



Munich Personal RePEc Archive

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

Fuerst, Franz and McAllister, Patrick

University of Reading, Henley Business School

April 2008

Online at <https://mpra.ub.uni-muenchen.de/16625/>
MPRA Paper No. 16625, posted 10 Aug 2009 07:59 UTC



Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Property Values

Franz Fuerst and Patrick McAllister

School of Real Estate and Planning,
Henley Business School
University of Reading
PO Box 219,
Whiteknights,
Reading,
RG6 6UD,

e.mail : f.fuerst@rdg.ac.uk or p.m.mcallister@rdg.ac.uk

Acknowledgement

The authors wish to thank the CoStar Group for providing the large dataset needed to perform this analysis. Three anonymous referees provided valuable comments and guidance that improved the quality of this paper. All errors remain our own.

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. These are 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 submarkets, eco-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 led 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, prices need to reflect environmental costs and benefits. In a real estate context, higher risk-adjusted returns of certified assets potentially provide a signal that is transmitted from the investment market to the space market subsequently causing an increase in the supply of green buildings. 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. The contributions are twofold. Firstly, it seeks to provide a theoretical grounding for the expected price differential between certified and non-certified buildings. Given that the literature suggests that certified buildings may offer a bundle of benefits linked to lower operating costs, improved employee productivity, tax credits and image benefits relative to non-certified buildings, we use a static partial equilibrium framework to demonstrate short-run price effects of certification. 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 the persistence of rental price premia is contingent upon the level of market penetration and changes in regulation and technology. It is argued that asset price premia are a reflection of higher rental incomes, lower holding costs and/or reduced risk premia.

The second contribution of the paper is empirical. We measure both the effect of voluntary certification on occupational prices (rents) and on asset prices (sales). In the empirical analysis, certified buildings are compared to a sample of non-certified buildings which were selected to include properties in the same submarket 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 submarkets controlling for differences in age, height, quality, sub-market etc. We first estimate the rental regression for a sample of 197 LEED and 834 Energy Star as well as over 15,000 benchmark buildings. The results suggest that certified buildings have an average rental premium of 4-5%. Furthermore, based on a sample of sale prices for 559 Energy Star and 127 LEED-certified buildings, we find price premia of 26% and 25% respectively with higher levels of certification achieving higher premia.

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 environmentally responsible 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

The market for eco-friendly products has been expanding for a range of consumer products in response to a willingness-to-pay (WTP) 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 number of industries. 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. As of May 1, 2009, there are 657 LEED-certified office buildings and 2,393 Energy Star rated commercial buildings in the CoStar database. 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. The thresholds are mainly absolute in the sense that all buildings put forward that meet the required standards are certified. In LEED for new construction and major renovations for commercial premises, buildings may qualify for four levels of certification: Certified, Silver, Gold and Platinum. In contrast to the rather comprehensive assessment of buildings under the LEED scheme, Energy Star certification considers solely the energy performance of a property. Buildings are awarded a score out of 100. Another difference to LEED is that Energy Star is a measure of *relative* energy efficiency and environmental performance. Only buildings that are in the top quartile of buildings put forward are eligible for Energy Star accreditation.

It is notable that there have been reports of some real estate developers making fraudulent claims about having obtained LEED certification in the early stages of construction (see Burr, 2009). This underlines the perceived attractiveness of the LEED certification scheme. Furthermore, LEED certification is more costly to obtain in terms of fees, encompasses a broader range of sustainable attributes and is comparable to other real estate eco-certification schemes in the UK, Germany and Australia. There is an expectation that premia should vary between Energy Star and LEED certified buildings and also within the different levels of LEED buildings.

There is a large body of work on the attractions of and case for green buildings. Depending on the linkage between price and production cost, the existence and size of a cost premium to construct certified buildings may be relevant to price premia. There are two main types of additional costs associated with obtaining eco-certification for commercial buildings. The

first are the payments to the certifying body for rating the building. The second are the additional production costs associated with meeting the certification standards. In terms of the latter, there have been a number of studies of the construction cost premium associated with achieving certification (see, for example, Kats, 2003; Berry, 2007; Morrison Hershfield, 2005). These studies suggest small construction cost premia of around 2% on average. The most recent and authoritative studies have come from Davis Langdon (a global construction consultancy). Their most recent study compared 83 building projects with a primary goal of LEED certification with 138 similar building projects without the goal of sustainable design (Davis Langdon, 2006). Confirming the findings of earlier studies, they found no significant difference in average costs for building projects with a primary goal of LEED certification as compared to non-certified buildings.

In return, a range of benefits are attributed to green buildings or associated with features common in green buildings. Owners, developers and occupiers may obtain benefit from the diverse range of subsidies and tax benefits¹ that have appeared for LEED-certified buildings. For tenants these are related to reduced operating costs of the building (mainly associated with energy and other utility savings), improved productivity of the occupying business (associated with reduced staff turnover, absenteeism *inter alia*), possible tax and other incentives and other competitive advantages linked to marketing and image benefits. It is expected that these benefits will produce increased rental bids from potential tenants. It should be noted that the nature of the lease contract will determine whether tenants benefit directly from reduced energy and other utilities. Tenants with net rental contracts pay these costs directly and therefore should be attracted premises with lower operating costs, whilst tenants on gross rental contracts will not benefit directly from such savings.

In addition to the possible rental premiums, owners may also benefit from reduced holding costs (due to lower vacancy rates and higher tenant retention), reduced operational costs (due to energy and other utility savings), reduced depreciation (linked to the use of latest technologies) and reduced 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). The crucial question is then if and to what extent occupiers of certified of space exhibit a willingness to pay for the cost savings and other benefits associated with eco-certified space. In this sense, WTP reflects the amount of money a consumer is willing to contribute to equalize a utility change (Mäler, 1974; Field and Field 2009). Besides observing revealed preferences WTP is primarily measured through

¹ A number of states have introduced various incentives to encourage greater supply of certified buildings.

contingent valuation surveys (Becker et al, 1964). In a real estate context, contingent valuation surveys have revealed that occupiers 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. It is important to distinguish between what occupiers and investors state that they are ready to pay from what they really pay.

