0.11	-2.33	0.02
MARKET=DETROIT	-0.309	0.14	-2.25	0.02
MARKET=EAST BAY/OAKLAND	0.117	0.11	1.05	0.29
MARKET=HARTFORD	-0.082	0.11	-0.74	0.46
MARKET=HAWAII	-0.305	0.15	-2.01	0.04
MARKET=HOUSTON	-0.237	0.11	-2.19	0.03
MARKET=INDIANAPOLIS	0.025	0.11	0.23	0.82
MARKET=INLAND EMPIRE	0.059	0.12	0.50	0.61
MARKET=JACKSONVILLE (FLORIDA)	-0.240	0.11	-2.12	0.03
MARKET=KANSAS CITY	-0.448	0.13	-3.51	0.00
MARKET=LAS VEGAS	0.443	0.10	4.24	0.00
MARKET=LONG ISLAND (NEW YORK)	0.511	0.10	4.89	0.00
MARKET=LOS ANGELES	0.392	0.11	3.66	0.00
MARKET=LOUISVILLE	-0.478	0.10	-4.57	0.00
MARKET=MILWAUKEE/MADISON	-0.434	0.12	-3.55	0.00
MARKET=MINNEAPOLIS/ST PAUL	-0.698	0.13	-5.55	0.00
MARKET=NASHVILLE	-0.409	0.10	-3.91	0.00
MARKET=NEW ORLEANS	-0.429	0.11	-4.09	0.00
MARKET=NEW YORK CITY	0.717	0.12	6.17	0.00
MARKET=NORTHERN NEW JERSEY	0.193	0.11	1.72	0.09
MARKET=ORANGE (CALIFORNIA)	0.248	0.11	2.32	0.02
MARKET=ORLANDO	0.056	0.11	0.51	0.61
MARKET=PHILADELPHIA	-0.116	0.11	-1.03	0.30
MARKET=PHOENIX	0.193	0.11	1.77	0.08
MARKET=PORTLAND	-0.094	0.11	-0.84	0.40
MARKET=RICHMOND VA	0.460	0.10	4.39	0.00

MARKET=ROANOKE	0.236	0.11	2.25	0.02
MARKET=SACRAMENTO	0.259	0.11	2.32	0.02
MARKET=SALT LAKE CITY	-0.210	0.22	-0.97	0.33
MARKET=SAN DIEGO	0.402	0.11	3.67	0.00
MARKET=SAN FRANCISCO	0.397	0.11	3.58	0.00
MARKET=SAVANNAH	0.573	0.11	5.42	0.00
MARKET=SEATTLE/PUGET SOUND	0.129	0.11	1.17	0.24
MARKET=SOUTH BAY/SAN JOSE	0.368	0.11	3.35	0.00
MARKET=SOUTH FLORIDA	0.146	0.11	1.33	0.18
MARKET=SPOKANE	-1.013	0.11	-9.61	0.00
MARKET=ST. LOUIS	-0.197	0.14	-1.45	0.15
MARKET=TAMPA/ST PETERSBURG	-0.069	0.13	-0.52	0.60
MARKET=WASHINGTON DC	0.343	0.11	3.18	0.00
MARKET=WESTCHESTER	-0.383	0.22	-1.78	0.08

R-squared	0.55	Mean dep var	3.13
Adjusted R-squared	0.54	S.D. dep var	0.45
S.E. of regression	0.30	AIC	0.47
Sum squared resid	235.08	Schwarz criterion	0.60
Log likelihood	-561.20	DW-stat	1.52

Ramsey RESET Test:

F-statistic	7.96	Prob. F(1,2546)	0.00
Log likelihood ratio	8.14	Prob. Chi-Square(1)	0.00

Wald Test:

Equation: EQ_RENT_GREEN

Test Statistic	Value	df	Probability
F-statistic	31.09	(1, 2556)	0.00
Chi-square	31.09	1	0.00

Normalized Restriction (= 0)	Value	Std. Err.
C(1) (GREEN)	0.186	0.02

Ramsey RESET Test:

F-statistic	7.96	Prob. F(1,2546)	0.00
Log likelihood ratio	8.14	Prob. Chi-Square(1)	0.00

White Heteroskedasticity Test:

