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Measuring 'Green Value': An International Perspective

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Measuring 'Green Value':
An International Perspective

Report for Royal Institution of Chartered Surveyors

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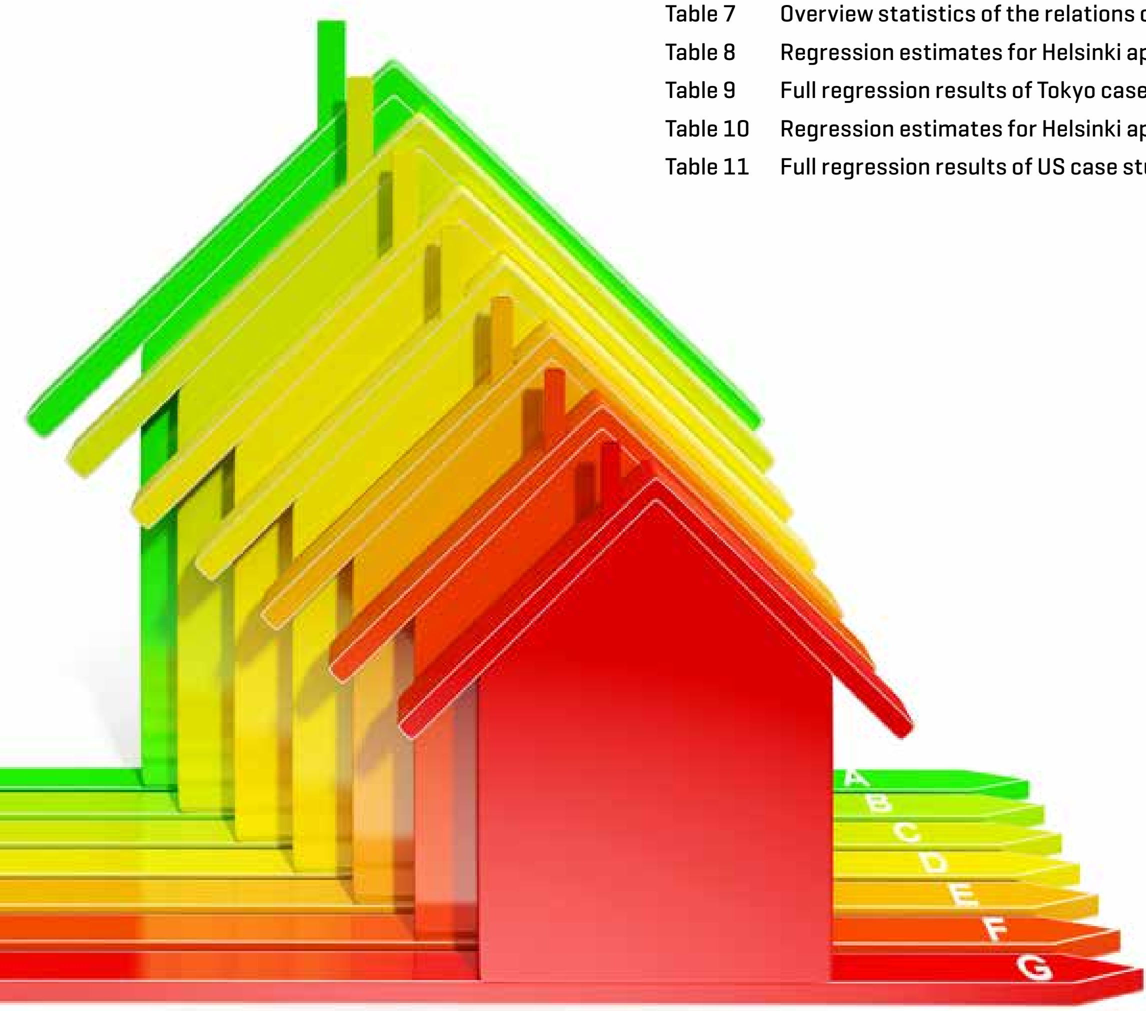

Executive Summary

Environmental performance and sustainability metrics are increasingly considered important criteria in the property investment decision. At the same time, sustainability research in the property market context has reached a critical juncture. The seminal pricing studies from 2008 onwards provided first valuable insights into the pricing of sustainable real estate. However, these studies are also characterised by important limitations. The present research aims to broaden the existing evidence base using new data sources while deepening the research on the dynamics of the well-researched markets such as the US office market using more extensive and more in-depth datasets. To this aim, three international case studies of 'green value' are conducted (one each in Finland, Japan and the United States) and conclusions drawn from these results regarding the existence of a green premium across countries and property types.

Three extensive datasets with information on transactions prices and/or rental rates along with property and 'green' characteristics are applied to these three case studies. The first dataset contains roughly 50,000 housing transactions in the Tokyo condominium market including information on eco-certification of these properties. Apart from the standard variables needed for a hedonic analysis, this dataset allows us to study characteristics of 'green' buyers and households. We find small but significant price premia that persist across most market segments and time periods. The Tokyo study also reveals that asking prices for green properties are only minimally higher than actual transaction prices. We also find evidence of a strong positive link between household income and a willingness to pay for a green label, even when holding the property itself constant.

The second case study focuses on Energy Performance Certificates and housing attributes for a sample of flats in the Helsinki metropolitan area. The evidence is not clear-cut but overall we find a significant price premium, at least for the most energy-efficient buildings and apartments. The Helsinki dataset allows us to isolate the impact of energy efficiency better than was the case in previous studies. New control variables in this dataset that were not typically included in earlier studies of this topic area included a property condition rating, information about 'time on market' and an energy efficiency rating which is based on actual measured consumption rather than an assessor's estimate of the intrinsic energy efficiency of a building (as is the case, for example, in the United Kingdom). The results of this case study suggest that above-average 'green' features appear to be financially rewarded even in markets that are characterised by high energy efficiency standards with regard to insulation and other thermal characteristics.

The third case study is based on the largest study in this topic area to date, based on a panel dataset, including operating expenses, rents and building characteristics in six large office markets in the US. It has allowed us to gain a better understanding of the three-way interaction between green labels (LEED and Energy Star), operating expenses and office rents. Using this unique dataset we are able to isolate a pure cost saving benefit from additional certification ('green glow' effect). The effect of both components on rents increases with rating scores, i.e. with the degree of 'greenness' reported by the rating. However, the dynamic investigation of the relationship reveals a slightly different effect. It appears that if information from a previous period is allowed to influence the current rent the overall certification effect creates a discount in the gross rent. Notwithstanding these inconclusive findings resulting from more advanced dynamic model specifications, the case study of the US office market is broadly in line with both earlier studies of the same market and the findings of the other two case studies described in this report.

In summary, this research project draws together evidence on 'green value' from three continents (Asia, Europe and North America), two housing markets and one commercial property market. While these new and more in-depth results are encouraging for the existence of 'green value' in the property markets of the most developed economies, more needs to be done to apply this type of econometric analysis in the largest and most dynamic emerging markets. The number of studies on Chinese cities and property markets is a positive sign in this respect but very little evidence exists to date from some other important markets such as India, Brazil or Russia to name just the most prominent examples.

1.0 Background and Objective

Environmental performance and sustainability metrics are increasingly considered important criteria in the property investment decision. Investors require information on the costs and benefits associated with developing, managing and investing in buildings with superior environmental performance. Hence, the main reasons for 'going green' include reducing costs, enhancing asset value and hedging against energy price volatility and the risk of obsolescence. A number of empirical studies have sought to explore the economics of sustainability and energy efficiency in residential and commercial buildings and investigated the contribution of policies that promote sustainability. Despite its growing prominence, this strand of research is still in its infancy and the existing empirical evidence is relatively piecemeal and fragmented. This RICS Education Trust project aims to make a significant contribution through further, more fine-grained econometric studies of 'green value'.

Sustainability research in real estate has reached a critical juncture. The seminal studies (Miller, Spivey, Florance, 2008, Fuerst and McAllister, 2011, Eichholtz, Kok and Quigley, 2011, 2013, Reichardt, Fuerst and Zietz, 2012 to name just a few) provided first valuable insights into the pricing of sustainable real estate. However, these studies are also characterised by important limitations. Firstly, they typically focus on specific sectors, in specific countries and over specific timeframes which means that their results may not be readily generalisable to other sectors, places and time periods. This is particularly relevant as the majority of studies were conducted using data from the US office market, possibly because of data availability. Secondly, these studies rely on a very small number of data sources (notably from the CoStar Group) which provide a great wealth of information on property characteristics but are rather limited regarding the environmental performance and general sustainability indicators.

Perhaps surprisingly, the residential sector has attracted a much smaller number of academic studies in this topic area, despite its large size and obvious relevance for both the general economy and sustainable development. The reasons for this lack of empirical evidence are not clear. Larger fragmentation of investors and a lower fraction of professional or institutional investment in the market driving the discourse around 'green value' may be a contributing factor. Also, housing markets are highly regulated and prone to inefficiencies in many countries which makes it more difficult to measure the contribution of sustainability and energy efficiency to prices and rents. 'Green' financial instruments are also still not used widely in the residential sector which makes capitalisation into the lump-sum house price the only channel for economic rewards of sustainability in many cases. As this poses a significant risk for any upfront investment in energy efficiency, 'green value' might not be readily observable in housing markets.

Despite these apparent obstacles, the existing evidence of the residential market points to a significant green premium. An early study by Dian and Miranowski (1989) showed that increasing energy efficiency increases housing prices. Banfi et al. (2005) have published research findings indicating that rental housing tenants are prepared to pay up to 13% higher rent for buildings that have adopted energy-saving measures. Similarly, Fuerst et al (2012) found a price effect of higher energy performance in the British housing market for a large sample of sales transactions in the 1995-2011 time period, indicating a 14% premium of the highest band of energy ratings over the lowest band. They also find that this effect tends to be larger for terraced dwellings and flats compared to detached and semi-detached houses. Similarly, Zheng and Kahn (2008) and Zheng, Kahn and Deng (2012) find significant price premia for 'green' properties in the Chinese housing market and a study by Deng, Li and Quigley (2012) finds substantial economic returns to green buildings in Singapore. Wameling (2010) reports higher selling prices for dwellings with lower primary energy demand in the German housing market while Salvi et al (2010) find higher rental rates for Minergie-labelled flats in the Swiss market. Kok and Kahn (2012) as well as Hyland et al (2013) arrive at similar conclusions for the Californian and the Irish housing market respectively.

The present research aims to broaden the existing evidence base using new data sources while at the same time deepening the research on the dynamics of the well-researched markets such as the US office market using more extensive and more in-depth datasets. To this aim, three international case studies of 'green value' are conducted (one each in Japan, Finland and the United States) and conclusions are drawn from these results regarding the existence of a green premium across countries and property types.

The analysis of the three case studies is carried out using three distinct empirical datasets with information on transactions prices and/or rental rates along with property and 'green' characteristics. The first dataset contains roughly 50,000 housing transactions in the Tokyo condominium market including information on eco-certification of these properties. Apart from the standard variables needed for a hedonic analysis, described in more detail in the next section, this dataset allows us to study characteristics of 'green' buyers and households which has not been possible with the data used in previous studies. The second dataset involves a similar dataset using Energy Performance Certificates and housing attributes for a sample of flats in the Helsinki metropolitan area. This sample is much smaller (about 6000 transactions) but is nonetheless very valuable because it contains performance data on actual energy consumption and allows us to study the value of energy efficiency in a setting with higher requirements regarding heating and possibly also lighting and electricity due to climatic conditions. The third dataset is a panel dataset including operating expenses, rents and building characteristics in six large office markets in the US. This dataset allows us to gain a better understanding of the three-way interaction between green labels (LEED and Energy Star), operating expenses and office rents.

1.1 General research design

A hedonic analysis is conducted in all three case studies to measure if and how energy efficiency and eco-certification are priced in the property market. The underlying premise of hedonic models is that values of numerous attributes of a multi-faceted economic good are reflected in capitalised prices and (annualised) rents. Therefore, dwelling occupiers receive utility from each of the many attributes of a property. Dwelling prices are hedonic in that they represent a bundle of attributes such as location advantages, space, quality of product etc. The number of hedonic attributes could, theoretically at least, be large in number. However, usually a small number of key characteristics tend to be the key price determinants. When examining the impact that 'green' features and ratings might have on prices, it is essential that the main price determinants are identified and controlled for to allow for an 'apples with apples' comparison. Therefore, to conduct the hedonic regression analysis, the following attribute data are required:

- size (floor areas and/or number of bedrooms)
- dwelling type (detached, semi, terraced etc.)
- age (year built or suitably constructed age bands)
- location (exact address)
- location attributes

The basic hedonic rent model takes the following form:

$$P_i = \alpha_i + \sum_{i=1}^{I} \beta_i X_i + e_i$$

where P_i is the transaction price of a property, X_i is a vector of several explanatory locational and physical characteristics as listed above, β_i is a vector of parameters to be estimated and e_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_e. The hedonic weights assigned to each variable are equivalent to its overall contribution to the price (Rosen 1974). The hedonic model proposed by Rosen (1974) as described above led to the development of market equilibrium theory for products differentiated according to the proposition by Tinbergen (1959), and it shows how differentiated assets such as housing can be analyzed, both from an economic theory and econometric model perspective. Specifically, it scrutinises the relationship between the product supplier's offer, product consumer's bid function, and hedonic price function structure, and defines the product's market price based on consumer and producer behaviour. Although actual empirical analysis is not performed, it also outlines the econometric estimation procedure.

In the estimation of many hedonic functions, however, due to strong data limitations, it is not possible to gather all the variables designated as important by the theory. As indicated by Ekeland, Heckman, and Nesheim (2004) and Shimizu (2009), one faces the problem known as omitted variable bias, which occurs if important variables are left out of the function estimation; the estimated regression coefficient lacks impartiality and is biased. With the hedonic model proposed by Rosen (1974), even in simplified cases (cases in which producers are treated as homogeneous), extremely complex analysis is needed in order to distinguish preferences and technical structures based on hedonic price functions. Epple (1987) formulated an econometric model developed from Rosen's theory, assuming that there are large numbers of consumers and producers. The problem with Rosen's theory is that in the structural equation formed by supply and demand, it is not possible to eliminate the following scenario: specifically, important attributes are not observed and if the important attributes are correlated with observed attributes, the problem of simultaneity bias – in which there is neither impartiality nor consistency – will occur in the coefficient estimation of hedonic price function observed attributes in equilibrium (Ekeland, Heckman, and Nesheim, 2004). With regard to this point, Epple's model is an approach that proposes a hedonic price function which is able to properly handle observation errors. However, this approach performs estimation by making an a priori assumption for the utility function and deriving a hedonic price function for closed market equilibrium in which exogenous variables are not required.

This framework can then be easily modified and extended to test for the price impact of 'green' ratings and features in the following way:

$$P_i = \alpha_i + \sum_{i=1}^{I} \beta_i X_i + \sum_{i=1}^{I} \beta_i G_i + e_i$$

where G_i simply represents the green features. Depending on the individual case study and dataset, the green feature is represented by the Tokyo Green Rating (3 star rating), the Finnish EPC Rating (A to G along with energy consumption psf) or the LEED and Energy Star labels and building operating expenses respectively.

1.2 Expected results

The findings of existing studies on sustainable real estate have significant limitations and are becoming rapidly obsolete. In general, they indicate a signal of positive or, in some cases, negligible price effects associated with environmental certification. The following three case studies provide an update to the empirical evidence in this fast-paced area of research and expand the research into key countries and markets that were hitherto not or only minimally covered by empirical evidence on the 'green value proposition'. Beyond that, they also test the propositions that (1) higher income buyers have a higher willingness to pay (WTP) for eco-certified homes than lower income households both in absolute and relative terms (Tokyo), (2) the energy efficiency of a property has a substantial impact in countries with cold winters and a high number of heating-degree days (Helsinki) and (3) the existence and magnitude of a 'green premium' are sensitive to how utility payments are made by the tenant as well as to the actual score achieved by a property in the rating process (US office market).