Notwithstanding the high growth rates of eco-certified buildings in recent years -albeit from a low base, their relatively low proportion of the overall market may appear puzzling given the apparent benefits of certified relative to non-certified buildings. 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). In a similar vein, 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, 2008, 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. Effects may be identified in either the occupier and/or the investment market. Failure to observe price premia 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 analyze the anticipated price effects. The first part of this analysis is based on Rosen's assumption that any good or service consists of a variety of utility-bearing characteristics (z_1, z_2, \dots, z_n) that make up the hedonic price function Rosen (1974). In the context of office rent determination, these are comprised of various structural, locational and lease characteristics that enter into the empirical model as independent variables. The empirically determined hedonic prices are indicative of an implicit market so that demand and supply functions can be derived for both short-run and long-run competitive equilibria. Although certified and non-certified properties may not be close substitutes in the marketplace - particularly for the group of eco-consumers - we assume in the first step that they are variations of an ingredient i (in our case eco-certification) of a

product. In a vector z of bundles of relevant characteristics, z_i represents the presence and level of eco-certification of a given building. The resulting bid or value function of a consumer is determined by the concave utility values of u_{z_i} (the utility of certification in the presence of all other relevant attributes), u_x (the utility of all other products consumed) and y (the budget constraint). The bid function θ_{z_i} is thus described as:

$$\theta_{z_i} = \frac{U_{z_i}}{U_x} > 0, \theta_u = -\frac{1}{U_x} < 0, \text{ and } \theta_y = 1 \quad (1)$$

At a given utility and budget, this function reveals a consumer's implicit willingness to pay for a given vector of building attributes z . Within the space of possible indifference surfaces arising from this, utility is maximized where the consumer's bid function equals the market price as $\theta_{z_i}(z^*, u^*, y^*) = p_i(z^*)$ where $*$ denotes optimum quantities.

Turning to producers, the offer function φ is determined by the vector of characteristics containing among others eco-certification (or lack thereof) z_i , a profit maximizing condition π , and a shift parameter β reflecting the cost minimization of factor prices and production function parameters. Taking into account the optimal number of units produced with specification z_i , the producer's equilibrium function is determined at the intersection or tangency between the profit-attributes-costs indifference curve and the market characteristics –implicit price surface in the form $\varphi(z_i^*, \pi^*, \beta^*) = p_i(z^*)$. Figure 1 shows implicit equilibrium prices for the characteristic z_i representing eco-certification. The marginal price of eco-certification is shown by $p_i(z)$ where the optimal level of z is defined as the intersection of the marginal value to the consumer and the marginal cost to the producer.

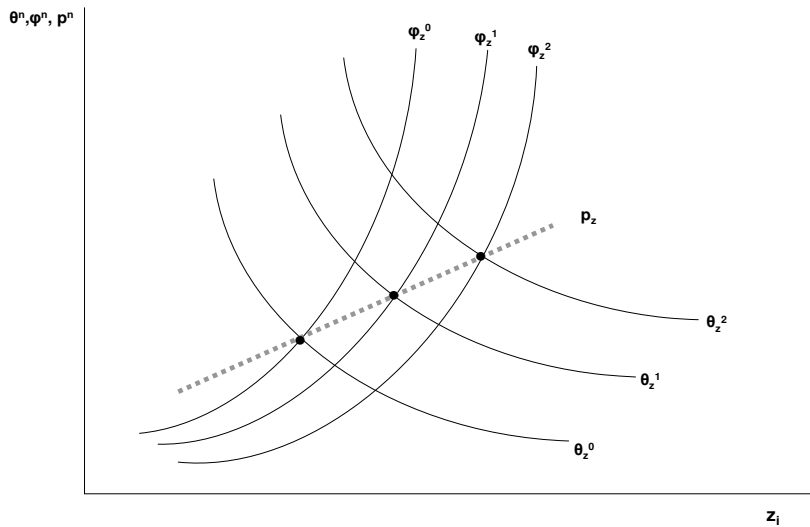


Figure 1: Marginal hedonic prices of eco-certification resulting from equilibrium reservation prices

NOTE: This figure shows derivatives of a consumer's bid function θ_{z_i} representing demand-reservation prices for buildings with various levels of eco-certification and the producer's function φ_{z_i} representing reservation supply

prices of an increment in the level of eco-certification z_i . The resulting dashed line $p_i(z)$ is then the marginal price of incremental levels of eco-certification z_i where reservation demand prices and reservation supply prices intersect.

To demonstrate the effect of a set of implicit marginal prices for various levels of eco-certification on aggregate supply, we use a static partial equilibrium framework (see Sedjo and Swallow, 2002). In line with our basic assumption in the first part of this analysis, we hypothesize that both types of products are not perfect substitutes but operate in a closely interrelated market so that an increase in demand for certified buildings will be reflected in a fall in demand for non-certified buildings. As demand for certified buildings increases, it will lead to an increase in their rents/prices and, given short-run inelasticity of supply, a premium will be observed. The key issue is the extent to which (or indeed whether) eco-certification changes the demand and supply functions for certified and non-certified buildings. Key factors are the additional costs associated with certification and the willingness of occupiers to pay an additional sum for certified buildings. The additional costs and willingness to pay are also expected to increase as the level of certification increases producing different equilibrium prices and quantities for different levels of certification.