F-statistic	3.35	Prob. F(61,2551)	0.00
Obs*R-squared	193.73	Prob. Chi-Square(61)	0.00

Appendix 2

Impact of LEED and Energy Star certification on rents (in dollars per sq.ft

Dependent Variable: **LOG(RENT)**
Method: Least Squares
Included observations: 2613
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LEED	0.092	0.04	2.07	0.04
ENERGY_STAR	0.116	0.02	5.32	0.00
LOG(YEAR_TOTAL)	0.384	0.02	18.41	0.00
LOG(PERCENT_LEASED)	0.019	0.01	1.69	0.09
LOG(STORIES)	0.110	0.01	14.01	0.00
LOG(LAND_AREA)	-0.014	0.01	-2.02	0.04
LOG(TYPICAL_FLOOR)	-0.010	0.01	-0.94	0.35
MARKET=ATLANTA	-0.10	0.12	-0.84	0.40
MARKET=AUSTIN	-0.04	0.12	-0.33	0.74
MARKET=BALTIMORE	0.19	0.11	1.73	0.08
MARKET=BOSTON	0.17	0.12	1.36	0.18
MARKET=CHARLOTTE	-0.12	0.12	-0.98	0.33
MARKET=CHICAGO	-0.16	0.12	-1.32	0.19
MARKET=CINCINNATI/DAYTON	-0.56	0.13	-4.23	0.00
MARKET=CLEVELAND	-0.46	0.12	-3.80	0.00
MARKET=COLORADO SPRINGS	-0.49	0.12	-3.98	0.00
MARKET=COLUMBUS	-0.48	0.12	-3.93	0.00
MARKET=DALLAS/FT WORTH	-0.24	0.12	-2.07	0.04
MARKET=DENVER	-0.27	0.12	-2.26	0.02
MARKET=DETROIT	-0.35	0.16	-2.20	0.03
MARKET=EAST BAY/OAKLAND	0.11	0.12	0.87	0.39
MARKET=HARTFORD	-0.09	0.12	-0.76	0.45
MARKET=HAWAII	-0.31	0.16	-1.90	0.06
MARKET=HOUSTON	-0.25	0.12	-2.10	0.04
MARKET=INDIANAPOLIS	0.01	0.12	0.09	0.93
MARKET=INLAND EMPIRE	0.05	0.13	0.36	0.72
MARKET=JACKSONVILLE (FLORIDA)	-0.25	0.12	-2.08	0.04
MARKET=KANSAS CITY	-0.46	0.13	-3.44	0.00
MARKET=LAS VEGAS	0.46	0.11	4.02	0.00
MARKET=LONG ISLAND (NEW YORK)	0.52	0.11	4.63	0.00
MARKET=LOS ANGELES	0.38	0.12	3.24	0.00
MARKET=LOUISVILLE	-0.49	0.12	-4.22	0.00
MARKET=MILWAUKEE/MADISON	-0.43	0.13	-3.38	0.00
MARKET=MINNEAPOLIS/ST PAUL	-0.71	0.14	-5.25	0.00
MARKET=NASHVILLE	-0.42	0.12	-3.64	0.00
MARKET=NEW ORLEANS	-0.44	0.12	-3.79	0.00
MARKET=NEW YORK CITY	0.71	0.12	5.70	0.00
MARKET=NORTHERN NEW JERSEY	0.18	0.12	1.48	0.14
MARKET=ORANGE (CALIFORNIA)	0.23	0.12	2.02	0.04
MARKET=ORLANDO	0.04	0.12	0.35	0.72
MARKET=PHILADELPHIA	-0.13	0.12	-1.07	0.29