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2.0 Case study 1: Tokyo

The first case study examines 'green value' in the Japanese housing market. Using a unique transaction database of condominiums in the Tokyo metropolitan area, we seek to establish whether an eco-label carries a significant premium in asking and/or transaction prices.

There are a number of existing studies on the Japanese market for green buildings, for example Yoshida and Shimizu (2010) and Shimizu (2010) who have conducted an analysis focusing on the new condominium market using asking prices and transaction prices. However, due to the small size of their sales transactions sample, the results did not reach a satisfying level of statistical reliability. A larger study was conducted by Yoshida and Sugiura (2010). Using a sample of roughly 35,000 condominiums the authors find that eco-labelled condominiums were sold at a discount, rather than a premium and offer a number of empirical and methodological explanations for this result. The present study seeks to clarify the conflicting findings regarding the Tokyo market and contributes to the body of evidence by applying the largest and most comprehensive dataset to date in this investigation of 'green value' in the Japanese context. Crucially, it contains information on the property development company as a proxy for quality as well as buyer characteristics which were possible omitted variables in the earlier studies cited above.

2.1 Data

The principal source for the sales transactions database applied in this case study is the Tokyo Association of Real Estate Appraisers (2010) which collects transaction prices for new condominiums and used condominiums. Green labels are currently only awarded in the Tokyo market for new builds and not for used condominiums. While our use of new builds only, may limit the application of our findings to the general housing market, it avoids the reported problems arising from any discontinuities that may exist in how property characteristics are priced in the new-build and re-sale markets.

The dataset was collected using a survey of house price and attribute information. The most important piece of information concerns prices per unit, both the asking price (which is the producer's offer price) and the recorded transaction price. Further, in order to ensure consistency with the hedonic theory model, data relating to buyer characteristics such as income, household size, etc., was gathered. The questionnaire survey was conducted by the Recruit Housing Institute, starting in November 2011. Surveys were conducted in writing, via submissions from a large number of home buyers. Contract data were also used to collect accurate transaction prices. In addition, information on freehold/leasehold and the form of management were recorded by the questionnaire survey, i.e. is the building managed through visits, through day shifts (a manager works in the administrative office during the day time only) or by having a permanent presence on site (a manager works in the administrative office and is present on a 24-hour basis). The intuition behind gathering this information was that the quality and availability of management services is said to be reflected in condominium prices. More importantly, it can also be viewed as a proxy for other unobservable quality characteristics that might otherwise be captured by the green label which, in the worst case, could lead to omitted variable bias and overstated green premiums. Standard hedonic characteristics such as the total number of condominium units, lot area, and overall building area were also included. Moreover, we assume that price differentials may also arise based on the developer's and (main) construction company's reputation and brand power.[1]

Market conditions and dynamics are an important control variable in any hedonic analysis. Therefore, we included the first-month contract rate as a proxy. The first-month contract rate reflects the percentage of units sold within the first month of marketing a particular property. It is thought that a higher first-month contract rate reflects better general market conditions but a higher relative rate (i.e. relative to the market average at the time) also indicates how affordable the housing unit prices are in relation to the condominium's features.

In addition to the Recruit Housing Institute's survey data, the Japanese Real Estate Economic Institute's database was used. Along with the developer's asking price, the following key variables were drawn from the Real Estate Economic Institute's database: name of the development company, development overview (development scale), location characteristics (coordinates, address, nearest station, distance to nearest station), and building characteristics (building area, land area, building structure). This information was matched to the data gathered by the Recruit Housing Institute. Appendix 2 contains a complete overview of the variables used in the analysis. Using these sources, a large database was assembled for the 10-year period from 2001 to 2011.

With regard to markers of 'green buildings', data for labelling based on Tokyo Metropolitan Government's Green Labelling System for Condominiums were used. This is based on the Green Building Program which was introduced in June 2002 and mandates that all large-scale construction or major refurbishment projects exceeding 10,000m submit an environmental plan at the time of planning as well as a completion notice. Additionally, in October 2005, the Green Labelling System for Condominiums was started which required the gathering and publishing of information based on four environmental evaluation items.

The four evaluation items are: a) quality of building insulation which addresses reduction in the building's heat load; b) facility energy-saving performance, which addresses energy-saving systems; and c) lifespan extension and d) greening of the building, which address lifespan extension, etc., and greening. The evaluation results for the respective items are expressed as a number of star symbols ranging from one to three stars. In addition, in order to increase recognition among consumers, condominium buildings under the obligation to submit an environmental plan document had to indicate the scores of the evaluation items. Moreover, from January 2010 onward, the system was changed to cover not only owner-occupied condominium buildings but also rental condominium buildings and the floor space for which notification is required was lowered to 5,000m^2 in total. This change also stipulated that owners of smaller buildings were also permitted to apply for this label at their own discretion.

1 A dummy variable was created to distinguish the leading construction companies: (1) Takenaka Corporation, (2) Obayashi Corporation, (2) Kajima Corporation, (4) Shimizu Corporation, and (5) Taisei Corporation; second-tier construction companies (6) Kumagai Gumi, (7) Toda Corporation, (8) Penta-Ocean Construction, (9) Konoike Construction, (10) Sato Kogyo, (11) Mitsui Construction, (12) Mitsubishi Construction, (13) Sumitomo Construction, (14) Nishimatsu Construction, and (15) Haseko Corporation; and (16) other.

The hedonic model used for this analysis includes a dummy variable for buildings with two or more stars for either a) building insulation (covering reduction in the building’s heat load) or facility energy-saving performance (covering energy-saving systems) and 0 otherwise. The dummy variable is not applied to buildings which have only one star under the Green Labelling System for Condominiums as this was deemed too low to qualify as a credible ‘green’ product. Moreover, with regard to building performance evaluation, the existence of a Housing Design Performance Evaluation Document and Housing Construction Performance Evaluation Document based on the Housing Quality Assurance Act is also considered in our analysis. This is done to ensure that the measured price contribution of a green label is separated from the effect of conventional Housing Performance Evaluation and quality assurance documents.

Adequate location controls are essential in any attempt to disentangle the factors contributing to property prices. In the present analysis we use a fine-grained 500m x 500m mesh block in which the condominium is located as a unit. Specifically, the characteristics are built-up area, average floor space, standard deviation of floor space, number of floors for each building and the standard deviation for the number of floors. Next, area-based information on the proportion of the population aged 65 and over and the proportion of office workers in the pertaining census mesh block were added. To account for unobserved spatial characteristics, we also generate a local administrative district dummy.

A further set of dummy variables indicates proximity to a railway line and the time required to Tokyo Station from the nearest station was also included as a regressor.

Buyer characteristics are an important feature of our analysis as outlined above. The following variables were considered: home buyers’ annual income, age, occupation, household size, number of children and identifier for first time buyers. With regard to occupation , differences by employment status[2], work category[3], and industry category[4] were examined.

We first investigate the distributions and descriptive statistics of the underlying dataset. The average asking price has a value of 45.49 million yen, the average value for the actual transaction price was approximately 1.5 million yen lower, at 43.91 million. The floor space ranges from 10m^2 studio condominiums to large-scale condominiums exceeding 200m^2. The walking time to the nearest public transit station is 7 minutes on average, while the average time to Tokyo Central Station is 23 minutes which shows that these properties are generally well served by public transportation. Looking at housing buyer characteristics, the average age of buyers was 37 and the average number of people in the household was 2.3, demonstrating that these buyers are typical Japanese households and could hence be considered as representative of Japanese home buyers in general. However, an important caveat is that the household head’s average income was 8.51 million, a level that is about twice the Japanese average income.

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2 With regard to employment status, the survey was conducted using the following classification: 01. permanent employee, 02. contract employee, 03. civil servant/public organisation employee, 04. self-employed, 05. physician/lawyer/tax accountant/accountant/etc., 06. part-time/casual, 07. homemaker, 08. student, and 09. unemployed. There were no samples corresponding to contract worker, part-time worker, homemaker, or student.

3 The survey was conducted using the following classification for employment category: 01. clerical job, 02. sales job, 03. technical job, 04. service/retail job, 05. construction/manufacturing job, 06. specialized job, 07. management job, and 08. company executive.

4 The following items were surveyed as industry categories: 01. agriculture, forestry, and fishing, 02. construction, 03. manufacturing, 04. transportation/warehousing, 05. finance/securities/insurance, 06. advertising/publishing/broadcasting, 07. printing/typesetting, 08. fashion-related, 09. travel/hotel/leisure, 10. restaurant/bar, 11. housing/real estate, 12. trading/wholesaling, 13. retail, 14. software/information services, 15. beauty, 16. medical/welfare, 17. education, 18. creative professions, and 19. other

2.2 Model specification

Following the overall research strategy outlined in the previous section and taking into account buyer characteristics which are limiting conditions for the bid price function, we specify the following model:

$$P_{(i,\,j,\,t)} = \int (G_i\,,\, X_{(i,\,j)}\,,\, NE_k\,,\, HH_{(i,\,j)})$$

$P_{(i,\,j,\,t)}$: New condominium price of condominium *i* and dwelling *j* at time ***t*** (1: asking price, 2: transaction price)

G_i : Green label of condominium *i*

$X_{(i,\,j)}$: Building characteristics of condominium *i* & dwelling *j*

NE_k : Location characteristics of region ***k***

$HH_{(i,\,j)}$: Buyer characteristics of condominium *i* and dwelling *j*

This specification has a number of desirable properties as compared to previously estimated hedonic functions. Firstly, with regard to the price ($P_{(i,\,j,\,t)}$), both the asking and the recorded transaction prices are known in each individual case, allowing us to investigate whether sellers have unrealistically high expectations of the market value of a 'green label'. Secondly, with regard to housing prices, in general, a price differential is generated ($X_{(i,\,j)}$) based on differences in condominium (*i*) features such as building structure and the size of the lot area, as well as features related to the dwelling (*j*), such as the floor space, the unit's position (whether or not it is a corner unit), etc. In terms of the condominium building's features (*i*), it has increasingly been pointed out that a price differential is generated by the condominium developer or the developer's brand (the developer's reliability and quality assurance, which is difficult to observe visually) and by the construction company. With regard to these variables, developer and construction company information was also gathered and incorporated.

Further to these kinds of building and dwelling characteristics, the characteristics of the surrounding environment, such as the streetscape of the area (*k*), the commercial density, etc., have a major effect on housing prices. This is known as the neighbourhood effect (NE_k). The neighbourhood effect includes not only the living environment but also the ease of commuting to work or school and the ease of shopping, which are represented by transportation convenience (accessibility of nearest station, time to central business district, etc.).

Moreover, as shown in hedonic theory, it is also to be expected that a price differential will be generated via changes in the bid price function based on buyer characteristics ($HH_{(i,\,j)}$). The required floor space and housing features change in accordance with the buyer's annual income and household size, and if they are not linear, these characteristics have to be taken into account. In particular, since it is to be expected that factors such as a building's environmental performance will change considerably according to housing buyers' preferences, it may be too much to assume that there is a homogenous utility function (Shimizu, Nishimura, and Karato, 2007).

Based on this kind of model analysis, the following three estimation models were set.

Here, factoring in the time element, the hedonic price function is estimated focusing on the condominium price ($P_{(i,\,j,\,t)}$) at time *t*.

First, as a standard model, the following model was taken as a starting point (Model 1).

$$\log P_{(i,\,j,\,t)} = a_0\,,\, a_1 T_{(i,\,j)} + a_2 G_i + a_3 G_i T_{(i,\,j)} + \sum_m a_4^m X_{(i,\,j)}^m + \sum_n a_5^n NE_k^n + \sum_t a_6^t D_t + \varepsilon_{(i,\,j)}$$

$T_{(i,\,j)}$ is a transaction dummy (1 in the case of the transaction price; 0 in the case of the asking price), while D_t (t = 2001 to 2011) is a time dummy. With regard to the green label effect (G_i), it is to be expected the degree to which the effect appears will change depending on the asking price (which is the producer's offer price) or the transaction price (which is linked to the bid price). Accordingly, the difference between the two has been incorporated by inserting a cross-term ($G_i \times T_j$) with the transaction price dummy (T_j), which is 1 for the transaction price and 0 for the asking price.

Next, it was expanded into a hedonic function factoring in buyer characteristics, which in theoretical terms should be considered, but which were difficult to incorporate into the model due to data limitations (Model 2).

$$\log P_{(i,\,j,\,t)} = a_0\,,\, a_1 T_{(i,\,j)} + a_2 G_i + a_3 G_i T_{(i,\,j)} + \sum_m a_3^m X_{(i,\,j)}^m + \sum_n a_4^n NE_k^n + \sum_s a_5^s HH_{(i,\,j)}^s + \sum_t a_6^t D_t + \varepsilon_{(i,\,j)}$$

Moreover, how the green label effect (G_i) changed in accordance with the passage of time was analyzed (Model 3).

$$\log P_{(i,\,j,\,t)} = a_0 + a_1 T_{(i,\,j)} + a_2 G_i + a_3 G_i T_{(i,\,j)} + \sum_m a_3^m X_{(i,\,j)} + \sum_n a_4^n NE_k + \sum_s a_5^s HH_{(i,\,j)} + \sum_t a_6^t D_t + \varepsilon_{(i,\,j)} + \sum_t a_7^t G_i D_t + \varepsilon_{(i,\,j)}$$

2.3 Estimation Results

The estimation results for the three models are outlined in Table 1. The baseline estimation (Model 1) reveals that the average asking price for a condominium with a green label (two or three stars out of three) is 6% higher compared to a similar condominium without a label. In other words, the developers of condominiums with superior environmental performance offered them at a marginally but significantly higher price. However, the actual achieved transaction prices are more relevant to our central research hypothesis about the existence of a green premium. The general transaction price variable indicates that transaction prices were on average 3.5% lower than asking prices in the observed period 2001-2011. Green-labelled properties transacted with another marginal discount of 0.9%. The total green premium actually observed in the residential sales market therefore reduces to 1.6% (6%-3.5%-0.9%). Although relatively small in magnitude, this price premium is statistically significant.

A more detailed list of coefficient estimates is contained in Appendix 1 which reveals a number of additional insights into the pricing of green and non-green condominiums. In cases where a Housing Design Performance Evaluation Document (Part A)[5] exists, condominium prices are marginally higher (0.6%) while the presence of a Housing Performance Construction Evaluation Document (Part B) entails a 0.5% premium. These evaluation document variables are important for isolating the 'pure' effect of the green label effect from other types of quality evaluation of newly built properties. Next, similarly distinguishing buildings based on management costs, maintenance/renovation investments, etc., shows that such costs and transaction prices are positive related. Furthermore, the price was lower when the type of land ownership was 'general leasehold' or considerably lower for 'fixed-term leasehold'. The price was 2.2% higher when the dwelling is a corner unit. The coefficients of all other control variables including the time-period dummy variables exhibited the expected signs.

Model 2 in Table 1 reports the estimation results using robust regression, an estimation technique which gives proportionally less weight to influential outliers, thereby reducing the potential bias that a small group of properties with extreme or unusual prices and other attributes may introduce to the results. However, the results are only slightly different to the baseline model with a 5.9% asking price premium and a 1.8% transaction price premium for green-labelled properties.

Next, we examine the impact of buyer characteristics on the prices of eco-labelled properties (Models 3-6 of Table 1 and Appendix 1). To this aim, we divide the buyers into income quartiles and then estimate the impact of all price determinants separately for each income quartile. The results show that the green asking price premia (expressed as a fraction of the total price) are found to increase in line with the household incomes of buyers (from 4% to nearly 8%). A similar patterns emerges for recorded transaction prices (as opposed to asking prices) i.e. the green price premium is mainly driven by households with above-average incomes. Given that these are percentages of the total price, the spread in terms of absolute monetary values of these price premia is likely to be even more pronounced. This finding is significant in that it demonstrates for the first time that 'green' features are more prone to attracting higher-income buyers which contradicts the frequently made argument that energy efficiency and the resulting lower utility bills are a larger concern for more income-constrained households.