In Figure 2, the rental supply and demand curves for space are plotted for certified and non-certified buildings. The central assumption is that the supply and demand curves are different for certified and non-certified buildings and among the different levels of certification e.g. LEED Silver relative to LEED Platinum. Assuming increased costs associated with certification, supply is more inelastic as developers require increased prices to offset these costs ($S^{ncb} \rightarrow S^{cb1}$).² In addition, the demand curve for certified buildings shifts outwards as occupiers are assumed to be prepared to pay more for certified products ($D^{ncb} \rightarrow D^{cb1}$). The resulting equilibrium prices and quantities P^{ncb} , P^{cb1} and Q^{ncb} , Q^{cb1} indicate higher prices and lower quantities for certified buildings. However, the demand curves converge since it is assumed that the marginal willingness to pay a premium by eco-consumers diminishes as the quantity supplied increases³. This means that, when large quantities are consumed at a low price, the premium disappears. *In extremis*, when the price is effectively zero, the quantities demanded are equal for certified and non-certified space.

² There is also a possibility, however, that the ratio of differential value of certified space to total marginal value depends on the level of price. This would produce a different set of demand curves and ultimately different equilibrium prices.

³ An alternative demand curve rotation could be hypothesized. For instance, it could be argued that, if occupiers gain less utility from consumption of the first unit of a certified product relative to subsequent units, the premium that occupiers are willing to pay increases as their total consumption of the certified product increases. Following this assumption, the demand curves pivot around the intercept on the vertical axis.

However, the market for certified buildings is not homogeneous. The additional costs and WTP are assumed to increase as the level of certification increases producing different equilibrium prices and quantities for different levels of certification. Again, assuming a simplified two-tier certification system, prices increase from P^{cb1} to P^{cb2} where $cb2$ is a higher level of certification than $cb1$.

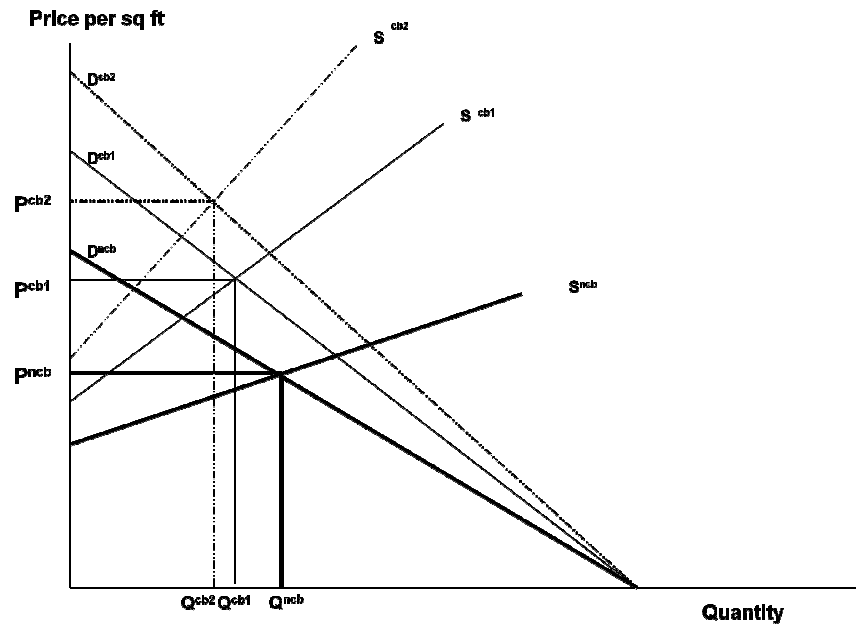


Figure 2: Short-run effect of introducing certification into the market

NOTE: This figure shows the various aggregate demand and supply curves for non-certified buildings and for buildings with different qualities of eco-certification. Certification is assumed to increase production costs so that there is an upward shift in the supply curve. It is assumed that higher levels of certification have higher costs and that the supply curve shifts further upwards and the becomes more inelastic ($S^{ncb} \rightarrow S^{cb1} \rightarrow S^{cb2}$). In the same manner the demand curve for certified buildings shifts outwards to reflect an assumed increase in WTP for certified products ($D^{ncb} \rightarrow D^{cb1} \rightarrow D^{cb2}$). Thus, different partial equilibrium quantities and prices are established.

Whilst the discussion above essentially analyzes possible market outcomes in a static partial equilibrium framework, the dynamic aspects of market entry and diffusion pertaining to price effects need to be explored. In the long-run, the dynamic interaction between the markets for certified and non-certified space is more intricate depending on, among other factors, the market share of certified space. As market penetration of the new product progresses, the supply curves of certified space shift downwards which increases aggregate quantities and reduces prices.

When measuring the change in demand arising from the introduction of a new product, two separate effects have to be disentangled: a variety effect resulting from increased product differentiation in a particular market and a pure price effect resulting from changes of prices of existing products following the introduction of the new product (see Hausman and Leonard, 2001 and Brynjolfsson et al., 2003). Leaving aside the variety effect on both certified and non-certified space, we hypothesize that economies of scale in eco-building production and services will tend in the longer term to reduce the marginal and average costs of certification. The comparatively more advanced production technology involved in producing eco-certified buildings is expected to command a price premium that is relatively large at the time of initial market entry but declines with increasing standardization and market share of the certified product. Thus, the price premium is simultaneously eroded by both supply-side factors, i.e. lower cost of producing a unit of certified space and demand-side factors, i.e. diminishing image benefits to consumers as certified space becomes the norm. In this setting, premiums are expected to decline to a level that purely reflects the cost savings.

However, long run price differentials are likely to be driven by technological progress, market penetration rates and regulation, all of which are very difficult to foresee at this point. If regulatory standards were both static and absolute and market penetration increased, utility from eco-certification would be expected to decrease as an increasing proportion of the building stock reached the level of environmental performance required for certification. Where environmental performance standards are relative (e.g. certification granted based on evidence of environmental performance in the top quartile of all buildings), there will by definition be a group of buildings that are considered a separate market segment irrespective of general standards. Premia for this group of buildings are likely to persist. However, where there are absolute certification standards, required environmental performance thresholds are unlikely to remain fixed at current levels and definitions. When environmental standards become more stringent in absolute terms, buildings certified under a previous regime will be affected by regulatory obsolescence and may become regarded as an inferior market segment. As a result, in the long run, rental price effects are contingent upon changes in the regulatory regime and upon the blend of relative and absolute thresholds that are introduced. These changes will also influence capital values.