MARKET=PHOENIX	0.18	0.12	1.52	0.13
MARKET=PORTLAND	-0.10	0.12	-0.82	0.41
MARKET=RICHMOND VA	0.47	0.11	4.18	0.00
MARKET=ROANOKE	0.25	0.11	2.21	0.03
MARKET=SACRAMENTO	0.25	0.12	2.04	0.04
MARKET=SALT LAKE CITY	-0.21	0.22	-0.99	0.32
MARKET=SAN DIEGO	0.39	0.12	3.28	0.00
MARKET=SAN FRANCISCO	0.38	0.12	3.21	0.00
MARKET=SAVANNAH	0.58	0.11	5.12	0.00
MARKET=SEATTLE/PUGET SOUND	0.12	0.12	0.97	0.33
MARKET=SOUTH BAY/SAN JOSE	0.36	0.12	2.99	0.00
MARKET=SOUTH FLORIDA	0.13	0.12	1.12	0.26
MARKET=SPOKANE	-1.00	0.11	-8.78	0.00
MARKET=ST. LOUIS	-0.18	0.14	-1.29	0.20
MARKET=TAMPA/ST PETERSBURG	-0.08	0.14	-0.58	0.57
MARKET=WASHINGTON DC	0.33	0.12	2.83	0.00
MARKET=WESTCHESTER	-0.38	0.23	-1.69	0.09

R-squared	0.55	Mean dep var	3.13
Adjusted R-squared	0.54	S.D. dep var	0.45
S.E. of regression	0.30	AIC	0.47
Sum squared resid	235.05	Schwarz criterion	0.60
Log likelihood	-561.05	DW-stat	1.52

Ramsey RESET Test:

F-statistic	2.03	Prob. F(1,2554)	0.15
Log likelihood ratio	2.08	Prob. Chi-Square(1)	0.15

Wald Test:

Equation: EQ_RENT_LEED

Test Statistic	Value	Df	Probability
F-statistic	4.30	(1, 26)	0.04
Chi-square	4.30	1	0.04

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(1)	0.09	0.04

White Heteroskedasticity Test:

F-statistic	3.29	Prob. F(62,2550)	0.00
Obs*R-squared	193.79	Prob. Chi-Square(62)	0.00

Appendix 3

Impact of level of LEED certification on rents (in dollars per sq.ft.)

Dependent Variable: **LOG(RENT)**
Method: Least Squares
Included observations: 2613
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LEEDLEVEL	**0.03**	**0.02**	**1.92**	**0.05**
ENERGY_STAR	0.12	0.02	5.07	0.00
LOG(YEAR_TOTAL)	0.38	0.03	12.29	0.00
LOG(PERCENT_LEASED)	0.02	0.01	2.16	0.03
LOG(STORIES)	0.11	0.01	14.46	0.00
LOG(LAND_AREA)	-0.01	0.01	-1.99	0.05
LOG(TYPICAL_FLOOR)	-0.01	0.01	-1.00	0.32
MARKET=ATLANTA	-0.09	0.22	-0.43	0.67
MARKET=AUSTIN	-0.03	0.22	-0.16	0.87
MARKET=BALTIMORE	0.22	0.37	0.60	0.55
MARKET=BOSTON	0.17	0.22	0.79	0.43
MARKET=CHARLOTTE	-0.11	0.22	-0.51	0.61
MARKET=CHICAGO	-0.15	0.22	-0.69	0.49
MARKET=CINCINNATI/DAYTON	-0.55	0.22	-2.48	0.01
MARKET=CLEVELAND	-0.46	0.22	-2.08	0.04
MARKET=COLORADO SPRINGS	-0.49	0.28	-1.75	0.08
MARKET=COLUMBUS	-0.47	0.22	-2.15	0.03
MARKET=DALLAS/FT WORTH	-0.24	0.22	-1.10	0.27
MARKET=DENVER	-0.26	0.22	-1.20	0.23
MARKET=DETROIT	-0.34	0.28	-1.23	0.22
MARKET=EAST BAY/OAKLAND	0.11	0.22	0.50	0.62
MARKET=HARTFORD	-0.09	0.30	-0.29	0.77
MARKET=HAWAII	-0.31	0.28	-1.11	0.27
MARKET=HOUSTON	-0.24	0.22	-1.12	0.26
MARKET=INDIANAPOLIS	0.02	0.37	0.04	0.97
MARKET=INLAND EMPIRE	0.05	0.22	0.23	0.82
MARKET=JACKSONVILLE (FLORIDA)	-0.25	0.22	-1.10	0.27
MARKET=KANSAS CITY	-0.46	0.22	-2.04	0.04
MARKET=LAS VEGAS	0.45	0.37	1.21	0.23
MARKET=LONG ISLAND (NEW YORK)	0.59	0.37	1.58	0.11
MARKET=LOS ANGELES	0.38	0.22	1.77	0.08
MARKET=LOUISVILLE	-0.48	0.37	-1.30	0.19
MARKET=MILWAUKEE/MADISON	-0.42	0.26	-1.59	0.11
MARKET=MINNEAPOLIS/ST PAUL	-0.71	0.23	-3.04	0.00
MARKET=NASHVILLE	-0.42	0.37	-1.12	0.26
MARKET=NEW ORLEANS	-0.44	0.37	-1.17	0.24
MARKET=NEW YORK CITY	0.71	0.22	3.24	0.00
MARKET=NORTHERN NEW JERSEY	0.18	0.22	0.82	0.41
MARKET=ORANGE (CALIFORNIA)	0.24	0.22	1.10	0.27
MARKET=ORLANDO	0.05	0.22	0.21	0.83