Further interesting findings (Appendix 1) in terms of buyer characteristics are that first-time buyers exhibit generally a lower willingness to pay, particularly in the lower income segments. This may be taken as an indication of first-time buyers acting more cautiously on the housing market regardless of current income, possibly because of their relatively lower asset possessions compared to buyers who already own a property and seek to 'trade up'. A price differential also occurs based on occupation. Independent of current income and age, it is possible that this variable acts as a proxy for future income or the certainty (stability) of that income. The fact that annual income and employment generate differences in housing prices, supports our earlier proposition that prices of both green and non-green properties cannot solely be explained by property characteristics, but are also a function of socio-economic buyer characteristics.

5 The Housing Performance Indication System is based on the Housing Quality Assurance Act that was enacted on April 1, 2000. It evaluates housing performance based on fixed standards, such as complying with the obligatory 10-year defects liability period for basic structural areas of new housing. Under this system, Housing Performance Evaluation Documents are issued, which are divided into Housing Design Performance Evaluation Documents and Housing Construction Performance Evaluation Documents

Table 1 Hedonic regression results

	(1) baseline OLS	(2) Robust reg	(3) Income Q1	(4) Income Q2	(5) Income Q3	(6) Income Q4
	lp	lp	lp	lp	lp	lp
Transaction price discount	-0.0347***	-0.0316***	-0.0359***	-0.0354***	-0.0337***	-0.0343***
	(-27.87)	(-26.54)	(-11.72)	(-15.94)	(-16.16)	(-13.37)
Green asking price premium	0.0609***	0.0586***	0.0408***	0.0398***	0.0702***	0.0777***
	(18.66)	(18.31)	(3.63)	(6.74)	(13.12)	(12.45)
Green transaction price discount[2]	-0.00918*	-0.00948**	-0.0158	-0.00692	-0.00936	-0.00975
	(-2.40)	(-2.59)	(-1.16)	(-1.08)	(-1.50)	(-1.41)
sqft	0.0243***	0.0244***	0.0160***	0.0143***	0.0135***	0.0146***
	(77.74)	(115.41)	(97.94)	(98.75)	(98.93)	(98.12)
Constant	7.505***	7.508***	7.533***	7.757***	7.861***	7.954***
	(329.53)	(390.22)	(144.48)	(154.72)	(219.17)	(250.75)
Property & condo attributes	Yes	Yes	Yes	Yes	Yes	Yes
Developer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Location controls	Yes	Yes	Yes	Yes	Yes	Yes
Management fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Buyer characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	48740	48740	6940	12896	15328	13576
R^2	0.808	0.818	0.799	0.727	0.716	0.783
adj. R^2	0.807	0.818	0.795	0.723	0.714	0.781
AIC	-60598.0	–	-9091.1	-18262.5	-20896.4	-14952.0
BIC[3]	-59296.5	–	-8071.2	-17120.4	-19720.3	-13787.0

t statistics in parentheses * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Notes:

1 Green asking price premium on equivalent unlabelled condominiums

2 The dummy variable 'transaction price discount' indicates the average discount observed relative to the equivalent asking price. The dummy variable 'green transaction price discount' indicates the additional discount applied to the transaction of a green-labelled condominium. Both the general transaction price discount and the green transaction price discount have to be subtracted from the green asking price premium to arrive at the green transaction price premium. For example, in Model 1 the total green premium paid in transactions is 1.6% (6% - 3.5% - 0.9%)

3 N indicates the number of observations used in the regression. R^2 and adj. R^2 are a widely used goodness-of-fit measure for regression models, ranging from 0 to 1. AIC and BIC refer to the Akaike Information Criterion and the Bayesian Information Criterion respectively. Both are measures of the relative quality of a regression model and are frequently used by statisticians and econometricians in model selection.

Image source: skyearth-Shutterstock.com

Next, we examine how the added economic value of green buildings has changed over time (Table 2). For simplicity, only the estimates for the variables of interest are shown and the results for the large number of control variables are suppressed in this table. First, for the base asking price, the premium rose over time from 5.1% in 2005 to over 7.4% in 2009 but declined considerably in 2010 and 2011. When estimating the transaction discounts relative to asking prices, we find that there were significant discounts from 2008-2011 but no additional effect is found for green transactions. This suggests that the relationship between asking prices and transaction prices was similar for labelled and non-labelled properties when analysed on a year-to-year basis.

Table 2 **Hedonic regression results of the 'green premium' over time**

	Transaction discount	Green asking price premium	Green transaction price discount
2005	-0.037	0.051**	-0.046
2006	-0.037	0.044***	-0.001
2007	-0.034	0.066***	0.009
2008	-0.070***	0.063***	0.001
2009	-0.078***	0.074***	0.013
2010	-0.029***	0.040***	0.003
2011	-0.025***	0.0191	-0.015
N	48740		
***R*²**	0.807		
adj. *R*²	0.806		
AIC	-60227.9		
***BIC*[3]**	-58776.8		

t statistics in parentheses * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Notes:
'Transaction discount' refers to the average discount in transaction prices compared to asking prices in each year. 'Green asking price premium' indicates the average asking price premium of green-labelled condominiums compared to the asking prices for non-labelled condominiums in each year. 'Green transaction price discount' refers to the additional effect of transactions of green-labelled condominiums above and beyond the general 'transaction discount'.

2.4 Conclusions

This case study set out to test whether obtaining a green label adds value to residential properties in the Japanese housing market using a unique dataset of new condominium transactions in the Tokyo market. Based on our analysis, this question can be answered in much the same way as previous research has done across the world.

The hedonic analysis shows a clear price premium for green-labelled condominiums both in asking and transaction price although the effect for the latter is rather small (around 1.7% of the standard transaction price).

Taking into account buyer characteristics as well (Model 2), we find that wealthier buyers are willing to pay a higher premium for green-labelled properties, both in absolute and relative terms. It appears that eco-labelled condominiums in Tokyo are a luxury good that is offered primarily to high-income households who are able and willing to pay a premium for owning and occupying a green-labelled property.

In addition, if one looks at temporal changes in the premium, we find that the effect of green labels became larger over time before declining again in the final two years of the study period. In terms of the possible reasons for this, it may be the case that the awareness of green buildings has increased in the Japanese residential market in the years 2006-2010 and that the buyer segment actively seeking to invest in their value is expanding. Further analysis is required to ascertain whether the absence of the premium in the most recent year (2011) is a continued trend that marks the end of a 'green premium era' or is simply a one-off occurrence.

A number of caveats remain for this analysis. First, one could point out the problem of accuracy with regard to the green labels used as variables in order to distinguish properties with superior environmental performance. The current labelling system is based on applications from developers, and it does no more than indicate buildings' hypothetical environmental performance at the time of development. Buyers may be wary to pay significant premia for energy efficiency and cost savings that are not proven in operation.

In addition, unless the added economic value of green buildings estimated here is compared to potentially higher development costs, its use for future policy development is limited. It is possible that the premium we measured may still be too low in comparison to the added development expenses.

Moreover, when it comes to the development of green building policy, the problem remains of how it will be treated in the broader housing market that comprises mainly of existing (used) stock. Under the current system, green labels only cover newly developed buildings, but since it is expected that the existing housing market will expand in the future, the application of labels to existing stocks will have to be considered. Notably, when it comes to a buyer's choice of home, the decision is typically made under considerable budget restrictions. With the rapid changes in Japanese demographic structure, the population of people in their 30s and 40s -- which is the home-buyer segment that generates the greatest demand for housing -- is decreasing significantly. Given this context, it is to be expected that budget restrictions will become increasingly strict. It is necessary to keep monitoring whether there continues to be a fixed added value for green buildings. The economic value of green buildings will also change considerably depending on what kind of environmental regulations are implemented in future (Takagi and Shimizu, 2010).

Application to the office market is also a major issue. As research by Sugata, Kawamura, and Shimizu (2011) indicates, only a limited green label effect can be found in the office market. In order to develop green building policy, it is necessary to accurately estimate the extent of the economic value that may be anticipated.

Image source: skyearth-Shutterstock.com

3.0 Case study 2: Helsinki housing market

Our second case study presents further empirical evidence on the value of green labels, in this case Finnish energy efficiency ratings, in the housing market. Specifically, this ongoing research seeks to test the following research questions: 1) Does the energy efficiency rating have an independent impact on housing prices even if the associated lower maintenance costs are controlled for and if so, how large is this price effect? 2) Does the energy efficiency rating affect the liquidity of housing? 3) What is the connection between the energy efficiency rating and maintenance costs –to what extent does the 'greenness' of the rating affect the maintenance costs? 4) Has the value of energy efficiency rating changed as the rating system has matured and the awareness of the rating system has grown? 5) Do the lower maintenance costs induced by energy efficiency fully capitalise into housing prices? 6) What are the implications of the findings regarding the aforementioned questions for real estate investors, constructions companies, real estate brokers, policy makers and households?

This case study which reports the results pertaining to the first of these six research questions is carried out on a dataset provided by the major Finnish estate agents. The dataset includes information on both maintenance costs and energy ratings of privately-financed flats transacted during the 2006-2012 period. The data also include detailed information on a number of characteristics of each transacted unit such as age, size, address etc. These data make it possible to estimate hedonic regression models for the Helsinki housing market.

In line with other studies in this topic area, the dependent variable is the natural log of the total house purchasing price while the detailed housing characteristics are used as explanatory variables that determine the value of a dwelling. This allows us to estimate a separate value for each characteristic, i.e., a separate price function for housing. By including also the maintenance costs and energy efficiency ratings in the group of right hand side explanatory variables, we can investigate the impact of maintenance costs and energy efficiency rating on housing prices, and examine whether the energy grade has some additional impact on the transaction price of a house. Moreover, by including time dummies in the model, we can account for the time-variation in the housing price level as well as study whether the value of 'greenness' has changed over time (through interaction variables).

Regarding the investigation on whether the lower maintenance costs are fully reflected in the value of energy efficient housing, we estimate prediction models – using the techniques of time series econometrics – for the future path of energy prices. It is then assumed that these models represent a rational expectation of energy price growth and can thereby be used to compute the net present value of smaller energy consumption.

3.1 Dataset

This case study is based on transaction level housing sales data for Helsinki, the capital of Finland, from September 2010 to July 2012 to investigate the influence of energy ratings on housing sales prices and times. Our data consists of transactions of privately financed apartments. That is, the data excludes newly built dwellings (which were the focus of the previous case study on Tokyo). There are good reasons to focus on the privately financed sector: In Finland, privately financed housing can be bought and sold at market prices without any restrictions, whereas selling prices and rental prices are controlled in the publicly regulated (i.e. subsidised) sector. Furthermore, the data consist only of apartments, since data on apartments are more reliable than data on the other housing types: apartments are a substantially more homogenous group in their characteristics than the other housing types, and a notably greater number of transactions take place in the apartment market than in the market for other housing types in Helsinki. Therefore, the use of flat data diminishes the heterogeneity problem that is associated with housing price analysis even when hedonic modelling technique is used. In 2011, the total number of flats in Helsinki was 284,300, while the whole housing stock included 331,500 dwellings.

The housing sales data are provided by the private real estate agency Kiinteistomaailma, and includes all the flat transactions made using this agency's services. This is approximately 25% of all the transactions in the area during the sample period.

The data include detailed information on the characteristics of each transacted unit, such as age, size, address etc. Out of a total sample of 10,439 transactions recorded in the Kiinteistomaailma database, energy ratings are only known for a subsample of 5,943 transactions. Since energy certificates are issued for buildings, not individual flats, some of the ratings were inferred from transactions of flats within the same building whenever ratings were recorded by the estate agents for some transactions in a building but not for others. The selection of key characteristics that we include in the analysis is presented in Table 3. The average values are broadly in line with market observations as reported by the leading estate agents.

Figure 1 shows the distribution of energy rating bands among properties in our sample. It is evident that the medium rating band D and the somewhat lower band E make up the bulk of our sample.

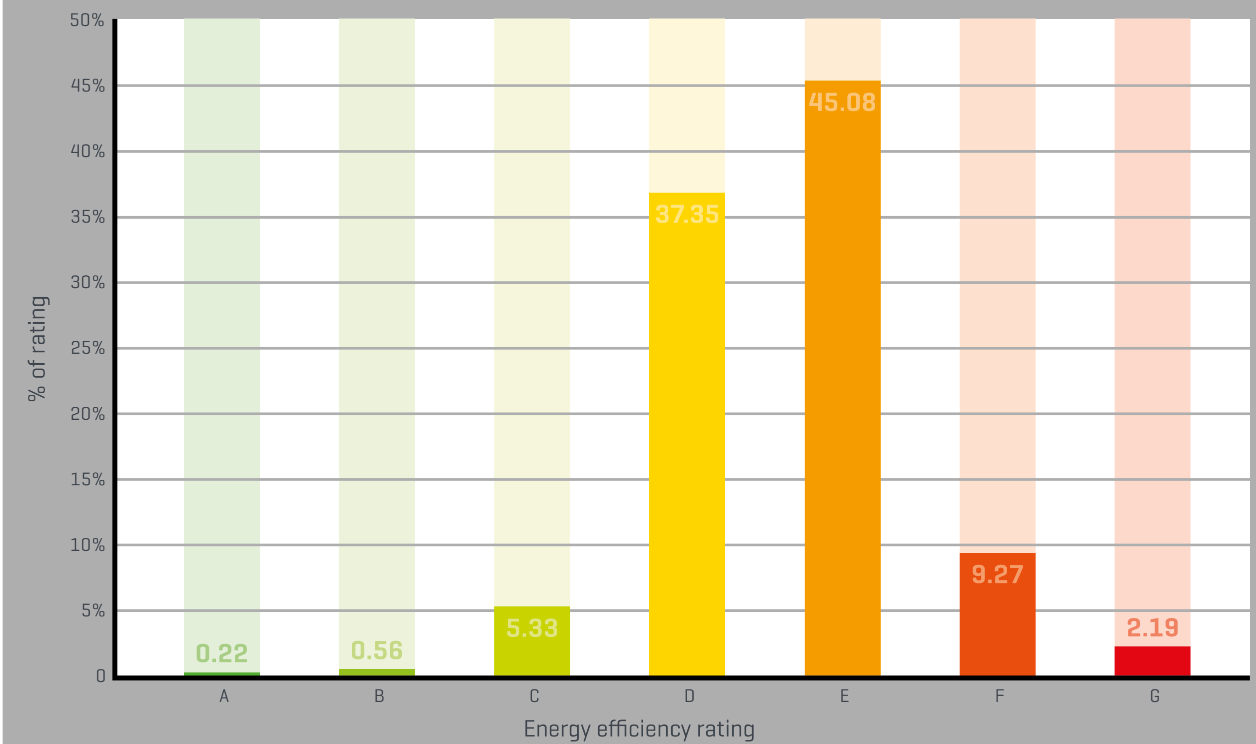
Information on maintenance costs are typically not available for most countries. In the Finnish case practically all flats are in the housing company form, which allows for the recording of maintenance costs for (almost) all the flat transactions. In the housing company form of housing ownership – which quite closely corresponds to the housing cooperative structure in some other countries –ownership of a certain set of shares of the company confers the right to use a certain part of the building owned by the company. The owners pay a monthly fee towards maintenance costs. The maintenance cost fee is public information and is typically recorded for each transacted unit. A transaction of shares in a housing company refers to a sale of shares entitling right to use a given dwelling owned by the company. One advantage of the housing company structure is risk pooling among the individual households owning units through shares. Another attractive factor is the economies of scale provided by a company owning a number of dwellings.

A number of caveats warrant mentioning here. First, the measurement of expected growth rate of maintenance costs can be relatively complicated. Second, from a construction company's / developer's point of view, it would be most interesting to know the value of energy efficiency regarding new housing construction, whereas the study excludes new builds and focusses on transactions of existing stock. Nevertheless, even the data on secondary market transaction is expected to reveal important information concerning the value of newly built housing, since new dwellings and older stock can be generally considered as close substitutes for each other – the same hedonic pricing principles and values must generally apply to newly built housing as to the existing housing stock. All in all, the unique Finnish data are expected to enable a more reliable analysis on the theme than those reported in the previous literature. This analysis has potential policy implications, implications regarding market efficiency, and implications for the construction sector, real estate brokers, investors as well as households.