In addition to rental premia, as discussed above there are additional ways in which asset pricing of marginal investors may be affected by certification. The Net Operating Incomes of certified buildings may be higher than those of non-certified buildings due to rental premia, higher occupancy rates, incomes from incentives and subsidies and reduced outgoings due to

lower operating costs. Expected income growth may also be higher than non-certified buildings due to reduced depreciation and obsolescence. In terms of the denominator of the standard valuation equation, it could be argued that the reductions in regulatory risk (sometimes referred to as future-proofing) associated with certified buildings and the relative reductions in uncertainty of income may mean that investors apply a lower risk premium. Whilst many of these anticipated effects on costs and incomes are, at present, largely conjectures, below we investigate whether expected effects on prices can be observed empirically.

Actual Price Effects – Empirical Research

There have been few studies that have attempted to measure the price effects of green building certification. Studies that have identified higher rents and improved returns based on the views and experiences of expert professions still require empirical verification. Recent reviews of the extant literature agree on the centrality of pricing to adoption but have found little convincing evidence of a certification premium (see Berry, 2007). In a further study, Nelson (2007) examines the performance differences between certified and non-certified buildings using a number of criteria. Drawing upon the CoStar database, the author compares LEED rated buildings and Energy Star buildings with a vastly larger sample of non-certified buildings in the CoStar database. He acknowledges the significant differences between the sample and the wider population and finds that certified buildings tend 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 identifies lower vacancy rates and higher rents in LEED-rated buildings.

There have been a group of studies that draw upon the CoStar database of US properties to identify the effect of environmental certification on sale prices and rents. 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. Using the same data, Miller *et al* (2008) also report respective sale price premiums of approximately 6% and 11% for Energy Star and LEED certified offices. Wiley, Benefield and Johnson (forthcoming) focused on the effect on rent, occupancy rate and sale price of eco-certification for Class A buildings in 46 office

markets across the USA⁴. Using a hedonic pricing approach, they found rental premia ranging from approximately 15-18% for LEED certified buildings and 7-9% for Energy Star certified buildings depending on the model specification. In terms of sales transactions, they estimated premia of \$130 per sq ft for LEED certified buildings and \$30 for Energy Star. However, although plausible, these results need to be treated with some caution. A limitation of their hedonic model is their control for location. In essence, they identify rental and sale premia for certified buildings relative to non-certified buildings *in the same metropolitan area*. However, if certified buildings tend to be more likely to be in better quality locations within a metropolitan area, observed premia may include a location as well as a certification premium.

Eichholtz, Kok and Quigley (EKQ) (2009) use a hedonic framework to investigate the effect of certification on the asking rents of 694 office buildings which were either LEED or Energy Star certified. Using GIS techniques, they control for location effects by identifying other office buildings in the CoStar database within a radius of 0.2 miles of each certified building. The authors identify a statistically significant rent premium on asking rent per square foot of 3.3% for Energy Star certified buildings. Surprisingly, they find no significant rent premium for LEED-certified buildings. However, when they use “effective” rents which reflect the effect of different occupancy levels in the rental income of properties (nominal asking rent multiplied by the occupancy rate), the premium increased to around 10% for Energy Star certified buildings and they find 9% premium for LEED-certified buildings (although the latter is not significant at the conventional levels). They also report similar results for 199 sales that took place between 2004 and 2007. They find a substantial 19% sale price premium for Energy Star certified buildings but no statistically significant sale price premium for LEED-certified buildings. If these findings are confirmed, the implications for developers considering LEED certification as well as ‘green’ investors would be considerable. It is therefore important that the absence of a premium for LEED buildings is either corroborated or refuted by other studies using a comparable analytical framework and dataset.

As noted, the size and nature of the rental and sale price differentials between LEED and Energy Star certified buildings identified by EKQ is contrary to expectations and, if genuine, have major implications for the adoption of LEED certification in particular. Our prior expectation for this study was that the LEED label is more prestigious than the Energy Star label. Miller *et al* (2008) and Wiley *et al* (forthcoming) find that LEED certified offices command a larger premium than Energy Star certified offices.

⁴ Sales data were available for 26 office markets.

There are a number of potential problems with the approach adopted by EKQ. A crucial part of any hedonic analysis is obviously the control for spatial and locational features of properties. The controls applied by EKQ, i.e. using a standard 0.2 mile radius for all markets may not produce a proxy for actual submarkets. Within some of their clusters, there are likely to be different qualities of location. In addition, there is an implicit assumption that a 0.2 mile radius is an appropriate geographical size for all locations. However, there can be significant variations in the density of development and size of submarket between different locations.

It is also possible that the definition of effective rents may be a source of bias in their results. If there are systematic differences in the proportion of single tenanted and multi-tenanted buildings between the certified and non-certified samples, the results may be biased. For instance, if certified buildings have a higher propensity to have a single occupier, an effective rent premium would be identified separate from any certification effect. For instance, Fuerst and McAllister (forthcoming) estimate that less than 10% of Energy Star certified offices have a single occupier compared to approximately 30% for the overall CoStar database. However, this source of potential bias may be mitigated by the fact that asking rents tend only to be recorded for multi-tenanted offices. Compared to EKQ, we apply a similar hedonic methodology to a similar data set. In contrast, we control for location effects using actual submarkets (as defined by CoStar) rather than arbitrary submarkets as this should reflect more accurately the varying density of office submarkets at both the metropolitan and the national level and incorporates the local market knowledge of experts who are likely to define these relatively homogenous markets better than an arbitrary fixed radius.

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. Following our theoretical exposition on hedonic prices and product differentiation in the real estate market, we apply a standard hedonic model to empirically test for the existence of a price and rent premium for eco-certified properties.