MARKET=PHILADELPHIA	-0.12	0.22	-0.56	0.57
MARKET=PHOENIX	0.18	0.22	0.84	0.40
MARKET=PORTLAND	-0.10	0.26	-0.37	0.71
MARKET=RICHMOND VA	0.47	0.37	1.26	0.21
MARKET=ROANOKE	0.31	0.37	0.84	0.40
MARKET=SACRAMENTO	0.25	0.22	1.12	0.26
MARKET=SALT LAKE CITY	-0.19	0.28	-0.68	0.50
MARKET=SAN DIEGO	0.39	0.22	1.80	0.07
MARKET=SAN FRANCISCO	0.39	0.22	1.78	0.07
MARKET=SAVANNAH	0.61	0.37	1.65	0.10
MARKET=SEATTLE/PUGET SOUND	0.12	0.22	0.56	0.58
MARKET=SOUTH BAY/SAN JOSE	0.36	0.22	1.65	0.10
MARKET=SOUTH FLORIDA	0.14	0.22	0.63	0.53
MARKET=SPOKANE	-1.01	0.37	-2.70	0.01
MARKET=ST. LOUIS	-0.13	0.28	-0.48	0.63
MARKET=TAMPA/ST PETERSBURG	-0.08	0.30	-0.25	0.80
MARKET=WASHINGTON DC	0.33	0.22	1.54	0.12
MARKET=WESTCHESTER	-0.38	0.30	-1.26	0.21

R-squared	0.55	Mean dep var	3.13
Adjusted R-squared	0.54	S.D. dep var	0.45
S.E. of regression	0.30	AIC	0.47
Sum squared resid	235.14	Schwarz criterion	0.60
Log likelihood	-561.54	DW-stat	1.52

Ramsey RESET Test:

F-statistic	2.05	Prob. F(1,2554)	0.15
Log likelihood ratio	2.09	Prob. Chi-Square(1)	0.15

Wald Test:

Equation: EQ_RENT_LEEDLEVEL

Test Statistic	Value	df	Probability
F-statistic	3.70	(1, 2555)	0.05
Chi-square	3.70	1	0.05

Normalized Restriction (= 0)	Value	Std. Err.
C(1) (Leed level)	0.034	0.018

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	20.23379	Prob. F(7,2882)	0.0000
Obs*R-squared	135.3766	Prob. Chi-Square(7)	0.0000
Scaled explained SS	273.9093	Prob. Chi-Square(7)	0.0000

Appendix 4

Impact of certification on transaction prices (in dollars per sq.ft.)

Dependent Variable: LOG(PRICESF)
Method: Least Squares
Sample: 1 4938 IF PRICESF>60 AND PRICESF<900