Table 3 Summary statistics for key variables of the Helsinki case study

Variable	Mean	Std. Dev.	Observations
Transaction price (EUR)	201,674	127,371	5943
Time on market (days)	49.5	62.1	5943
size (sq.m.)	55.0	24.1	5943
age (years)	54.3	25.2	5943
Maintenance cost (psm)	3.5	1.2	5943
Condition rating poor	0.038	0.191	5943
Condition rating satisfying	0.396	0.489	5943
Condition rating good	0.479	0.500	5943
Condition rating excellent	0.087	0.282	5943
Sauna (yes/no)	0.141	0.348	5943
Balcony (yes/no)	0.007	0.082	5943

Figure 1 Distribution of energy efficiency ratings



Source: Man (2011, p19)

Energy efficiency rating and maintenance costs

Since 2009, all flats that are on sale in Finland are required to obtain an energy efficiency certificate. The certificate is voluntary for single-family houses and flats in small housing companies, i.e., in companies with no more than six dwellings that were built before 2008. The certificate reports the heating energy, cooling energy and (other) electricity usage of the building. The energy efficiency value is based on the actual observed energy consumption of the building, and the energy usage values are stated as kWh per gross floor area (m^2) per year. The energy rating is valid for 10 years. Given the typical level of maintenance in the housing companies, the energy efficiency of a given building is unlikely to change within the 10 year period. The ratings are based on the following energy consumption bands:

A: 0-100 kwh/m^2/year

B: 101-120

C: 121-140

D: 141-180

E: 181-230

F: 231-280

G: >280

Due to the cold winter in Helsinki with subzero long-term average temperatures from November until March, buildings require good heat insulation regarding walls, floor, ceiling, loft, and windows to receive a high energy efficiency rating. A typical building that meets the requirements of building commands set in 2008 is generally D rated. Because the average outside temperature, and thereby the heating energy usage, can vary across years, the heating energy consumption is 'normalized' by taking account for the average temperature of the year whose consumption values are used in the computations relative the long-term average annual temperature.

A potential complication with the rating system is that the observed energy consumption is dependent on the habits of people living in the building, not only on the building characteristics. At the aggregate level in a relatively large sample, this is probably not a serious problem, as we can assume that different kinds of people (w.r.t. energy consumption habits) distribute evenly to different kinds of dwellings (w.r.t. energy efficiency). Another complication is caused by the varying number of people per square meter living in different buildings, as the energy consumption is normalized only w.r.t. the floor area. Fortunately, the energy consumption that influences the energy rating is not largely dependent on the number of people staying in the building. This is because the heating and cooling energy are typically only slightly affected by the number of dwellers and because the electricity usage that is used in the computations does not incorporate the electricity usage in individual flats – it includes only general building level electricity usage (outside lighting, stairway lighting, and various building level machinery such as lifts, pumps etc). The 'within flat' electricity consumption, i.e., the electricity usage of lighting and various machinery such as TV and washing machine, is charged from each household separately: this consumption that is largely dependent on a given household's size and habits does not enter the energy efficiency computations. The energy efficiency values take into account the heating of domestic water, though. The share of this energy consumption of the overall heating energy usage is generally only small – in 2011 the share was 17% in Finland (Statistics Finland, 2012) – diminishing the potential influence of this complication on the results.

In Finland, each dwelling in a housing company is charged the same per square meter maintenance fee. Typically, the maintenance fee is charged monthly. The housing companies' maintenance costs include the aforementioned company level energy consumption costs and several other expenditures including administration, cleaning services, refuse disposal, insurances, and real estate tax. Similar to the energy rating computations, the company level maintenance costs do not include the within a flat electricity consumption, as these electricity bills are charged separately from each household. According to Statistics Finland, the average share of heating energy expenditure on the overall maintenance costs of Helsinki area apartment stock was 20% in 2010-2011. Corresponding values for electricity and gas is 3%, and 7% for water (including sewage)[6]. Ideally, our analysis should use energy costs rather than total maintenance costs which contain non-energy factors as well, but the latter can serve as a reasonable proxy in the absence of this information.

3.2 Results

We first present the estimates of our baseline regression model. As Table 4 shows, there is a significant positive effect for the group of higher rating bands (A and B) which achieve a price premium of approximately 6%. A price premium of 1.8% for C-rated buildings is only significant at the 10% level compared to the holdout medium category D. There is also some evidence for price discounts to lower-rated buildings with the exception of the lowest category G which warrants further investigation of the composition of this group. Similar to the previous case study, we then re-run the regression using robust regression which reduces the weight given to observations that are found to be statistical outliers. We find that this reduces both the magnitude of the premiums found for the top-rated properties and reduces their significance. The large number of control variables exhibit generally the expected sign. In the next step, we estimate a quantile regression for each decile of the price distribution separately, i.e. the bottom, third, fifth, seventh and ninth decile of prices (Models 3-7). There does not appear to be a distinct progression pattern with regard to the price segment of the market.

Table 4 **Regression estimates for Helsinki apartments**

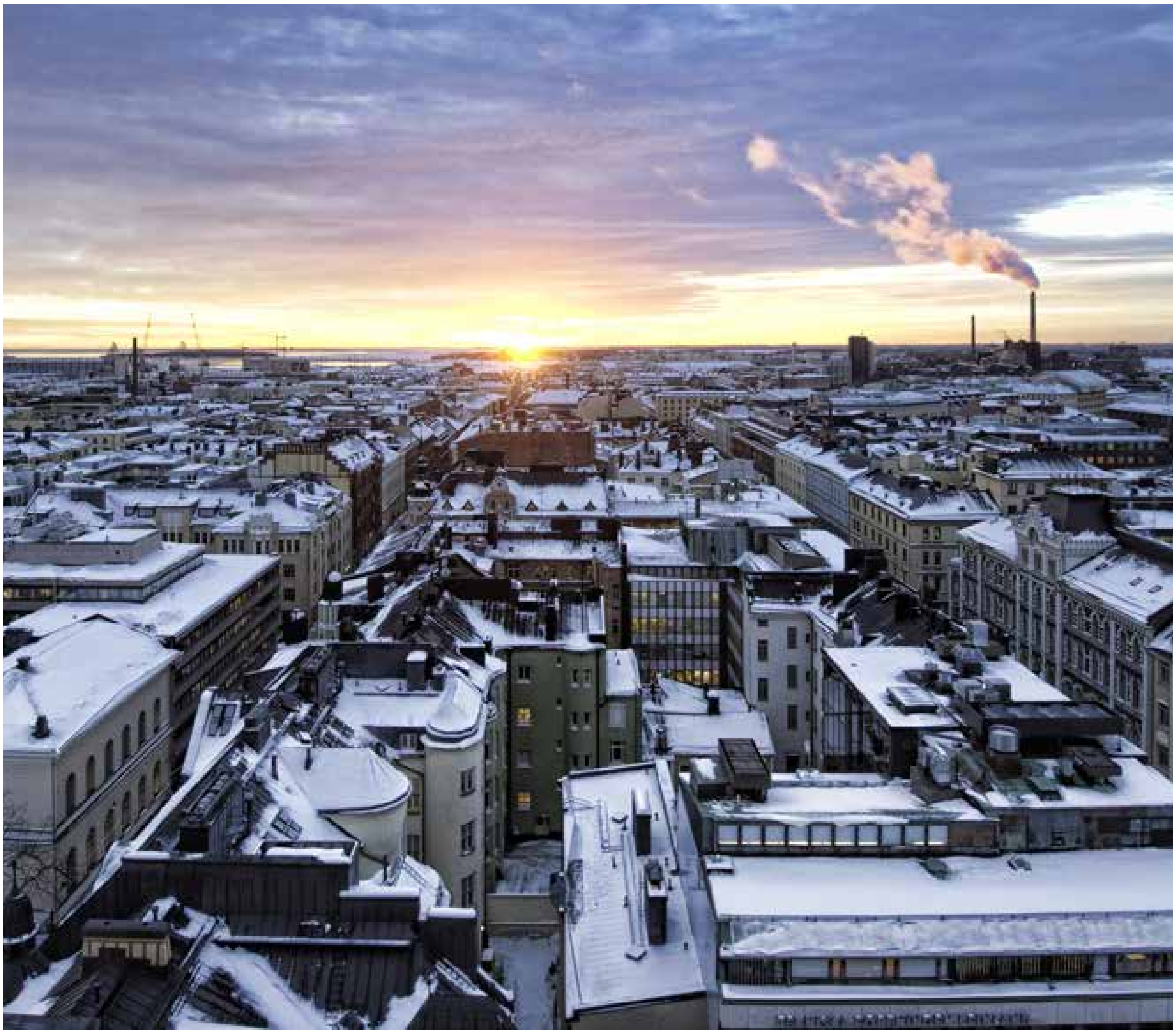
	(1) ln_pricesf OLS	(2) ln_pricesf Robust regres	(3) ln_pricesf Quantile 10	(4) ln_pricesf Quantile 30	(5) ln_pricesf Quantile 50	(6) ln_pricesf Quantile 70	(7) ln_pricesf Quantile 90
rating_AB	0.0627**	0.0360	0.00515	0.0479	0.0536*	0.0386	0.0548
	[2.61]	[1.57]	[0.15]	[1.66]	[2.12]	[1.62]	[1.61]
rating_C	0.0179	0.00491	0.0411**	0.0158	0.00726	0.0113	-0.0208
	[1.80]	[0.52]	[2.83]	[1.32]	[0.68]	[1.11]	[-1.50]
rating_D	reference	reference	reference	reference	reference	reference	reference
rating_E	-0.0140**	-0.0119**	-0.0133*	-0.0132*	-0.0118*	-0.0114*	-0.0208**
	[-2.98]	[-2.66]	[-1.98]	[-2.33]	[-2.36]	[-2.36]	[-3.05]
rating_F	-0.00578	-0.00660	-0.0214	0.00311	-0.00433	-0.00191	-0.0151
	[-0.74]	[-0.89]	[-1.88]	[0.33]	[-0.52]	[-0.24]	[-1.37]
rating_G	0.0101	0.0000311	0.00490	-0.00663	-0.00710	0.0105	0.0129
	[0.69]	[0.00]	[0.24]	[-0.37]	[-0.46]	[0.70]	[0.62]
age	-0.00805***	-0.00775***	-0.00694***	-0.00720***	-0.00817***	-0.00819***	-0.00961***
	[-17.69]	[-17.92]	[-10.41]	[-13.52]	[-16.83]	[-16.76]	[-13.11]
age_sq	0.0000644***	0.0000622***	0.0000569***	0.0000573***	0.0000648***	0.0000653***	0.0000763***
	[17.60]	[17.89]	[10.07]	[12.99]	[16.58]	[17.16]	[14.03]
maint_cost_sqm	0.0120***	0.0115***	0.00899**	0.0122***	0.0118***	0.0122***	0.00822***
	[6.71]	[6.75]	[2.83]	[5.35]	[6.14]	[6.99]	[3.50]
airline_distance	-0.0870***	-0.101***	-0.0869***	-0.0812***	-0.0752***	-0.111***	-0.112***
	[-6.27]	[-7.69]	[-4.09]	[-4.92]	[-5.08]	[-7.55]	[-4.85]
airline_distance_sq	0.00505***	0.00592***	0.00445***	0.00476***	0.00453***	0.00641***	0.00612***
	[6.22]	[7.66]	[3.57]	[4.97]	[5.23]	[7.45]	[4.54]
size	-0.00693***	-0.0113***	-0.00684***	-0.00778***	-0.00888***	-0.0105***	-0.0131***
	[-28.77]	[-49.51]	[-18.50]	[-23.68]	[-34.40]	[-43.89]	[-37.30]
size_sq	0.0000252***	0.0000596***	0.0000196***	0.0000291***	0.0000406***	0.0000531***	0.0000754***
	[17.78]	[44.29]	[7.93]	[13.47]	[26.75]	[42.68]	[46.93]
sauna	0.0955***	0.0935***	0.117***	0.101***	0.0757***	0.0812***	0.0623***
	[11.24]	[11.58]	[8.94]	[9.94]	[8.37]	[9.11]	[4.72]
constant	9.115***	9.236***	8.890***	9.045***	9.170***	9.322***	9.528***
	[273.52]	[291.50]	[194.27]	[229.20]	[258.11]	[267.62]	[178.12]
quarterly fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	5943	5943	5943	5943	5943	5943	5943
R^2	0.803	0.828	0.567	0.602	0.593	0.577	0.544
adj. R^2	0.800	0.825	–	–	–	–	–
AIC	-5043.5	–	–	–	–	–	–
BIC[3]	-4347.8	–	–	–	–	–	–

t statistics in parentheses * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

3.3 Conclusions

This case study investigated whether energy efficiency ratings, which are mandatory in various forms throughout the European Union, affect house prices. Using a sample of several thousand apartment transactions in the Helsinki market, we tested whether higher ratings were significantly associated with higher prices, keeping a large number of property and neighbourhood characteristics constant. We find a significant price premium for the high-rated (A-B) apartments even when controlling for maintenance costs. This can be interpreted as a 'clientele effect', i.e. there is a small but distinct group of environmentally aware buyers who aim to buy the highest rated units, thereby increasing demand and prices for these units. These groups generally exhibit a high willingness to 'live green' and or expect a significant future rise of energy prices. Beyond the top tier of energy ratings, results are much more inconclusive and there does not appear to be much differentiation between the lower ratings.

A number of implications arise from this case study. Firstly, higher energy efficiency appears to be financially rewarded even in a market that arguably maintains some of the highest building and energy efficiency standards in the world due to its harsh winters. One may expect that marginally higher energy efficiency will not command a premium where the standard of the average property is already 'good enough' for all intents and purposes but there seems to be a market for above-average and state-of-the-art 'green' apartments. A potential policy recommendation for countries with less energy-efficiency building stock, (as is the case in the United Kingdom) could then be that a gradual tightening of minimum requirements for energy efficiency over the next few years would not necessarily take away the financial incentives of buildings with above average energy-efficiency.



4.0 Case study 3: The US Office Market

The US commercial property market is often regarded as the leading ground for innovation and optimal practice in this type of real estate (Florance et al 2010). Therefore, examining how office properties in this location interact with sustainability can offer an interesting insight into the direction in which the rest of the property in the world is likely to follow in this regard.

While a number of different possibilities to introduce and measure sustainability are available to building owners and managers two voluntary certification methods have gained the biggest share of the market. The first is referred to as LEED, is controlled by the US Green Building Council and refers to overall sustainability with different criteria for different levels and types of certification in individual aspects of "greenness". The second is a program led by the US Environmental Protection Agency, named EnergyStar and takes into account only energy efficiency in relation to comparable buildings.

While both certification methods provide interesting information about sustainability of individual properties only EnergyStar offers the certification rigor which allows a direct comparison of certification (and therefore energy efficiency) level of a large number of buildings. In effect an analysis of how energy certification affects value of buildings seems to offer an interesting information on this relationship.

The widely accepted logic indicates that energy efficiency should offer a considerable cost saving (Newsham et al. 2009). However, in office buildings this benefit has been difficult to show conclusively (Szumilo and Fuerst 2013). Nevertheless, a premium associated with energy certification has been found consistently in commercial properties (Fuerst and McAlister 2011 and 2010, Reichardt et al 2012). A theory that in office properties additional benefits associated with energy efficiency can be more valuable than the cost saving has also been developed. Health benefits attributable to better air quality and optimal room temperature have been cited as notable effects of increased efficiency of energy use (Fisk and Rosenfeld 1997). In addition productivity benefits resulting from an optimal working environment can offer significant value in offices (Miller et al. 2009). Possible marketing benefits associated with lower CO_2 emissions and corporate social responsibility polices may also be closely related to levels of energy efficiency of occupied space. In effect the source of the value of energy efficiency in office buildings seems to be difficult to determine conclusively.