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 mean 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:

$$\ln R_i = \alpha_i + \beta x_i + \phi Z_i + \varepsilon_i \quad (2)$$

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 characteristics⁵, 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_ε^2 . 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 types of hedonic models. The first type explains rents and the second explains price per square foot in sales transactions.

Hedonic Rent Model

$$\begin{aligned} \ln R_i = & \beta_0 + \beta_1 \ln A_i + \beta_2 \ln S_i + \beta_3 \ln L_i + \beta_4 \ln T_i + \beta_5 \ln G_i + \beta_6 N_i + \beta_7 BC_i + \beta_8 SU_i \\ & + \beta_9 GR_i + \varepsilon_i \end{aligned} \quad (3)$$

In this model, A_i represents the age of the property, measured from the year of construction or the year of a major refurbishment (whichever occurred more recently), S_i is the number of stories of the property, L_i represents the lot size, T_i and G_i are the latitude and longitude geographic coordinates of the property which capture any large-scale effects of the spatial distribution of properties across the country, N_i is a dummy variable indicating a net lease (taking the value of zero for a gross or full-service lease), BC_i are controls for building class

⁵ We acknowledge the substantial body of literature on the rental effects of age, vacancy levels, size and number of stories. For a more comprehensive discussion of 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.

(standard categories A,B,C and F) and SU_i are controls for submarkets (853 in total) and ε_i is the error term which is assumed to be independent across observations and 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. In alternative model specifications, the GR_i dummy variable is replaced by separate terms for LEED and Energy Star certification (Model 2) and level of LEED certification (Model 3).

Hedonic Transaction Price Model

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

$$\ln R_i = \beta_0 + \beta_1 \ln A_i + \beta_2 \ln S_i + \beta_3 \ln L_i + \beta_4 \ln T_i + \beta_5 \ln G_i + \beta_6 E_i + \beta_7 MC_i + \beta_8 SU_i + \beta_9 GR_i + \varepsilon_i \quad (4)$$

where E_i is a time trend variable which accounts for general price inflation and other unobserved trends over time. This variable increases in semi-annual increments. Beyond this control for the overall trend, we also included MC_i , which indicates market conditions at the time of sale proxied by the average quarterly return of the NAREIT index. All other variables are the same as in the rent model.

The type of specification used in the rent and transaction price models allows us to detect differences in the weight of parameter estimates across submarkets, building class categories and market conditions by estimating separate intercepts. This Least Squares Dummy Variable (LSDV) approach has the advantage of controlling for a number of omitted variables, for example small-scale spatial effects at the submarket level that we could not model explicitly as the data necessary to do this were not available to us. The LSDV approach 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 two 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. Our benchmark sample consists of approximately 24,479 office buildings in 853 submarkets in 81 metropolitan areas spread throughout the United States. 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, size, height, location, lease type, building class and submarket.

In the first step, we drew details of approximately 1,900 eco-certified buildings of which 626 were LEED certified and 1,282 were Energy Star. Of the LEED buildings, 31% (n=192) are certification-level, 29% (n=180) are Silver, 32% (n=201) are Gold and 7% (n=45) are Platinum level. In the second step, buildings were selected in the same metropolitan areas and submarket as the certified sample. Sample selection was based on the criteria a) same submarket or market as certified buildings and b) at least 10 comparable observations for each certified building in the database. Although the market weightings may be different between the benchmark and the certified samples, our regression model controls for market-specific effects. In total, we have used 9,806 observations of transaction prices and 18,519 (asking) rent observations. While transaction prices are considered over a period of ten years from 1999 through 2008 to obtain a sufficiently large sample, all rent observations are as of Q4 2008.

Results

Descriptive Statistics

The descriptive statistics are displayed in Table 1. There are clearly some differences between eco-certified and non-certified buildings. The former tend to be newer. In particular, the median age of LEED certified buildings is five years. The comparable figure for the benchmark sample is 23. While there is relatively 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 CBD locations. This is supported by the fact that Energy Star buildings tend to be on average nearly 20 times larger than non-certified buildings. Without controlling for the differences between the samples, certified buildings have higher asking rents and lower vacancy rates than non-certified buildings. Median asking rents are approximately 35% higher in LEED and Energy Star certified buildings. There are also some notable differences in terms of the proportions of each sample that are on triple net leases compared to gross or full service leases. Energy Star buildings have 12% and LEED buildings have 10% on net leases. The comparable figures for the control sample is 22%. More thorough investigation is required, however, to infer a general prevalence of gross leases in certified buildings as the higher share may simply be reflective of differences in property types (particularly mono- vs. multi-tenanted properties) between the certified and the non-certified samples. If confirmed, this would be consistent with the expectation that owners of certified buildings attempt to capture operating cost savings by offering primarily gross or full-service leases.

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

Overall	RENT \$ psf	PRICE \$ psf	% LEASED	SIZE (sq ft)	STORIES	AGE
Mean	19.50	141.19	63.82	52,771	3.32	28.37
Median	18.00	113.81	79.80	10,800	2.00	23.00
Std. Dev.	9.16	112.50	38.87	145,147	5.75	27.48
Skewness	2.40	1.77	-0.69	7.57	5.92	1.97
Kurtosis	14.47	8.77	1.88	92,807	50.21	8.42
Observations	16,488	9,120	24,951	16,488	24,479	21,147
LEED	RENT \$ psf	PRICE \$ psf	% LEASED	SIZE (sq ft)	STORIES	AGE
Mean	26.39	247.07	90.89	176,080	6.39	12.14
Median	24.50	240.00	100.00	94,945	4.00	5.00
Std. Dev.	10.34	137.85	22.95	25,882	8.22	19.46
Skewness	1.53	0.41	22.95	467	3.04	3.17
Kurtosis	7.23	3.37	-2.87	48.46	13.20	13.91
Observations	197	127	626	626	581	469
Energy Star	RENT \$ psf	PRICE \$ psf	% LEASED	SIZE (sq ft)	STORIES	AGE
Mean	27.50	254.95	91.52	283,045	11.85	19.39
Median	25.00	231.47	96.15	201,014	8.00	19.00
Std. Dev.	11.32	137.00	12.78	262,829	11.32	13.26
Skewness	1.75	1.42	-3.15	2.02	1.68	2.38
Kurtosis	7.75	6.32	18.16	8.19	5.90	13.49
Observations	834	559	1,282	1,282	1,256	1,276

Hedonic regression results – rental rates

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. 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 Tables 2 and 3. Observations for building age were segmented into deciles to allow for potentially time-varying age effects.