Included observations: 2212

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GREEN	**0.114**	**0.05**	**2.47**	**0.01**
LOG(PERCENT_LEASED)	0.043	0.02	2.87	0.00
LOG(STORIES)	0.087	0.01	5.93	0.00
LOG(LAND_AREA)	0.061	0.01	4.33	0.00
LOG(TYPICAL_FLOOR)	-0.126	0.02	-6.58	0.00
LOG(YEAR_TOTAL)	2.275	1.31	1.73	0.08
LOG(SALE_YEAR)	-1.488	1.31	-1.14	0.26
MARKET=AUSTIN	0.168	0.09	1.82	0.07
MARKET=BOSTON	0.351	0.07	5.11	0.00
MARKET=CHARLOTTE	0.192	0.08	2.26	0.02
MARKET=CHICAGO	0.057	0.08	0.68	0.50
MARKET=CINCINNATI	-0.536	0.15	-3.70	0.00
MARKET=CLEVELAND	-0.474	0.11	-4.40	0.00
MARKET=COLORADO SPR	0.208	0.54	0.39	0.70
MARKET=COLUMBUS	-0.439	0.11	-4.04	0.00
MARKET=DALLAS/FTW	-0.177	0.10	-1.75	0.08
MARKET=DENVER	-0.188	0.08	-2.31	0.02
MARKET=EAST BAY/OAKLAND	0.243	0.10	2.38	0.02
MARKET=HARTFORD	0.401	0.54	0.74	0.46
MARKET=HOUSTON	-0.248	0.11	-2.36	0.02
MARKET=INDIANAPOLIS	-0.301	0.38	-0.78	0.43
MARKET=INLAND EMPIRE	-0.071	0.11	-0.64	0.52
MARKET=J'VILLE (FL)	-0.183	0.13	-1.36	0.18
MARKET=KANSAS CITY	-0.418	0.16	-2.60	0.01
MARKET=LOS ANGELES	0.707	0.07	10.13	0.00
MARKET=MARIN/SONOMA	0.811	0.54	1.50	0.13
MARKET=MINNEAPOLIS	0.275	0.21	1.29	0.20
MARKET=NEW ORLEANS	1.384	0.54	2.57	0.01
MARKET=NEW YORK CITY	0.401	0.10	4.02	0.00
MARKET=N NEW JERSEY	0.260	0.12	2.12	0.03
MARKET=ORANGE (CAL)	0.367	0.07	5.28	0.00
MARKET=ORLANDO	0.159	0.11	1.50	0.13
MARKET=PHILADELPHIA	-0.010	0.10	-0.10	0.92
MARKET=PHOENIX	0.408	0.08	5.05	0.00
MARKET=PORTLAND	-0.064	0.32	-0.20	0.84

MARKET=SACRAMENTO	0.398	0.14	2.94	0.00
MARKET=SALT LAKE CITY	1.461	0.54	2.71	0.01
MARKET=SAN DIEGO	0.617	0.09	6.90	0.00
MARKET=SAN FRANCISCO	0.632	0.08	8.40	0.00
MARKET=SEATTLE	0.502	0.08	6.26	0.00
MARKET=S BAY/S JOSE	0.719	0.08	8.92	0.00
MARKET=SOUTH FLORIDA	0.357	0.08	4.74	0.00
MARKET=ST. LOUIS	-0.279	0.54	-0.52	0.61
MARKET=TAMPA	-0.596	0.54	-1.11	0.27
MARKET=WASHINGTON DC	0.580	0.07	7.76	0.00

R-squared	0.301213	Mean dependent var	5.364223
Adjusted R-squared	0.287025	S.D. dependent var	0.633698
S.E. of regression	0.535081	Akaike info criterion	1.607335
Sum squared resid	620.4367	Schwarz criterion	1.723327
Log likelihood	-1732.713	Durbin-Watson stat	0.767209

Ramsey RESET Test:

F-statistic	15.79022	Prob. F(1,2633)	0.0001
Log likelihood ratio	16.01810	Prob. Chi-Square(1)	0.0001

Wald Test:

Test Statistic	Value	df	Probability
F-statistic	4.699037	(1, 2633)	0.0303
Chi-square	4.699037	1	0.0302

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	134.2788	Prob. F(8,2670)	0.0000
Obs*R-squared	768.6128	Prob. Chi-Square(8)	0.0000
Scaled explained SS	12631.87	Prob. Chi-Square(8)	0.0000

Appendix 5

Impact of Energy Star and LEED certification on transaction prices (in dollars per sq.ft.)