As the value of properties is determined by associated cash flows it seems appropriate to analyse this aspect in search for effects of energy efficiency. This case study will look at rents in US office buildings and determine their relation to energy efficiency certification level over time.

4.1 Current Research

There is a rapidly growing body of research on the economic value of sustainability certification premium in the office property market. As this type of properties offers the best quality data most of the studies focus on this area. Nevertheless, the majority of studies focuses on cross sectional investigations. Pivo and Fisher (2010) have used this method and examined a total of almost 1,199 buildings in the US office market from the NCREIF database and found a significant rental premium as well as an increase in the market value associated with certification. They have also identified a corresponding discount in utility expenses. Another major cross sectional study was undertaken by Fuerst and McAllister (2011a) and looked at a similar market but commanded a larger sample of 24,479 offices in the US with the information provided by the CoStar Group Inc. They also concluded that certification was associated with an increase in rents as well as selling price. Similar studies have confirmed the results consistently finding a premium associated with sustainability certification (Miller, Spivey & Florance 2008).

One of the most significant panel studies in this area has been undertaken by Fuerst and co-workers (2012) and examined 7,140 properties on a quarterly basis in the period from Q1 2000 to Q4 2009 for 10 biggest metropolitan markets in the United States. Using a two period difference in difference method and a fixed-effects panel model estimated using a pooled OLS the authors find general support for a rental premium related to sustainability certification. Another panel data study has been presented by Eichholtz and colleagues (2013). A pooled OLS analysis of a sample based on CoStar's database containing data for 4,541 properties from 2007 to 2009 revealed further evidence in support of the existence of the rental premium caused by sustainability certification. The authors have also considered a dynamic change in rents and its susceptibility to influences of energy efficiency and found significant effect. However, a small number of time periods did not allow for a comprehensive analysis and generalizable conclusions.

Some further evidence of the dynamic effect of certification on buildings over time has also been published subsequently. Das et al. (2011) also looked at a panel data that included quarterly information for 123 properties in Washington and San Francisco over a period Q1 2007 to Q1 2010 with property characteristics taken from the CoStar Group's database. Using a first difference model they find that certification is related to a positive change in rents over the period while an additional robustness check using a random effects models on a limited sample confirms this finding. Kok, McGraw and Quigley (2011) analysed the dynamic diffusion of sustainability in office buildings using annual information from EnergyStar and LEED databases within the period of 1995 to 2010 in 48 US metropolitan areas. Controlling for other factors the authors have used the Arellano-Bond method to estimate the annual change in the fraction of certified office space in a specific metropolitan statistical area. The results suggest that local income as well as electricity prices (in the case of energy efficiency certification) are significant determinants of adoption of sustainability in office properties.

There also have been studies that related energy certification levels to financial performance. In general the findings from the US market seem to indicate that there is a positive relationship between LEED certification level and rents (Eichholtz et al. 2013, Dermisi 2009, Fuerst and McAllister 2011). There is also some data from other markets like the UK where the energy performance certificates (EPC) ratings have not been related to a significant change in rents or transaction values (Fuerst and McAllister 2011). In the Dutch market, however, the level of rents has been shown to be influenced differently by different levels of energy certification in a sample of 1,072 rental transactions from 2005 to 2010 period (Kok and Jennen 2012).

The general consensus of the available literature seems to be that levels of energy efficiency are positively related to rents as some evidence for this is found in both cross sectional and panel data studies. The theory seems to apply both in the period of certification and subsequent periods although limited evidence is available for a time-dynamic effect. Moreover, most studies investigate the phenomenon in the time period prior to year 2010. Although it may seem that this provides relatively recent information almost all papers relate to "green buildings" as a rapidly developing trend. This indicates the importance of updating the body of knowledge on this topic as the idea matures and its effects are better reflected in the markets. This research aims to address those two concerns with an analysis of quarterly developments of rents in energy efficient buildings over a long time period which includes observations as recent as late quarters of 2013. This would not only allow an examination of relatively current trends in the market but also a detailed analysis of how they have developed over time.

Table 5 Summary statistics of selected non dichotomous variables

Variable		Mean	Std.Dev.	Min	Max
Rent	overall	**19.34**	**8.34**	**0.04**	**120**
	between	–	7.98	0.2	102.84
	within	–	2.77	-35.35	95.46
Vacancy	overall	**0.18**	**0.26**	**0**	**1**
	between	–	0.19	0	1
	within	–	0.19	-0.78	1.15
Unemployment rate	overall	**8.32**	**2.69**	**3**	**19**
	between	–	1.77	5.44	13.14
	within	–	2.08	1.60	15.31
US Consumer Price Index	overall	**1.05**	**0.05**	**0.98**	**1.16**
	between	–	0.05	1.00	1.16
	within	–	0.03	0.97	1.15
EnergyStar certification score	overall	**2.55**	**14.65**	**0**	**100**
	between	–	10.64	0	94.83
	within	–	9.30	-84.85	90.05

The "overall" line gives the values for the whole sample of 364636 observations. The "between" line gives the average values for 14283 individual properties. The "within" line gives values for deviation from mean of individual property with the global average added back in (see the manual for STATA for information on xtsum command for details).

4.2 Data

The empirical analysis is conducted on a panel dataset of 46,471 US office properties provided by the CoStar Group. It includes all recorded office properties in the following markets: Chicago, Houston, Denver, Los Angeles and Orange County which have been consistently ranked amongst cities with the highest number or proportion of sustainable buildings This information has been gathered quarterly over a period from Q2 2006 to Q3 2013. In addition the dataset includes information from the US Statistics Bureau on economic indicators on a local (unemployment rate) and national (US consumer price index) level, which have been shown in other studies to have an influence on rental prices. This data was next cross referenced with the information available from the EnergyStar website on certification and included years of certification and a corresponding level of performance. From this dataset a sample was selected based on availability of the key information required by models (rent and vacancy). This method was investigated for possible selection biases by examining correlation of missing values to other variables in the sample as well as comparing summary statistics of different sub samples against each other and external sources. No issues were identified. Finally the sample on which the models were tested included high quality data on 14,283 properties over 30 time periods and the total number of observations was 364,636. Characteristics of selected variables are presented in Tables 5 and 6.

The variable that represents rents in a building is calculated using the average of asking rents for different parts of the building reported by the party responsible for leasing space in a particular property. For all cases where the value has not been reported for a fully leased property it has been assumed that the last available asking rent is the current average rent. Should the previous asking rent not be available the observation was removed from the sample as irrelevant for the study. Table 5 reveals large variation in rents across buildings and over time. This has been expected given the large differences between locations in the sample, three (A,B and C as rated by the Building Owners and Managers Association) classes of office space included as well as a volatile economic period over which the data was collected. This effect is further reflected in a similar variation in vacancy rates. The unemployment rate variable also reflects this via its large overall variation. While the Consumer Price Index (CPI) data does not appear to vary greatly it needs to be noted that it is constant for all entities as it was recorded at a national level. Energy score variable takes values of 0 for non-certified properties and from 75 to 100 for certified ones reflecting their level of energy efficiency relative to a comparison group.

Eco-certifications are the proxy of choice for researchers seeking to study the effect of 'sustainability' at the building level. The two main certification protocols developed in the US office markets have differences that are important. While LEED requires a comprehensive investigation of all features of a property which includes energy efficiency, EnergyStar focuses on efficiency of energy use. In order to receive a certificate a building has to be rated in the top 25% of similar properties in the country judged by its energy efficiency. A statistical tool is used to determine reasonable peers for each building to be rated. Certified properties receive scores from 75 to 100 representing the percentile of most energy efficient buildings in the group that they have been placed in. Please note that the information on certification is updated annually while the other time-varying characteristics are reported on a quarterly basis. Although this is a potential limitation of the study no alternative method of measuring this value has been identified.

Table 6 **List of variables included in the model and numbers of observations for dichotomous variables**

Description of variables	
Charg	is a binary variable set to indicate one if the lease includes various additional charges
G	is a binary variable set to indicate one if the lease is a gross lease
Mg	is a binary variable set to indicate one if the lease is a modified gross lease
Elec	is a binary variable set to indicate one if the lease includes electricity
Util	is a binary variable set to indicate one if the lease includes all utilities
Cle	is a binary variable set to indicate one if the lease includes cleaning
Nnn	is a binary variable set to indicate one if the lease is a triple net lease
Nn	is a binary variable set to indicate one if the lease includes a double net lease
N	is a binary variable set to indicate one if the lease is a net lease
Mix	is a binary variable set to indicate one if lease types in the building are mixed
Neg	is a binary variable set to indicate one if lease terms are negotiable
Ec	is a binary variable set to indicate one if the lease includes electricity and cleaning
CPI	Represents the US CPI factor with base period: 2006 quarter 2
Unempl	Represents the unemployment rate at a county level
Vac	Represents the percentage of the building that is not leased
Esscore	Represents the Energy Star certification score
Esct1	Represents the value of Energy Star certification score in the previous period (lagged value)
Es75	is a binary variable set to indicate one at Energy Star certification from 70 to less than 76
Es80	is a binary variable set to indicate one at Energy Star certification from 76 to less than 81
Es85	is a binary variable set to indicate one at Energy Star certification from 81 to less than 86
Es90	is a binary variable set to indicate one at Energy Star certification from 86 to less than 91
Es95	is a binary variable set to indicate one at Energy Star certification from 91 to less than 96
Es100	is a binary variable set to indicate one at Energy Star certification from 96 to 100

4.3 Methodology

Table 7 shows that both energy certification as well as energy scores seem to be related to an increased rent in the sample. However, the simple mean comparison does not account for individual characteristics of buildings or their environment. It also pools all observations over the entire study period. Hence, a dynamic hedonic regression model is required to overcome these limitations of the simple comparison.

Table 7 **Overview statistics of the relations of rents to energy score**

	All	Non cert	Certified	ES75	ES80	ES85	ES90	ES95	ES100
Mean	19.34	19.17	24.88	23.43	23.16	24.16	24.53	26.96	27.18
St.Dev	8.34	8.26	9.11	9.84	7.97	8.88	9.30	9.65	8.58
N	364636	353843	10793	582	2173	2350	2412	2199	1077

The use of hedonic models is a very popular tool in describing determinants of rents in office buildings in the real estate literature. However, using a simple OLS estimation model for this study would certainly reveal very little reliable information about the investigated phenomenon due the violation of the assumption of independent statistical errors which will be correlated for specific entities. In effect the estimates would be inefficient and the standard errors misleading. However, given the nature of the data a panel model seems ideal for describing the relationship. As the study focuses on investigating the impact of energy scores on rents it is important to note that the change of the rating within specific entities are expected to be an important factor in determining this relationship. Furthermore given the fact that individual characteristics of buildings are usually important elements of a model (Dunse and Jones 1998) but almost always difficult to capture using large sample data a fixed effects specification of the panel models seems appropriate. After an initial analysis a fixed-effects panel regression has been confirmed as the superior of alternatives based on the Hausman test. In effect the general model used in the study can be presented as:

$$y_{it} = \alpha + \beta X_{it} + \mu_{it} \qquad (1)$$

with i = 1, …, N, t = 1, …, T

The X_{it} is the vector of explanatory variables that determine y, i denotes an entity, μ_{it} denotes the usual error term and t time. As this model only reflects the influence of current period explanatory variables on the dependent variable it may have some limitations as there is research that suggests that a partial adjustment process may be more effective in predicting office rents (D'Arcy et al. 1997, Jones and Orr 2004). This basic model has also been modified to answer the specific questions about the time lag of the effect relevant to this study. In effect a dynamic panel model of the following specification has also been :

$$y_{it} = \alpha y_{i,\,t-1} + \beta X_{it} + \mu_{it} + \nu_i \qquad (2)$$

with i = 1, …, N, t = 1, …, T

where μ_{it} is the usual error term, ν_i is the usual individual effect and the two are independent of each other and among themselves.

4.4 Model

All our models assume that levels of rents in office buildings are caused and can be explained by a number of independent factors. Variables that remained unchanged for specific entities throughout the period of recording data were not considered given the specification of the panel regression as a fixed-effects model.

The contemporary influence of most of factors that do vary over time for individual entities has been either shown empirically or suggested in theory by other researchers. For example the level of consumption on a national level has been shown by Ling and Naranjo (1998) to be important and is expected to have a positive effect on rental prices. Similarly unemployment on a regional level is an important determinant of this value although a negative relation is expected (Hekman, 1985). In effect both variables are included. Regarding more building specific determinants of the rent a type of the lease needs to be taken into the account (Grenadier 1995). While as many as 12 different types of leases have been marked in the available dataset their individual effect on the independent variable depends on the base case therefore all relevant coefficients will have to be interpreted in this context.

Equations (1) and (2) represent two basic models used for investigating the relationship of rents and energy certification in this study. In order to comprehensively research this association a number of variations of the proxy for energy efficiency have been included and subsequently tested. First a model including a variable giving the score for energy certification for a particular property in a particular period has been included in order to assess the overall significance of the influence.

However, this assumes a linear relationship. In order to address that limitation a series of dummy variables for different ranges of certification is investigated next. This approach can be affected by multicollinearity but may also give an idea of the functional form of the relation. Where necessary and appropriate a suitable functional form of energy certification is included in the model to achieve the best possible fit. Although to our best knowledge this specific approach has not been described as used in any other studies on this subject various forms of specification of energy certification have been used to the same effect (Fuerst and McAllister 2011, Szumilo, Forthcoming).

As most studies show that certification positively influences rents we expect to see similar overall results. However, it should be noted that the base lease type has been chosen to be a gross lease. This means that as long as energy certification is only associated with additional property costs and charges this positive effect would be reflected with a negative sign as shown in Figure 2. Effectively this would mean that for certified properties gross rents are lower which would reflect a financial value created by a cost saving. Naturally this effect is expected to have a value lower than the total difference between a net and a gross lease. However, should the overall sign of the effect of energy certification be positive it could be interpreted as a value created in addition to the cost saving. In other words, if a gross lease for energy certified properties is more expensive there is a value of energy certification that tenants are willing to pay which is greater than the cost saving mentioned above. In Figure 2 this is reflected as a premium within the triple net lease. The total effect of energy certification is a combined effect of the cost saving and the premium (or discount) included in the base rent.