When controlling for the most important rent determinants such as age, height, size and sub-market location, we find a statistically significant rent premium of 4-5% in eco-certified buildings compared to non-certified buildings in the same sub-market area. The control variables used in the regression show the expected signs and most of them reach the desired significance levels. This regression explains just over 60% of the cross-sectional variation in rents in the entire sample.

Model 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. While the premium for LEED is higher as expected, there is very little difference between the premia for LEED and Energy Star buildings. 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, Silver, Gold and Platinum. While the coefficients have the expected signs, only the Certified and Platinum levels are significant.

Although it is not a central part of the study, it is interesting to compare the results of the control factors with the findings of other studies of office rent determinants. Given a variation in data sources and model specifications, previous studies do not always provide consistent findings on the relationship between variables such as age, and height inter alia and office rents/prices. As expected, we find that the coefficient for the age variable is negative. In addition, consistent with previous research (for example, see Bollinger, Ihlanfeldt and Bowes, 1998; Shilton and Zaccaria, 1994), we find that there is a significantly positive relationship between height and rent. We also find a negative relationship between size and rent. In common with Laverne and Winson-Geideman (2003), we find a negative relationship between triple net leases and the rental level.

Table 2: Results from hedonic model estimation of rental rates

		Model 1	Model 2	Model 3
Dependent variable		Rent psf (log)	Rent psf (log)	Rent psf (log)
Constant	3.73***	3.72***	3.65***	
Eco-certified LEED	0.05***			
	Certified	0.05**		
	Silver		0.09**	
	Gold		0.04	
	Platinum		0.03	
Energy Star		0.16***		
Net Lease	-0.11***	0.04***	0.04***	
	No. of stories (log)	-0.11***	-0.11***	-0.11***
	Size square feet (log)	0.06***	0.06***	0.06***
	Site area (log)	-0.01***	-0.01***	-0.01***
	Age (log)	0.01*	0.00*	0.00*
	3-6 years	-0.06***	-0.06***	-0.06***
	7-10 years	-0.12***	-0.12***	-0.12***
	11-19 years	-0.14***	-0.14***	-0.14***
	20-23 years	-0.16***	-0.16***	-0.16***
	23-26 years	-0.18***	-0.18***	-0.18***
	27-31 years	-0.19***	-0.19***	-0.19***
	32-42 years	-0.20***	-0.20***	-0.20***
	43-62 years	-0.23***	-0.24***	-0.24***
	>62 years	-0.23***	-0.23***	-0.23***
	Longitude (log)	-0.01***	-0.01***	-0.01***
	Latitude (log)	-0.43***	-0.43**	-0.41**
	Class A	0.21***	0.21***	0.22***
	Class B	0.09***	0.09***	0.09***
	Adjusted R-squared	0.63	0.61	0.63
	F test	26.32***	26.27***	26.15***
	Included observations	10,970	10,970	10,969

*** - significant at 1% level

** - significant at 5% level

* - significant at 10% level

Hedonic regression results – sale prices

Table 3 reports the results of the hedonic regressions with sales price per square foot as the dependent variable. Three separate models were estimated with the same independent variable. All models display similar results and have similar explanatory power. The explanatory power of this model is lower relative to the regressions for the sample of rents. For most of the independent variables, the coefficients have the expected signs. Compared to buildings in the age segment 0-2 years, the coefficient for the other age segments is positive. It is notable that buildings constructed in the first two years tend to sell at a discount compared to older buildings. The coefficient on the age variable increases for buildings aged up to ten years and then starts to decline. Model 1 suggests a sales premium of just below 30% for eco-certified buildings. In Model 2, we distinguish between LEED and Energy Star and find premia of 25% and 26% respectively.⁶

When we break down the LEED sample into its various levels, we find significant premia for Silver, Gold and Platinum rated buildings. Whilst the size of the premia appears extremely high, it should be noted that the sample size for Platinum rated buildings is very small. From a total of 6153 sales, only eight involved Platinum rated buildings. The sample sizes for Certified (n=35), Silver (n=47) and Gold (n=34) are higher and the raw data support the case for substantial premia with median sale prices of \$194, \$252 and \$232 compared to a whole sample mean sale price of \$113.

The results suggest a much higher relative sales price premium compared to rental price premia. There are a number of potential explanations. A possible reason may be the combined effects on capital value of higher rental income, lower operating costs, increased occupancy rates, image benefits (to investors) and a lower risk premium.

⁶ The larger average premium of 30% for eco-certified buildings compared to LEED and Energy Star premia is due to the existence of a number of buildings that hold both types of certification. For these buildings, the rental premium will effectively be split between the LEED and Energy Star coefficients resulting in a lower premium compared to the overall eco-certified variable.