Dependent Variable: LOG(PRICESF)
Method: Least Squares
Included observations: 2212

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ENERGY_STAR	**0.103**	**0.05**	**2.21**	**0.03**
LEED	**0.314**	**0.13**	**2.42**	**0.02**
LOG(PERCENT_LEASED)	0.045	0.02	2.96	0.00
LOG(STORIES)	0.085	0.01	5.81	0.00
LOG(LAND_AREA)	0.062	0.01	4.42	0.00
LOG(TYPICAL_FLOOR)	-0.128	0.02	-6.66	0.00
LOG(YEAR_TOTAL)	2.164	1.31	1.65	0.10
LOG(SALE_YEAR)	-1.375	1.31	-1.05	0.29
MARKET=AUSTIN	0.169	0.09	1.83	0.07
MARKET=BOSTON	0.353	0.07	5.15	0.00
MARKET=CHARLOTTE	0.192	0.08	2.26	0.02
MARKET=CHICAGO	0.045	0.08	0.53	0.60
MARKET=CINCINNATI	-0.536	0.15	-3.70	0.00
MARKET=CLEVELAND	-0.475	0.11	-4.41	0.00
MARKET=COLORADO SPR	0.221	0.54	0.41	0.68
MARKET=COLUMBUS	-0.440	0.11	-4.05	0.00
MARKET=DALLAS/FTW	-0.177	0.10	-1.76	0.08
MARKET=DENVER	-0.192	0.08	-2.36	0.02
MARKET=EAST BAY/OAKLAND	0.246	0.10	2.40	0.02
MARKET=HARTFORD	0.418	0.54	0.77	0.44
MARKET=HOUSTON	-0.242	0.11	-2.30	0.02
MARKET=INDIANAPOLIS	-0.303	0.38	-0.79	0.43
MARKET=INLAND EMPIRE	-0.072	0.11	-0.65	0.52
MARKET=J'VILLE (FL)	-0.184	0.13	-1.36	0.17
MARKET=KANSAS CITY	-0.442	0.16	-2.75	0.01
MARKET=LOS ANGELES	0.707	0.07	10.13	0.00
MARKET=MARIN/SONOMA	0.820	0.54	1.52	0.13
MARKET=MINNEAPOLIS	0.290	0.21	1.36	0.17
MARKET=NEW ORLEANS	1.400	0.54	2.60	0.01
MARKET=NEW YORK CITY	0.402	0.10	4.04	0.00
MARKET=N NEW JERSEY	0.262	0.12	2.14	0.03
MARKET=ORANGE (CAL)	0.367	0.07	5.28	0.00
MARKET=ORLANDO	0.159	0.11	1.49	0.14
MARKET=PHILADELPHIA	-0.015	0.10	-0.16	0.88
MARKET=PHOENIX	0.411	0.08	5.08	0.00
MARKET=PORTLAND	-0.049	0.32	-0.16	0.88
MARKET=SACRAMENTO	0.400	0.14	2.96	0.00

MARKET=SALT LAKE CITY	1.473	0.54	2.73	0.01
MARKET=SAN DIEGO	0.615	0.09	6.88	0.00
MARKET=SAN FRANCISCO	0.632	0.08	8.40	0.00
MARKET=SEATTLE	0.504	0.08	6.28	0.00
MARKET=S BAY/S JOSE	0.719	0.08	8.92	0.00
MARKET=SOUTH FLORIDA	0.358	0.08	4.76	0.00
MARKET=ST. LOUIS	-0.473	0.55	-0.86	0.39
MARKET=TAMPA	-0.581	0.54	-1.08	0.28
MARKET=WASHINGTON DC	0.579	0.07	7.75	0.00
R-squared	0.30	Mean dependent var		5.36
Adjusted R-squared	0.29	S.D. dependent var		0.63
S.E. of regression	0.53	Akaike info criterion		1.61
Sum squared resid	619.17	Schwarz criterion		1.72
Log likelihood	-1730.45	Durbin-Watson stat		0.77

Ramsey RESET Test:

F-statistic	0.586696	Prob. F(1,2545)	0.4438
Log likelihood ratio	0.597693	Prob. Chi-Square(1)	0.4395

Wald Test:

Test Statistic	Value	df	Probability
F-statistic	4.594999	(1, 2546)	0.0322
Chi-square	4.594999	1	0.0321

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	3.708524	Prob. F(9,2583)	0.0001
Obs*R-squared	33.07850	Prob. Chi-Square(9)	0.0001
Scaled explained SS	38.09257	Prob. Chi-Square(9)	0.0000