Figure 2 **Possible effects of energy efficiency on gross rents**

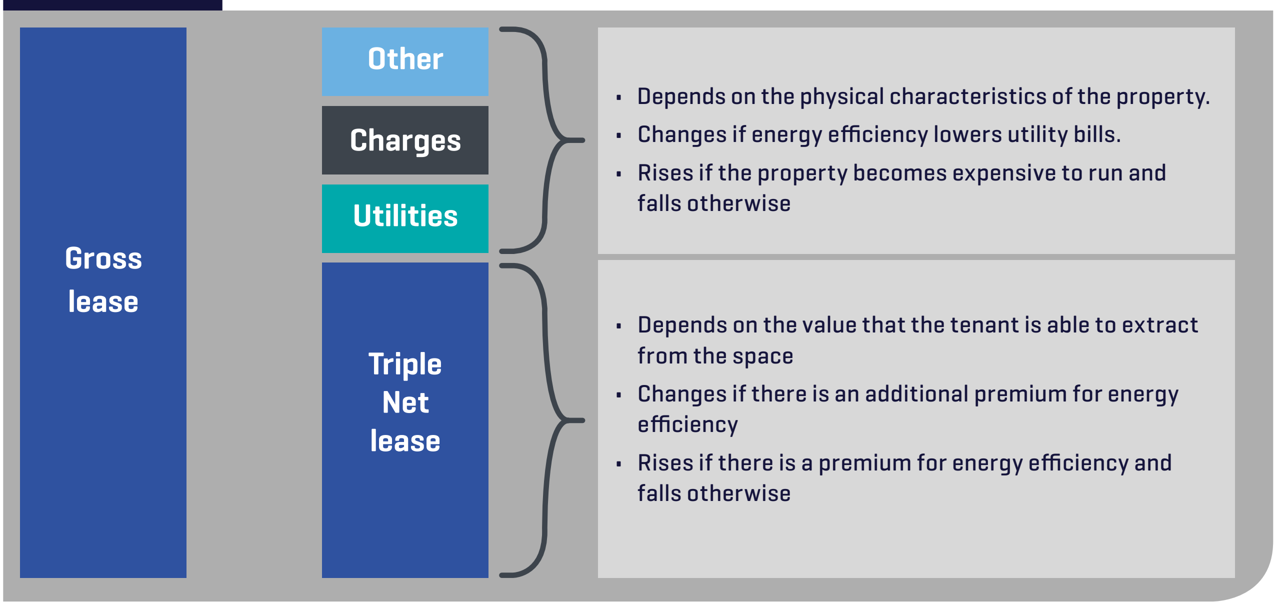


Table 8 **Heteroskedasticity robust regression summary results for alternative specifications of models (1) and (2).**

	Random effects GLS regression			AB first difference two step estimator		
	Static Models			Dynamic Models		
	Linear energy score	Discrete energy score		Log-linear energy efficiency	Linear energy score	Dichotomous energy efficiency
esscore	0.0002***	-		-	-0.000049**	-
	-5.02	(-)		-	-0.000025	-
es75	-	0.021***		-	-	0.000182
	(-)	-2.22		-	-	-0.004
es80	-	0.011***		-	-	-0.005
	(-)	-1.75		-	-	-0.004
es85	-	0.019***		-	-	-0.006
	(-)	-2.89		-	-	-0.004
es90	-	0.02***		-	-	-0.005
	(-)	-3.2		-	-	-0.003
es95	-	0.033***		-	-	-0.004
	(-)	-4.61		-	-	-0.005
es100	-	0.021***		-	-	-0.003
	(-)	-2.12		-	-	-0.006
	-	-		-0.001*	-	-
	(-)	(-)		-0.001	-	-
Rentl1	-	-		0.721***	0.721***	0.721***
	(-)	(-)		-0.031	-0.011	-0.011
Rentl2	-	-		0.006	0.006*	0.006*
	(-)	(-)		-0.007	-0.003	-0.003
Rentl3	-	-		-0.000062	-0.000059	-0.000042
	(-)	(-)		-0.006	-0.003	-0.003
Rentl4	-	-		0.014**	0.014***	0.014***
	(-)	(-)		-0.005	-0.002	-0.002
N	364636	364636	*No. of obs.*	-	-	-
Pooled R^2	0.865	0.865	*No. of groups*	(-)	(-)	(-)
adj. p. R^2.	0.8595	0.8595	*AB test for zero correlation in first difference errors*	-12.856	-15.186	-15.186
within R^2	0.0645	0.0645				
Between R^2	0.0582	0.0583		0.78***	0.77***	0.77***
Overall R^2	**0.0516**	**0.0517**				
Wald Chi2			*Wald Chi2*	**1732.5**	**7996.62**	**8029.76**

t statistics in parentheses * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Although potentially important, the variable reflecting the age of a property has not been included in the final model. Reliable information in this respect has only been available for around 80% of the sample. Although including it improved the goodness of fit of the models it had no influence on the coefficients of other variables while it required a significant limitation of the sample size. In effect the variable has been dropped as it offered no material information relevant to this research but required a limitation in modelling the investigated relationship.

Another characteristic of the data that has implications for the estimation methodology is the fact that energy certification scores are only recorded once per year. In effect a dynamic investigation of its effects should take that into consideration. In order to fully capture the dynamics of the relation between efficiency scores and rents a 4 period time lag has been selected for estimation of the model. This approach allows accurate modelling of the annual change in energy certification while it introduces no noise into the estimation.

4.5 Results

Table 8 presents a summary of heteroskedasticity robust results for the estimation of equation (1) in two different specifications with the only difference between the models being different approaches to representing energy certification (see the appendix of this report for full results).

All statistically significant lease type variables seem to have the expected signs given the specification of the base case. The coefficients that are a little surprising are ones for single double and triple net leases. A double net lease seems to command a higher discount than triple or single contracts. However, given the small number of double net observations in the sample and their similarity to other types of contracts (modified gross or net plus some charges) it is likely that a nomenclature selection bias is influencing this result. The results still seem to be reflecting the significant effect of the lease types on rents reasonably well as all other findings are in line with expectations. The national consumer price index is also positively correlated with rents which is in line with earlier predictions. The rate of vacant space displays a negative relation to the dependent variable just as predicted by other studies and earlier in this work. The coefficients for quarters of measurement also reveal no surprises and are all statistically significant. The rate of unemployment seems to be negatively influencing the dependent variable which is exactly as expected. However, it is important to note the time effect of variables such as the consumer price index, vacancy rates or the rate of unemployment which have been shown to affect properties for longer than just the current periods (Adams and Fuss 2010). The authors find that in the long run the relationship between those variables and rents is usually similar to its contemporary effects but nevertheless significant.

Figure 3 Static model coefficients and levels of certification

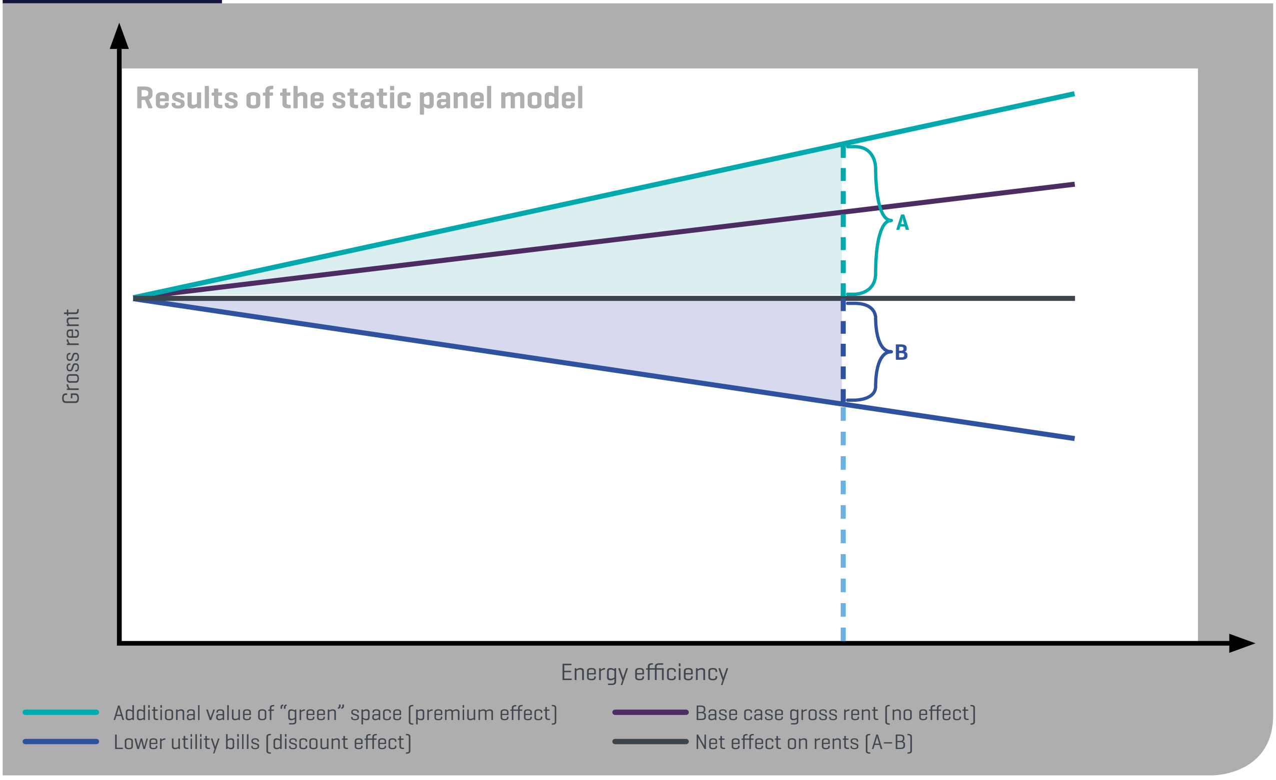
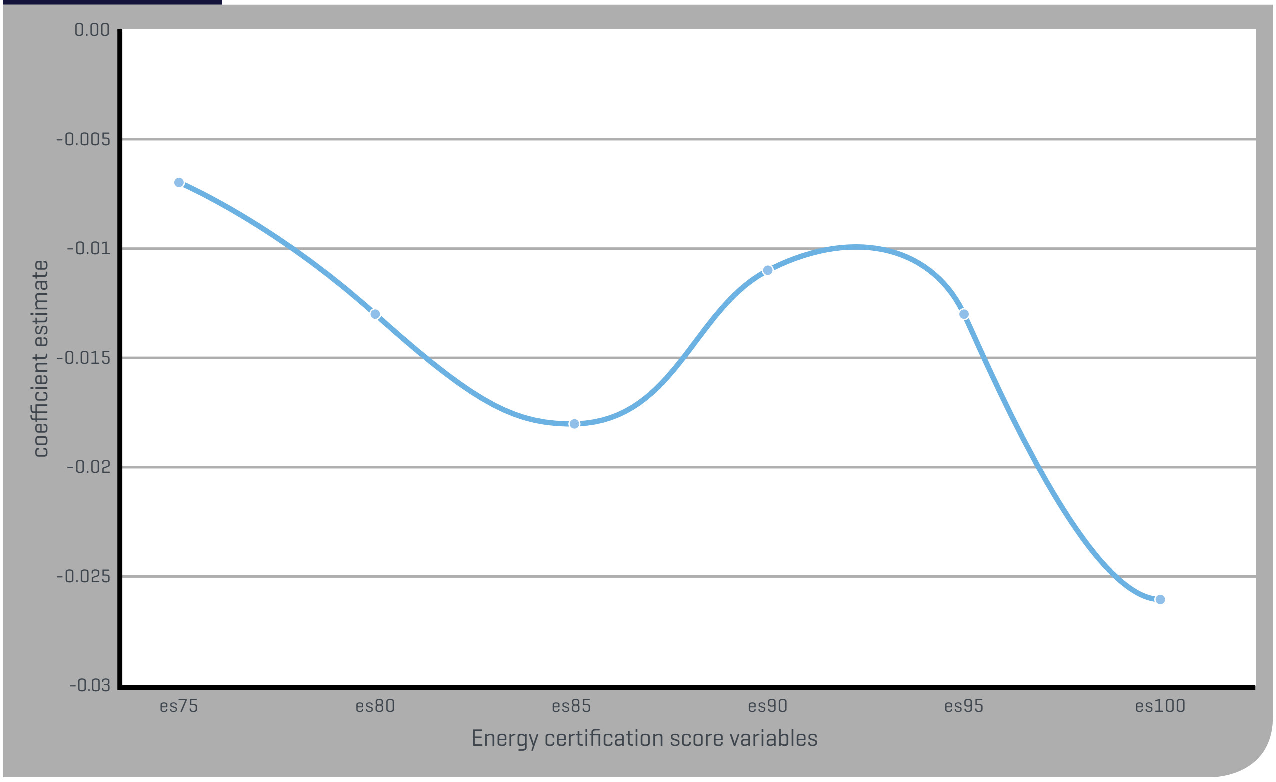


Figure 4 Premium and discount effects of certification on gross rents using a fixed effects model



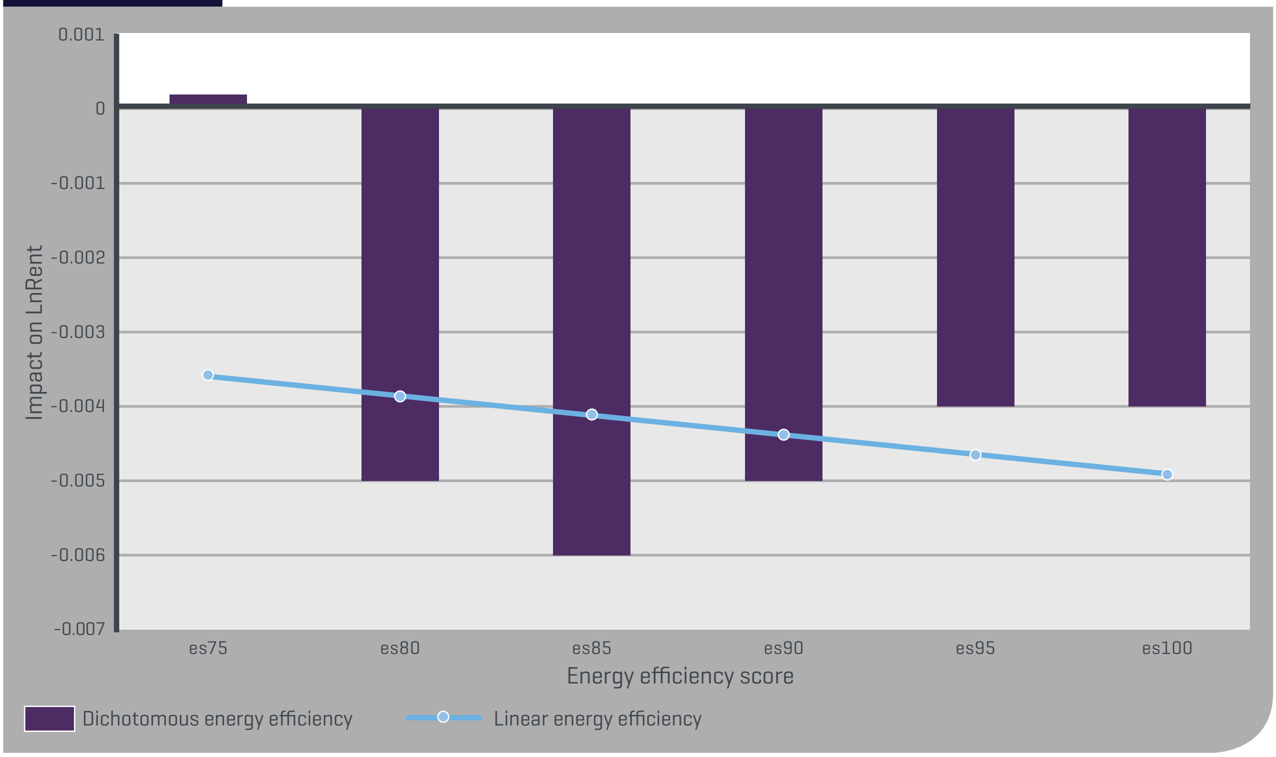
Hence, a dynamic panel data model may be better suited to describe the underlying effects and how they evolve over time. This type of model can also deal with structural breaks caused by the Global Financial Crisis and captures the delayed responses of rents to economic shocks.

In this estimation, all energy score variables and other significant regressors of the model remain unchanged. As the premium increases with the level of certification a relation to energy efficiency and therefore its costs can be inferred. However, as it can be seen from Figure 4 a reduction in expense alone does not account for a positive effect on a gross lease. This is in line with earlier predictions and seems to indicate that energy certification not only creates a cost saving but also offers an additional benefit for which tenants are willing to pay a premium. In Figure 4 the net effect of energy certification can be calculated as the sum of A and B. A is the premium effect of additional services associated with energy efficiency that can be extracted from the office space and is expected to have a positive impact on rents. B is the discount expected from the fact that energy bills are lowered and therefore costs associated with operating the property decrease. As, assuming a gross lease, this saving can be transferred directly to the tenant B is expected to be negative. The magnitude of the two effects determines the sign of the net effect of energy efficiency rating on gross rents.

Figure 3 shows a graphic interpretation of the coefficients for different levels of certification. Although the relation does not appear to be perfectly linear it seems to be possible to approximate it reasonably well with a straight line with a positive slope. This seems to indicate that there is a positive relation of rents not only with general certification but also with the level of energy efficiency. Put simply, the premium associated with additional services offered by efficient space outweighs the discount related to the saving on operating expenses.

Table 3 presents the results for model (2) estimated using the two step Arellano-Bond approach (the xtabond2 command) with robust standard errors and a time period lag of four. The dynamic nature of the second model (based on equation 2) seems to have allowed for slightly different effects than in the previous paragraph. Again all the control variables are as expected. Regarding lease types, most variables most variables are significant and negative as they should be given the base case of a gross lease. Interestingly the triple net lease continues to offer a discount smaller than single and double net leases which is likely to be caused by the same factors as in the previous section. The economic factors included in the model still all have a statistically significant influence on rents although the magnitude of this effect is lower.