Table 3: Results from hedonic model estimation of sales prices

		Model 1	Model 2	Model 3
Dependent variable		Sale price psf (log)	Sale price psf (log)	Sale price psf (log)
Constant	1.25	1.08	1.51	
Eco-certified	0.30***			
LEED		0.25***		
Certified			0.12	
Silver			0.33***	
Gold			0.26**	
Platinum			0.67**	
Energy Star		0.26***	0.27***	
No. of stories (log)	0.16***	0.16***	0.16***	
Size square feet (log)		-0.23***	-0.23***	-0.21***
Site area (log)		0.09***	0.09***	0.09***
Age (log)				
3-6 years		0.15***	0.15***	0.16***
7-10 years		0.51***	0.51***	0.52***
11-19 years		0.45***	0.45***	0.46***
20-23 years		0.40***	0.40***	0.41***
23-26 years		0.38***	0.38***	0.38***
27-31 years		0.38***	0.38***	0.38***
32-42 years		0.28***	0.28***	0.28***
43-62 years		0.27***	0.27***	0.28***
>62 years		0.29***	0.29***	0.30***
Longitude (log)		-0.01***	-0.01***	-0.01***
Latitude (log)		0.78*	0.82*	0.79*
Class A		0.44***	0.45***	0.45***
Class B		0.06***	0.06***	0.06***
Time trend variable		0.03***	0.03***	0.03***
Moderately strong market		-0.08***	-0.08***	-0.08***
Moderately weak market		-0.10***	-0.10***	-0.10***
Weak market		-0.10***	-0.10***	-0.10***
SUBMARKET CONTROLS				
Adjusted R-squared		0.42	0.42	0.42
F test		8.68***	8.68***	8.64***
Included observations		6,157	6,157	6,156

*** - significant at 1% level

** - significant at 5% level

* - significant at 10% level

Conclusion

Growing global concern about climate change is increasingly affecting the preferences of consumers and investors. In addition, throughout the regulatory hierarchy, international, national and local governmental 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 eco-certification of commercial buildings will become progressively more important.

A priori inference suggests that eco-certified buildings should obtain a rental and an asset price premium. It is expected that investors' holding costs should be lower due to attractiveness to occupiers associated with business performance, image, fiscal and/or other government incentives and lower running costs. This can lead to a rental premium and/or lower vacancy rates. For investors, there may be higher NOI due increased demand from occupiers, lower void rates, lower costs of ownership and an element of protection from future regulatory changes. The results of the empirical analysis confirm these expectations. The hedonic regressions suggest that there is a rental premium of approximately 5% for LEED certification and 4% for Energy Star. For sales prices, we find price premia of 25% for LEED-certified buildings and 26% for Energy Star.

Yet, there are a number of caveats attached to the interpretation of this and similar empirical studies of *typical* price differentials. Firstly, the controls for inherent heterogeneity between certified and non-certified buildings are bound to be imperfect even when applying the most diligent sample selection process and the most comprehensive set of variables in the hedonic model. For example, it is possible that the eco-certification process is only one element of additional investment to create a market leading product. To control for all facets of such an approach to positioning an asset in the upper segment of the market is virtually impossible in the framework of a hedonic model. Secondly, these empirical studies provide a cross-sectional snapshot of price differentials for a specific sample in a specific time period. It is expected that price differentials for certified buildings should vary over time and between buildings. Attempts to profit from any current or historic price premia are faced with the standard 'developer's dilemma' – that their supply response to *current* price differentials between certified and non-certified buildings is likely to affect the *future* price differential. Although the results are in line with the findings of the majority of studies on price premia of

certified buildings, this is a study of a niche market with relatively small sample sizes. As data availability as well as level of detail and accuracy is likely to improve over time, future research will be able to address a number of more specific issues such as the individual contributions of image benefits, higher productivity or lower operating costs to the "green premium".

References

- Ambrose, B., P. Hendershott and M. Klosek. 2002. Pricing Upward-Only Adjusting Leases. *Journal of Real Estate Finance and Economics* 25: 33-49.
- Anderson, S. and R. Newell. 2004. Information programs for technology adoption: the case of energy-efficiency audits. *Resource and Energy Economics* 26: 27-50.
- Becker, G. M.; DeGroot, M. H.; and Marschak, J. 1964. Measuring Utility by a Single-Response Sequential Method. *Behavioral Science*. 9: 226-32.
- Berry, T. 2007. *Towards a green building and infrastructure investment fund: A review of challenges and opportunities*. Compass Resource Management.
- Bollinger, C.R., K.R. Ihlanfeldt and Bowes, D.R. 1998. Spatial Variations in Office Rents in the Atlanta Region. *Urban Studies* 35: 1097-1118.
- Bond, S., P. Loizou and McAllister, P. 2008 Lease Maturity and Initial Rent: Is There a Term Structure for UK Commercial Property Leases?, *Journal of Real Estate Finance and Economics*, **36**: 451-469.
- Booth, P. and D. Walsh. 2001. An option pricing approach to valuing upward only rent review properties with multiple reviews. *Insurance: Mathematics and Economics*. 28: 151-171.
- Brynjolfsson, E., Hu, Y. Smith, M. D. 2003. Consumer Surplus in the Digital Economy: Estimating the Value of Increased Product Variety at Online Booksellers. *Management Science*. 49: 1580-1596.
- Can, A. and I. Megbolugbe. 1997. Spatial Dependence and House Price Index Construction. *Journal of Real Estate Finance and Economics* 14: 203-222.
- Casetti, E. 1997. The Expansion Method, Mathematical Modeling and Spatial Econometrics. *International Regional Science Review* 20: 9-33.
- Clapp, J. M. 1980. The Intrametropolitan Location of Office Activities. *Journal of Regional Science* 20: 387-399.
- Clapp, J. M. 1993. *The Dynamics of Office Markets*. Washington: Urban Institute Press.
- Clapp, J. M. 2003. A Semiparametric Method of Valuing Residential Locations: Application to Automated Valuation. *Journal of Real Estate Finance and Economics* 27: 303-320.
- Clapp, J. M. 2004. A Semiparametric Method for Estimating Local House Price Indices. *Real Estate Economics* 32: 127-160.
- Dunse, N., C. Leishman and C. Watkins. 2002. Testing the Existence of Office Submarkets: A Comparison of Evidence from Two Cities. *Urban Studies* 39: 483-506.
- ECOFYS. 2003. *Cost Effective Climate Protection in the EU Building Stock*. Report for EURIMA.

- Eicholtz, P., N. Kok, and J. Quigley, Doing Well By Doing Good? Green Office Buildings, Working paper, *Fisher Center for Real Estate and Urban Economics*, UC Berkeley, May 2009.
- Ellison, L., S. Sayce and J. Smith. 2007. Socially Responsible Property Investment: Quantifying the Relationship between Sustainability and Investment Property Worth. *Journal of Property Research*, 24: 191 – 219.
- Englund, P., A. Gunnelin, M. Hoesli, and B. Söderberg. 2004. Implicit Forward Rents As Predictors of Future Rents. *Real Estate Economics* 32: 183-215.
- Field, B. C., M. K. Field. 2009. *Environmental Economics*, 5th Edition. San Francisco, CA: McGraw-Hill, 2009.
- Fuerst, F., P. McAllister. 2009. An Investigation of the Effect of Eco-Labeling on Office Occupancy Rates. *Journal of Sustainable Real Estate*. Forthcoming.
- Garrod, G. and K. Willis. 1999. Methodological issues in valuing the benefits of environmentally sensitive areas. *Journal of Rural Studies* 15: 111-117.
- Gat, D. 1998. Urban Focal Points and Design Quality Influence Rents: The Tel Aviv Office Market. *Journal of Real Estate Research* 16: 229-247.
- Glascok, J., S. Jahanian and C.F. Sirmans. 1990. An analysis of market rents: Some empirical evidence. *AREUEA Journal* 18: 105-119.
- Grenadier, S.R. (1995). The valuation of leasing contracts: a real options approach. *Journal of Financial Economics* 38: 297-331.
- Guy, S. 1998. Developing Alternatives: Energy, Offices and the Environment. *International Journal of Urban and Regional Research* 22: 264-282.
- GVA Grimley. 2007. *Towards Sustainable Offices*. Research Bulletin, Spring, 2007.
- Hausman, J. A. Leonard, G. K. (2002): The Competitive Effects of a New Product Introduction: a Case Study. *Journal of Industrial Economics*. 50/3, 237-264.
- Kats, G. 2003. *The Costs and Financial Benefits of Green Buildings – A Report to California's Sustainable Building Task Force*. Capital E, October 2003.
- Kotchen, M. 2006. Green Markets and Private Provision of Public Goods. *Journal of Political Economy* 114: 816-834.
- Laverne, R.J., and K. Winson-Geideman. 2003. The Influence of Trees and Landscaping on Rental Rates at Office Buildings. *Journal of Arboriculture*, 29/5: 281-290.
- McGraw Hill Construction. 2006. *Green Building Smart Report*.
- Mäler, K.-G. 1974 *Environmental Economics: A Theoretical Inquiry*, Baltimore: Johns Hopkins University Press.

- Miller, N., Spivey, J. Florance, A. (2008): *Does Green Pay Off?* University of San Diego Working Paper, final draft version: July 12, 2008.
- Mills, E. 1992. Office rent determinants in the Chicago area. *AREUEA Journal* 20: 156-171.
- Morrison Hershfield. 2005. *A Business Case for Green Buildings*. Internal Morrison Hershfield Report.
- Nelson, A. 2007. *The Greening of U.S. Investment Real Estate – Market Fundamentals, Prospects and Opportunities*. RREEF Research Report No. 57.
- RICS. 2005. *Green Value: Green Buildings, Growing Assets*. London: RICS.
- Roberts, T. 2007. Green Buildings Get Tax Relief. *Green Source*, April 2007, 22-23.
- Rosen, S. 1974. Hedonic prices and explicit markets: production differentiation in pure competition. *Journal of Political Economy* 82: 34–55.
- Rosen, K. T. 1984. Toward a Model of the Office Building Sector. *Journal of the American Real Estate and Urban Economics Association* 12: 261-269.
- Sanstad, A., M. Hanemann and M. Auffhammer. 2006. *End-Use Energy Efficiency in a 'Post-Carbon' California Economy: Policy Issues and Research Frontiers*. in *Managing Greenhouse Gas Emissions in California*, 2006.
- Shilton, L. and A. Zaccaria. 1994. The Avenue Effect, Landmark Externalities, and Cubic Transformation: Manhattan Office Valuation. *Journal of Real Estate Finance and Economic* 8: 151-65.
- Sirmans, C.F. and K.A. Guidry. 1993. The Determinants of Shopping Center Rents. *Journal of Real Estate Research* 8: 107-115.
- Sirmans, G.S., C.F. Sirmans and J. Benjamin. 1989. Determining Apartment Rent: The Value of Amenities, Services and External Factors. *Journal of Real Estate Research*, 4: 33-43.
- Slade, B.A. 2000. Office Rent Determinants during Market Decline and Recovery. *Journal of Real Estate Research* 20: 357-380.
- Stern, N., S. Peters, V. Bakhshi, A. Bowen, C. Cameron, S. Catovsky, D. Crane, S. Cruickshank, S. Dietz, N. Edmonson, S.-L. Garbett, L. Hamid, G. Hoffman, D. Ingram, B. Jones, N. Patmore, H. Radcliffe, R. Sathiyarajah, M. Stock, C. Taylor, T. Vernon, H. Wanjie, and D. Zenghelis. 2006. *Stern Review: The Economics of Climate Change*, HM Treasury, London.
- UNEP. 2007. *Buildings and Climate Change Status, Challenges and Opportunities*. Paris: UNEP.
- Upstream. 2004. *Sustainability and the Built Environment: An Agenda for Action*. RICS Foundation, London.
- Vandell, K. and Lane, J. 1989. The economics of architecture and urban design: some preliminary findings. *AREUEA Journal* 17: 121-136.

Wiley, J., Benefield, J. and Johnson, K. Green Design and the Market for Commercial Office Space, *Journal of Real Estate Finance and Economics*, forthcoming.