Figure 5 **Premium and discount effects of certification on gross rents using a dynamic model**



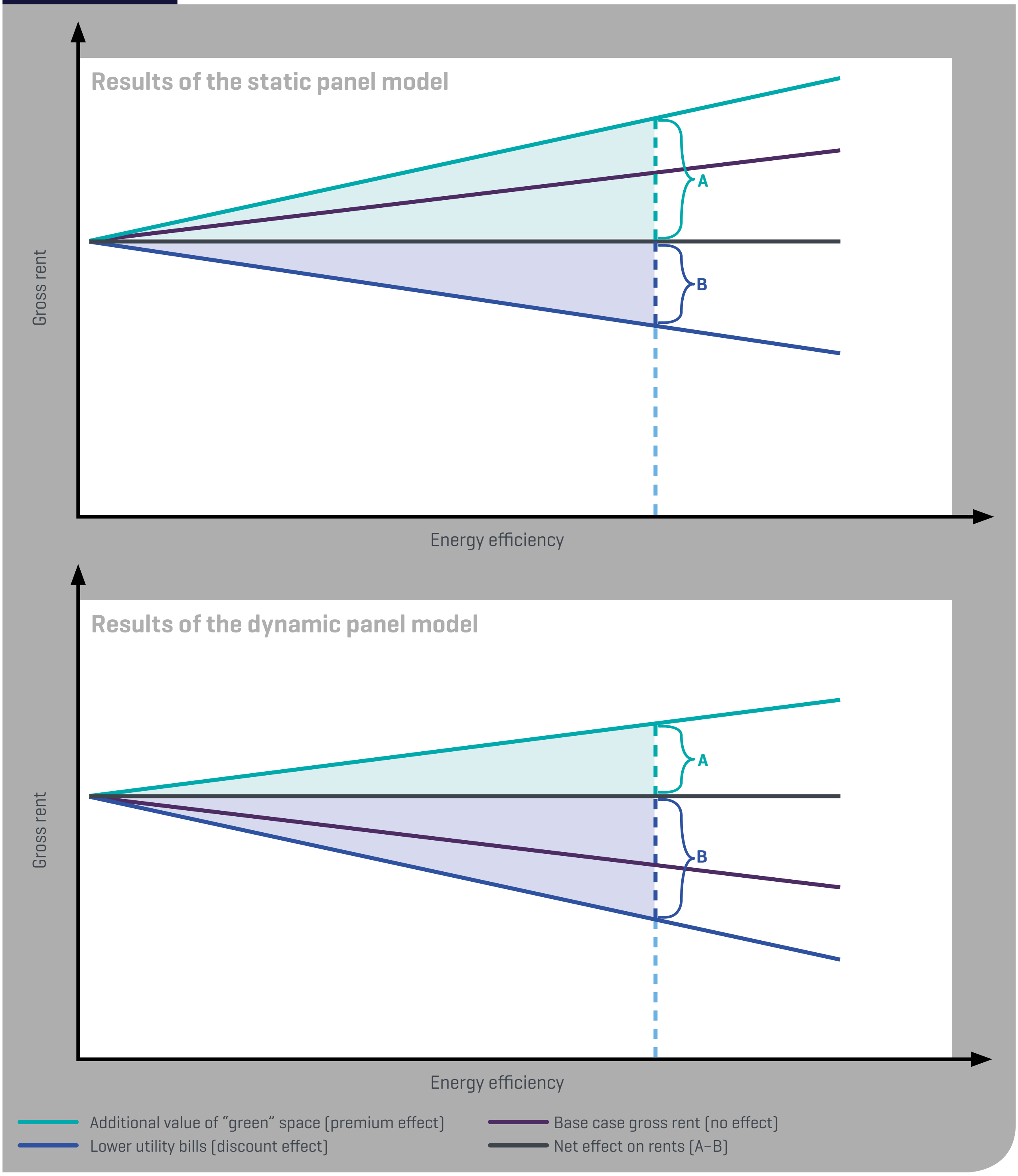
The CPI still has a positive influence but its effect is much lower than in the previous model. Finally, the effect of the unemployment rate and the inflation variable on the dependent variable are in line with expectations and findings of general real estate literature. This is an indication that the dynamic panel model seems to be appropriate for modelling this particular sample and the dependent variable.

Most importantly energy certification level is also significant although its magnitude has been reduced to a different range of values. Nevertheless it seems clear that energy certification score remains an important determinant. Moreover, the coefficients for energy certification in this case seem to be negative indicating that a gross lease which includes all bills and charges is lower for certified properties. This seems to suggest that in the dynamic relation of energy certification and rents the cost saving associated with energy efficiency (denoted as B in Figure 3) is its primary financial effect. The additional premium showed in the previous paragraph that allows building owners to demand higher rents in certified buildings seems to have a smaller or negligible effect in a dynamic model. This has been suggested by some researchers (Szumilo and Fuerst 2013) but has rarely been shown in empirical studies. With regard to the specification of the relationship its functional form once again seems unclear although a straight line with a negative slope seems a reasonable approximation. This is consistent with the findings of the static model which also showed that the financial benefit of energy efficiency increases with certification level (Figure 5). In this case, however, it is important to note that the value seems to be captured by party responsible for utility charges whereas in the previous case the benefit was not associated with this expense.

4.6 Discussion

The main purpose of this study is to measure the value of green features in real estate. This is investigated through the relation of energy efficiency levels on rents in office buildings. The analysis of a static panel model shows a positive influence of the level of certification on rents paid for gross leases. This is consistent with previous findings on this topic (Szumilo and Fuerst 2013, Fuerst and McAllister 2011). As indicated in the methodology section this can be interpreted as a combination of a cost saving which is passed on to tenants and reduces the gross rent and of a rental premium that can be charged for additional features of an energy efficient building. As in an energy efficient building the charges are expected to be lower the difference can be passed on to the customer. It would seem, however, that in a static model tenants are willing to pay a premium for energy efficiency. Moreover, the premium related to energy rating increases with the level of certification which seems to suggest that the more efficient a building is the larger the value created. While the functional form of this relationship still needs to be researched a linear approximation seems appropriate which is in line with expectations. It would seem that in this case the green value is created not only by the cost saving benefit of charges related to a lease but also by a premium related to additional benefits of energy efficiency. Interestingly the value of the reduction in charges seems to be smaller than the premium that tenants are willing to pay for high energy efficiency.

Figure 6 Graphical interpretation of regression results



The second model used a dynamic approach and included the value of rents from the previous period. This method allowed for information from a previous period to influence the contemporary rent variable. This allowed the modelled relationship to reflect a change in the circumstances rather than just their presence. The dynamic models seem to be robust in reflecting the investigated effect as not only the lagged variables are significant in determining rents but also effects of other variables are in line with expectations. The effect of energy certification is also reflected differently and, as follows from the above reasoning, more accurately. Energy score now has an overall negative effect which correlates to gross leases being on average less expensive in certified properties than in traditional buildings. In such case the owner of a certified property is covering all costs, which are likely reduced with certification as presented in the previous section and by other studies (Szumilo and Fuerst 2013). In effect the discount on gross rents can be interpreted as the value of energy efficiency which is created by the cost savings and passed directly onto tenants. This is further validated by the fact that the discount seems to be greater for highly rated properties but always falls within the expected range determined by the difference between a net and a gross lease. A conclusion can be drawn that as the cost benefit of energy efficiency increases with certification the additional value transferred to the tenant is also increasing by a reduction in a gross rent.

In conclusion, the results of this study suggest a distinct effect of energy efficiency on rents. Figure 6 presents a graphical interpretation of those findings. In the static panel model there appears to be a premium resulting from a combination of a cost saving benefit and an additional certification premium. It seems to increase the gross rent as the rating, and therefore effective efficiency, increases. This is consistent with similar studies on this topic conducted both on panel and cross sectional data.

However, the dynamic investigation of the relationship revealed a slightly different effect. It appears that if information from a previous period are allowed to influence the current rent the overall certification effect creates a discount in the gross rent. In this case the financial effect is still a combination of the cost saving and additional certification benefits although the ratio of those two factors seems to change. In effect the net effect has a different sign than in the case of a static model. Nevertheless, it would seem that the real benefit is now captured in a different way. Although the results of the dynamic and static examinations may appear to contradict the previous findings regarding the effect of energy certification on rents, they are in fact consistent in that both sets of findings show that energy efficiency and sustainability are linked to enhanced financial value.

Although this dataset did not allow for separation between the cost saving discount and a premium for additional benefits it would seem that their combined effect is noticeable and significant in both models. As explained in the methodology section the fact that the magnitude of the combined effect is lower the discount associated with having an triple net lease indicates that on average for both model the effect on rent is lower than the combined cost of all charges. Although it does not provide direct evidence it is consistent with the interpretation of the results as a reduction in those charges plus a premium.

The use of a panel study with a focus on energy certification ratings enabled a discovery of new information on the value of energy efficiency more research is needed to conclusively calculate this benefit. In this study only the combined effects of cost savings and a rental premium could be measured but isolating their individual influence on rents would be an ideal way of showing the value of energy efficiency accurately.

Image source: Philip Bird LRPS CPAGB – Shutterstock.com

5.0 Lessons from the three case studies

The empirical analysis of three very distinct markets in Japan, Finland and the United States confirms overall the findings reported in studies covering earlier time periods and core markets (most of the earlier studies on 'green value' were conducted on the US office market). In doing so, the present project has achieved the aim of broadening the existing evidence base using new data sources while at the same time deepening the research on the dynamics of the well-researched markets such as the US office market using more extensive and more in-depth datasets.

The analysis of the three case studies was carried out using three distinct empirical datasets with information on transactions prices and/or rental rates along with property and 'green' characteristics. The first dataset contains roughly 50,000 housing transactions in the Tokyo condominium market including information on eco-certification of these properties. Apart from the standard variables needed for a hedonic analysis, this dataset allows us to study characteristics of ‘green’ buyers and households which has not been possible with the data used in previous studies. One of the key lessons from this case study is the fact that asking prices for green properties were only minimally higher than actual transaction prices. This should alleviate concerns about previous studies that were carried out on asking prices and asking rents only due to a lack of transaction data. While more research needs to be conducted comparing asking and transaction prices, the general pattern appears to be similar for both types of prices. A further lesson of the Tokyo study is the strong link between household income and a higher willingness to pay for a green label.

Our second case study involved a dataset of Energy Performance Certificates and housing attributes for a sample of flats in the Helsinki metropolitan area. Some of the empirical evidence presented is inconclusive but overall we find a significant price premium for the most energy-efficient buildings and apartments. The Helsinki dataset allowed us to isolate the impact of energy efficiency better than was the case in previous studies. New control variables in this dataset included a property condition rating, information about 'time on market' and an energy efficiency rating which is based on actual measured consumption rather than an assessor's estimate of the intrinsic energy efficiency of a building (as is the case, for example, in the United Kingdom). A key lesson to be drawn from this case study is that above-average 'green' features appear to be financially rewarded even in markets characterised by high energy efficiency standards with regard to insulation and other thermal characteristics.

A potential policy recommendation for countries with less energy-efficiency building stock, (as is the case in the United Kingdom) could then be that a gradual tightening of minimum requirements for energy efficiency over the next few years would not necessarily take away the financial incentives of buildings with above average energy-efficiency.

The third case study involved a very large panel dataset including operating expenses, rents and building characteristics in six large office markets in the US and allowed us to gain a better understanding of the three-way interaction between green labels (LEED and Energy Star), operating expenses and office rents. Using this unique dataset we are able to isolate a pure cost saving benefit from additional certification ('green glow' effect). The effect of both components on rents increases with rating scores, i.e. with the degree of 'greenness' reported by the rating. However, the dynamic investigation of the relationship revealed a slightly different effect. It appears that if the influence of information from a previous period on the current rent is measured the overall certification effect creates a discount in the gross rent. Notwithstanding these inconclusive findings resulting from more advanced dynamic model specifications, the third case study of the US office market is broadly in line with both earlier studies of the same market and the findings of the other two case studies described in this report.

In summary, this RICS-sponsored project has drawn together evidence on 'green value' from two housing markets and one commercial market on three continents (Asia, Europe and North America). While these new and more in-depth results are encouraging for the existence of 'green value' in property markets, more needs to be done to apply this type of econometric analysis in the largest and most dynamic markets. The number of studies on Chinese cities and property markets is growing but very little evidence is known from some other important markets such as India, Brazil or Russia to name just the most prominent examples. Future research will seek to fill this gap.

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8.0 Appendices

Appendix 1

Table 9 Full regression results of Tokyo case study

	(1) baseline OLS	(2) Robust reg	(3) Income Q1	(4) Income Q2	(5) Income Q3	(6) Income Q4	(6) Time effects
	lp	lp	lp	lp	lp	lp	lp
Transaction price discount	-0.0347***	-0.0316***	-0.0359***	-0.0354***	-0.0337***	-0.0343***	-0.0347***
	[-27.87]	[-26.54]	[-11.72]	[-15.94]	[-16.16]	[-13.37]	[-27.40]
Green asking price premium	0.0609***	0.0586***	0.0408***	0.0398***	0.0702***	0.0777***	0.0644***
	-18.66	-18.31	-3.63	-6.74	-13.12	-12.45	-19.43
Green transaction price discount^2	-0.00918*	-0.00948**	-0.0158	-0.00692	-0.00936	-0.00975	-0.00918*
	[-2.40]	[-2.59]	[-1.16]	[-1.08]	[-1.50]	[-1.41]	[-2.37]
sqft	0.0243***	0.0244***	0.0160***	0.0143***	0.0135***	0.0146***	0.0155***
	-77.74	-115.41	-97.94	-98.75	-98.93	-98.12	-233.33
sqft_squared	-0.0000632***	-0.0000649***					
	[-27.92]	[-43.89]					
ts	-0.00962***	-0.00937***	-0.00867***	-0.00827***	-0.00735***	-0.0101***	-0.00934***
	[-51.06]	[-54.42]	[-19.56]	[-24.63]	[-22.17]	[-23.97]	[-48.92]
bus	-0.0358***	-0.0386***	-0.0283***	-0.0172**	-0.0468***	-0.0578***	-0.0366***
	[-9.59]	[-11.24]	[-3.67]	[-3.05]	[-6.34]	[-5.84]	[-9.47]
busTS	-0.00182***	-0.00214***	-0.000897	-0.00225***	-0.00156*	-0.00486***	-0.00213***
	[-5.27]	[-6.87]	[-1.35]	[-4.27]	[-2.39]	[-4.50]	[-5.94]
TA	-7.83E-09	2.61E-08	-0.000000128	3.36E-08	0.000000185***	-0.000000167***	-2.75E-08
	[-0.32]	-1.21	[-1.64]	-0.69	-4.3	[-3.83]	[-1.10]
ISP1	0.00679**	0.00689**	0.0109	0.00316	0.00387	0.00272	0.00687**
	-2.89	-3.17	-1.66	-0.71	-1.03	-0.6	-2.89
ISP2	0.00486**	0.00321	0.0104*	0.00842*	0.000887	-0.00413	0.00371
	-2.6	-1.89	-2.06	-2.55	-0.28	[-1.13]	-1.96
MG1	0.00126	0.000758	-0.00673	0.00158	0.00206	0.00412	0.00253
	-0.67	-0.42	[-1.46]	-0.5	-0.62	-1.02	-1.33
MG2	0.0238***	0.0232***	0.0247***	0.0239***	0.0204***	0.0158**	0.0265***
	-9.09	-9.8	-3.3	-5.09	-4.63	-3.13	-9.94
RL1	-0.00909***	-0.00805***	-0.00000228	-0.0049	-0.00573	-0.00999**	-0.00928***
	[-5.02]	[-4.68]	[-0.00]	[-1.44]	[-1.95]	[-2.63]	[-5.08]
RL2	-0.0402***	-0.0449***	-0.0285	-0.0432**	-0.0355**	0.00643	-0.0386***
	[-4.62]	[-5.76]	[-1.64]	[-3.09]	[-2.60]	-0.23	[-4.54]
corner	0.0213***	0.0216***	0.0280***	0.0188***	0.0162***	0.00959***	0.0178***
	-15.59	-16.46	-7.92	-7.61	-6.9	-3.55	-12.81

continued

continued

	(1) baseline OLS	(2) Robust reg	(3) Income Q1	(4) Income Q2	(5) Income Q3	(6) Income Q4	(6) Time effects
	lp	lp	lp	lp	lp	lp	lp
structure	-0.00894	-0.0117*	0.0233	0.00594	-0.0283***	-0.0279***	-0.0113*
	[-1.71]	[-2.42]	-1.92	-0.49	[-3.69]	[-3.90]	[-2.15]
TR	-0.000152***	-0.000141***	-0.000173**	-0.000253***	-0.0000641	-0.0000874	-0.000133***
	[-5.58]	[-5.17]	[-2.74]	[-5.36]	[-1.30]	[-1.41]	[-4.79]
tt	-0.00190***	-0.00197***	-0.00213***	-0.00169***	-0.00154***	-0.00111***	-0.00178***
	[-15.91]	[-18.90]	[-7.38]	[-7.93]	[-7.82]	[-4.62]	[-14.91]
FAR	-0.0000116	-0.00000557	-0.0000318	-0.0000109	-0.0000224	0.00000324	-0.0000114
	[-1.63]	[-0.93]	[-1.73]	[-0.82]	[-1.72]	-0.25	[-1.58]
comm	0.0143***	0.0146***	0.0225***	0.0103*	0.0129***	0.0058	0.0126***
	-6.68	-7.45	-4.34	-2.47	-3.5	-1.37	-5.81
indust	-0.0330***	-0.0317***	-0.0314***	-0.0217***	-0.0253***	-0.0388***	-0.0319***
	[-17.70]	[-18.40]	[-6.12]	[-7.22]	[-8.11]	[-9.22]	[-16.98]
rental	-0.0000486***	-0.0000455***	-0.0000251***	-0.0000450***	-0.0000406***	-0.0000646***	-0.0000485***
	[-17.94]	[-17.23]	[-3.42]	[-8.97]	[-8.91]	[-11.56]	[-17.51]
old	-0.0000223***	-0.0000230***	-0.0000263*	-0.0000172*	-0.00000433	0.00000189	-0.0000173***
	[-5.28]	[-5.55]	[-2.51]	[-2.25]	[-0.61]	-0.2	[-4.03]
strc2	0.0165**	0.0135**	0.0324**	0.0213	-0.0033	0.00733	0.0138**
	-3.15	-2.76	-2.59	-1.75	[-0.43]	-1	-2.59
officew	0.000296***	0.000293***	0.000198***	0.000316***	0.000268***	0.000255***	0.000295***
	-28.51	-30.47	-7.27	-16.06	-15.27	-12.16	-27.97
cost	0.00589***	0.00528***	0.00320*	0.00342***	0.00501***	0.00713***	0.00575***
	-11.07	-11.24	-2.53	-3.64	-6.19	-6.12	-10.61
year4	-0.0145***	-0.0135***	-0.0221***	-0.0174***	-0.0132***	-0.0175***	-0.0152***
	[-6.89]	[-6.28]	[-4.01]	[-4.37]	[-3.74]	[-3.89]	[-7.06]
year5	-0.0232***	-0.0211***	-0.0301***	-0.0261***	-0.0186***	-0.0348***	-0.0291***
	[-10.02]	[-9.38]	[-5.22]	[-6.13]	[-4.60]	[-7.01]	[-12.39]
year6	-0.00897***	-0.00816**	-0.00377	-0.0140**	-0.0127**	-0.00387	-0.0149***
	[-3.32]	[-3.13]	[-0.58]	[-2.93]	[-2.74]	[-0.66]	[-5.45]
year7	-0.0218***	-0.0200***	-0.0128	-0.0233***	-0.0221***	-0.0112	-0.0264***
	[-7.48]	[-7.24]	[-1.81]	[-4.50]	[-4.37]	[-1.72]	[-8.89]
year8	0.00652*	0.00565	0.0216**	0.0116*	0.00608	0.0159*	0.00507
	-2.08	-1.9	-2.85	-2	-1.14	-2.39	-1.6
year9	0.0535***	0.0574***	0.0712***	0.0681***	0.0485***	0.0448***	0.0503***
	-16.18	-18.92	-8.75	-12.09	-8.13	-6.39	-15.03
year10	0.155***	0.158***	0.0964***	0.145***	0.143***	0.163***	0.150***
	-39.14	-44.08	-8.57	-20.23	-21.17	-21.95	-37.78
year11	0.180***	0.191***	0.189***	0.164***	0.163***	0.177***	0.173***
	-37.02	-49.13	-13.46	-18.51	-19.15	-19.2	-35.52

continued

continued

	(1) baseline OLS	(2) Robust reg	(3) Income Q1	(4) Income Q2	(5) Income Q3	(6) Income Q4	(6) Time effects
	lp	lp	lp	lp	lp	lp	lp
year12	0.156***	0.158***	0.137***	0.147***	0.140***	0.155***	0.149***
	-38.84	-42.17	-11.38	-20.18	-20.63	-18.86	-36.28
year13	0.162***	0.164***	0.156***	0.147***	0.141***	0.155***	0.155***
	-48.56	-51.8	-16.35	-22.47	-24.56	-23.59	-45.17
year14	0.163***	0.164***	0.147***	0.153***	0.157***	0.177***	0.161***
	-46.76	-46.54	-15.09	-24.26	-25.89	-24.35	-45.23
age			0.000695***	0.000736***	0.000222	0.00000781	
			-4.38	-4.18	-1.36	-0.04	
number			-0.00526**	-0.00448***	-0.00262*	-0.00343*	
			[-2.81]	[-3.50]	[-2.20]	[-2.30]	
childdummy			-0.00517	-0.0011	-0.0023	0.00536	
			[-1.45]	[-0.42]	[-0.90]	-1.7	
first			-0.0359***	-0.0148***	0.000582	-0.00675*	
			[-6.88]	[-3.67]	-0.18	[-2.32]	
invest			0.0557*	-0.0832*	-0.153***	-0.117***	
			-2.07	[-2.27]	[-4.55]	[-6.35]	
hd4			0.00526	0.0160**	0.00752	-0.00105	
			-0.81	-3.27	-1.95	[-0.24]	
hd6			0.0716***	0.00667	0.0423***	0.0467***	
			-4.93	-0.43	-4.93	-6.88	
wd7			0.0151**	-0.00113	0.00143	0.0146***	
			-2.97	[-0.33]	-0.38	-3.67	
wd8			0.0133	0.00295	0.00827*	0.00779*	
			-1.57	-0.57	-2.41	-2.53	
wd9			0.0369**	0.00849	0.0190*	0.0183**	
			-2.87	-0.79	-2.36	-3	
yd6			0.00666	-0.00442	0.00767*	0.00850**	
			-0.92	[-0.77]	-2.37	-2.76	
_cons	7.505***	7.508***	7.533***	7.757***	7.861***	7.954***	7.788***
	-329.53	-390.22	-144.48	-154.72	-219.17	-250.75	-368.49
N	48740	48740	6940	12896	15328	13576	48740
R2	0.808	0.818	0.799	0.727	0.716	0.783	0.801
adj. R2	0.807	0.818	0.795	0.723	0.714	0.781	0.801
AIC	-60598	–	-9091.1	-18262.5	-20896.4	-14952	-58949.5
BIC	-59296.5	–	-8071.2	-17120.4	-19720.3	-13787	-57656.7

Appendix 2

Table 10 **Variable names and data sources for Tokyo case study**

Symbol	Variable	Content	Unit	Source
G	Green label dummy	Green building = 1	[0,1]	Tokyo Metropolitan Government
		Other building = 0		
T	Transaction price dummy	Transaction price = 1	[0,1]	RECRUIT
		Asking price = 0		
S	Floor space	Floor space of building/ square meters	m^2	Real Estate Economic Institute
TS	Distance to the nearest station	Distance to the nearest station	meters	Real Estate Economic Institute
Bus	Bus dummy	bus-transportation area = 1	[0,1]	Real Estate Economic Institute
		walk-transportation area = 2		
TT	Time to CBD (Tokyo station)*	Minimum railway riding time in daytime to one of the seven major business district stations.	minutes	VAL Institute
TU	Total unit	Total units of condominium	unit	Real Estate Economic Institute
Land	Site area	Site area of condominium	m^2	
TA	Total building area	Total building area of condominium	m^2	Real Estate Economic Institute
Cost	Management Cost	Property Management Cost	10000 yen/ month	RECRUIT
ISP1	With Housing performance evaluation report A dummy	With Housing performance evaluation report A = 1	[0,1]	RECRUIT
		Without Housing performance evaluation report A = 2		
ISP2	With Housing performance evaluation report B dummy	With Housing performance evaluation report B = 1	[0,1]	RECRUIT
		Without Housing performance evaluation report B = 2		
MG1	Management type(A) dummy**	Management typ is A = 1	[0,1]	RECRUIT
		other = 0		
MG2	Management type(B) dummy**	Management typ is B = 1	[0,1]	RECRUIT
		other = 0		
Corner	corner dummy	The location of unit is cober = 1	[0,1]	Real Estate Economic Institute
		Other location = 0		
STD	Studio type dummy	Floor space 30 square meters or less = 1	[0,1]	Real Estate Economic Institute
		Floor space over 30 square meters = 0		
RL1	Leasehold(A) dummy	Land right is leasehold(Type A) = 1	[0,1]	RECRUIT
		other = 0		
RL2	Leasehold(A) dummy**	Land right is leasehold(Type B) = 1	[0,1]	RECRUIT
		other = 0		
TR	Rate of Sales	Rate of sales in first month	[%]	Real Estate Economic Institute

continued

continued

Symbol	Variable	Content	Unit	Source
LU_g (g=0,...,G)	Land Use regulation dummy***	g-th Land use regulation area=1	[0,1]	Real Estate Economic Institute
		other =0		
HD_g (h=0,...,H)	Employment status dummy	h-th Employment status of Head of household =1,	[0,1]	RECRUIT
		other=0		
WD_i (i=0,...,I)	Job type dummy	i-th job type =1,	[0,1]	RECRUIT
		other=0		
YD_j (j=0,...,J)	Business type dummy	j-th business type =1,	[0,1]	RECRUIT
		other=0		
LD_g (h=0,...,H)	Location (ward) dummy	k-th administrative district = 1,	[0,1]	Real Estate Economic Institute
		Other district =0.		
RD_l (l=0,...,L)	Railway line dummy	l-th railway line =1	[0,1]	Real Estate Economic Institute
		Other railway line = 0.		
D_m (m=0,...,M)	Time dummy (yearly)	m-th year =1	[0,1]	RECRUIT
		Other year = 0.		

Appendix 3

Table 11 Full regression results of US case study

Dep. Variable: Ln(Rent)	Log-linear energy efficiency	Linear energy efficiency	Dichotomous energy efficiency	Linear energy score	Discrete energy score
	Arellano-Bond Dynamic Panel Models			Fixed effects models	
Cons	0.776***	0.776***	0.776***	2.864***	2.864***
	[0.094]	[0.039]	[0.039]	-107.83	-107.83
charg	0.108	0.108*	0.108*	-0.135***	-0.135***
	-0.069	-0.057	-0.057	[-2.1]	[-2.1]
mg	-0.026***	-0.026***	-0.026***	-0.037***	-0.037***
	-0.004	-0.004	-0.004	[-9.04]	[-9.04]
elec	-0.078***	-0.078***	-0.078***	-0.116***	-0.116***
	-0.017	-0.015	-0.015	[-6.32]	[-6.32]
util	-0.02**	-0.02**	-0.02**	-0.027***	-0.027***
	-0.009	-0.009	-0.009	(-3.15)	(-3.15)
cle	-0.168	-0.168*	-0.168*	-0.497***	-0.497***
	-0.133	-0.098	-0.098	[-3.39]	[-3.39]
nnn	-0.054***	-0.054***	-0.054***	-0.071***	-0.071***
	-0.003	-0.003	-0.003	[-21.29]	[-21.29]
nn	-0.041	-0.041*	-0.041*	-0.193***	-0.193***
	-0.026	-0.022	-0.022	[-6.05]	[-6.05]
n	-0.106***	-0.106***	-0.106***	-0.117***	-0.117***
	-0.009	-0.008	-0.008	[-13.26]	[-13.26]
n	0.00486**	0.00321	0.0104*	-0.00413	0.00371
	-2.6	-1.89	-2.06	[-1.13]	-1.96
mix	-0.031***	-0.031***	-0.031***	-0.056***	-0.056***
	-0.007	-0.006	-0.006	[-7.26]	[-7.3]
neg	-0.244***	-0.244***	-0.244***	-0.442***	-0.442***
	-0.039	-0.03	-0.03	[-14.62]	[-14.62]
ec	-0.07	-0.07*	-0.07*	-0.101***	-0.101***
	-0.045	-0.038	-0.038	[-2.03]	[-2.03]
CPI	0.00012**	0.00012***	0.00012***	0.082***	0.082***
	-0.000047	-0.000044	-0.000044	-3.15	-3.16
unemp	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***
	-0.000197	-0.000157	-0.000157	[-9.88]	[-9.89]
lnvac	–	–	–	-0.002***	-0.002***
	[-]	[-]	[-]	[5.02]	[-2.7]
q2	–	–	–	-0.003***	-0.003***
	[-]	[-]	[-]	[-7.49]	[-7.49]

continued

continued

Dep. Variable: Ln(Rent)	Log-linear energy efficiency	Linear energy efficiency	Dichotomous energy efficiency		Linear energy score	Discrete energy score
	Arellano-Bond Dynamic Panel Models				Fixed effects models	
q3	–	–	–		-0.003***	-0.003***
	[-]	[-]	[-]		[-7.53]	[-7.53]
q4	–	–	–		-0.003***	-0.003***
	[-]	[-]	[-]		[-7.29]	[-7.29]
Ines	-0.001*	–	–		–	–
	[0.001]	[-]	[-]		[-]	[-]
esscore	–	-0.000049**	–		0.0002***	-
	[-]	-0.000025	[-]		[-2.7]	[-]
es75	-	[-]	0.000182		-	0.021***
	[-]	-	-0.004		[-]	-2.22
es80	-	-	-0.005		-	0.011***
	[-]	[-]	-0.004		[-]	-1.75
es85	-	[-]	-0.006		-	0.019***
	[-]	-	-0.004		[-]	-2.89
es90	-	-	-0.005		-	0.02***
	[-]	[-]	-0.003		[-]	-3.2
es95	-	[-]	-0.004		-	0.033***
	[-]	-	-0.005		[-]	-4.61
es100	-	-	-0.003		-	0.021***
	[-]	[-]	-0.006		[-]	-2.12
Rentl1	0.721***	0.721***	0.721***		-	-
	-0.031	-0.011	-0.011		[-]	[-]
Rentl2	0.006	0.006*	0.006*		-	-
	-0.007	-0.003	-0.003		[-]	[-]
Rentl3	-0.000062	-0.000059	-0.000042		-	-
	[0.006]	[0.003]	[0.003]		[-]	[-]
Rentl4	-0.000062	-0.000059	-0.000042		-	-
	[0.006]	[0.003]	[0.003]		[-]	[-]
No. of obs.	293240	293240	293240	N	364636	364636
No. of groups	14267	14267	14267	*pooled R2*	0.865	0.865
AB test for zero correlation in first difference errors	-12.856	-15.186	-15.186	*adj. p. R2*	0.8595	0.8595
				within R2	0.0645	0.0645
	0.78***	0.77***	0.77***	*between R2*	0.0582	0.0583
Wald Chi2	1732.5	7996.62	8029.76	*overall R2*	**0.0516**	**0.0517**

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