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Explaining the Variation in the Value of Building Energy Efficiency Certificates: A Quantitative Meta-Analysis

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Abstract: The built environment has been identified as one of the cost effective platforms for reducing energy demand and greenhouse gas emissions. With policies and the know-how in existence, the real estate sector has already adopted measures such as building codes and energy efficiency labels to drive prices and spur demand with the objective of increasing the demand for energy efficient buildings. Since 2008, many studies have emerged estimating the price premium that is expected to be associated with energy efficient buildings. Evidence from such studies has so far been mixed. We use a meta-regression approach to identify some of the underlying drivers causing the variation. Our results reveal that energy efficiency is highly valued in the sales market and the non-residential sector. We also observed that Europe values energy efficiency over the US possible due to their relative strengths of their energy efficiency policies as revealed on the international energy efficiency rankings. Labels with categorical scales have a weak impact on the value of energy efficiency labels while the effects of regulation by voluntary strategies tend to decline with time, with the effect lasting over a period of thirteen years. These are vital information for policy issues in achieving significant cuts in greenhouse gas emissions.

Keywords: energy efficiency premium, meta-analysis, multilevel model, value transfer, valuation
JEL classification: P48, Q40, Q48, C53, C50, Q51, Q54

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1. Introduction

The built environment has gained important recognition as a means to substantially contribute to reducing carbon dioxide emissions and energy demand. The heating and cooling of buildings contribute about one-third of global greenhouse gas emissions and account for 40 percent of global energy use (Rode et al., 2011). Among the major emitting sources the building sector has the largest potential to reduce the emissions. Buildings have a long life span and about 80 percent of the building's emissions occur during the operational phase. Therefore, delaying on actions would lock energy consumption in for decades of needlessly high levels for new buildings due to the costly nature of retrofitting. According to SBCI (2009), policies, skills and technologies needed to ensure deep cuts in greenhouse gas emissions in new and existing buildings exist.

Regulations on building energy efficiency have existed for a long time and its practice of tracking heat flows and predicting cooling loads dates back to the 1950s. Energy efficiency and conservation became more prominent following the 1970 oil shock and the evolution of technologies measuring energy performance. Early energy conservation projects started in Denmark in 1972, Sweden in 1977 for residential homes and the US-State of Montana in 1979 for public buildings. The US and the UK followed suit in the 1980s (Leipziger, 2013). When measures for climate change mitigation were discussed more widely in the 1990s, the built environment was identified as one cost effective and important mitigation option. According to Leipziger (2013), the Danish government for instance had launched a mandatory energy rating scheme for commercial and residential buildings respectively in 1992 and 1993.After 1999 the use of energy efficiency labels has become more prominent in the housing market. The EU policy instrument, Energy Performance of Buildings Directive (EPBD) (Directive 2002/91/EC) for example provides a framework for energy efficiency measures and energy performance certification that is mandatory for all member states.

Many developed and developing countries have already set in place appropriate policies for reducing emissions and energy demand in new and existing buildings. These have been in the form of the introduction of building codes and energy efficiency performance requirements. It is known that buildings with low energy requirements come with low energy operational costs and as such is expected to create a market segment that commands some price premium. If the premium (which also denotes the producer's marginal benefit) is greater than or at least equal to the marginal cost, then there is an incentive to supply more energy efficient buildings. In order to provide information (such as actual and potential energy use) for market participants and subsequently spur the demand for energy efficient buildings, energy performance labels are displayed voluntarily or mandatorily as required by the local regulating bodies during the transaction phase. Thus, there can be a shift in demand if the designations are shown to have positive impact on sales and rental prices and hopefully on greenhouse gas emissions.

Standards of energy efficiency schemes differ by country and even within countries. Regulation in most countries has been mandatory requirements which allow builders to comply in the most cost effective way without opting out (LCTU, 2013 and IEA, 2010). This strategy has the advantage of correcting market failures and split incentives if properly implemented. Though the central underlying factor for the label lies on buildings' energy usage, the information has been uniquely adapted by various regulation bodies, some labels capture other types of greenness as well. For example, the award of U.S. Green Building Council's LEED[1] certification was introduced to promote sustainable building practices. The scheme generally covers five main areas including energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts. The Energy-Star certification is the US Environmental Protection Agency program that focuses on improving energy performance in buildings as a method of reducing greenhouse gas emissions. A building is awarded an Energy-Star label if its energy use ranks within the top quartile, relative to its peers and must maintain the specific benchmarks for energy usage annually (McGrath, 2013).

In the last half decade, researchers in energy/environmental economics and the real estate sector have raised concerns about the extent to which energy efficiency attributes are valued in the building sector. Studies have recently emerged using Rosen's (1974) hedonic price model as a workhorse in capturing the implicit prices of building energy efficiency attributes. Based on the assumption that markets value what they understand, it is hypothesized that individuals would have a positive marginal willingness to pay (price premium) if the information on the label is properly communicated and understood. Though evidence is generally skewed to a premium, there are mixed evidences. For instance, Fuerst and McAllister (2011b) find no significant relationship between energy performance ratings and rental and capital values for UK

[1] Leadership in Energy and Environmental Design.

commercial property assets. In Japan, Yoshida and Sagiura (2013) found a discount for green buildings in the first few years and a premium as time evolved for condominiums in Tokyo. Instead, Brounen and Kok (2011) found significant premia for Energy Performance Certificates (EPC) rated buildings in the Netherlands residential sector.

Leaning on the mixed evidences, the main question we raise in this paper is what explains the variation in the observed premia reported by the different studies. The paper uses the meta-regression analysis as a platform to explain the variations using energy label characteristics, building sector and markets as well as study characteristics. Meta-analysis is the quantitative synthesis of empirical studies used to gain new insights, explaining differences between similar studies or determining useful directions of research (van den Bergh, 1997). We also explore the appropriateness of our model for benefit transfer purposes due to its need for amenity valuation in the presence of data, time and financial constraints. Not denying the fact that most studies analyzing the relationship between energy performance ratings and building values give a narrative review of existing literature findings, this study is unique in using a meta-regression as its workhorse.

The paper is structured as follows: section 2 discusses the data collection, description and summary statistics; section 3 presents selection of the meta-regression specification; section 4 presents the results and discussion of the meta-regression output; section 5 introduces the benefit transfer aspect of the study while section 6 concludes and provides some policy recommendation.

2. Description of the data

An extensive search for published and unpublished (working papers and reports) studies relating to building energy efficiency certification was conducted on Google Scholar, Google Search, ScienceDirect, Munich Personal RePEc Archive (MPRA) and following the references of relevant literature. The search spanned from mid-February, 2014 to end of April, 2014 using parts of or whole phrases such as “building energy efficiency rating, valuing building energy labels, building value and energy efficiency, energy efficiency premium”; this implies search output are likely to omit non-English related studies. As general observation, literature investigating the relationship between energy consumption and building values started decades ago. However, following the late 2000s, there has been a rapid expansion in the number of studies investigating the capitalization rate of energy efficiency labels in building values. Since our interest is to explain the variation in premium estimates across studies, we selected primary studies based on whether they use the hedonic price model of Rosen (1974) for estimating the implicit prices of a differentiated product such as housing. According to this model the price for housing (most often log transformed to ease interpretation) is a function of product attributes of interest, here energy efficiency (E) and other covariates (X)

$$\log(P) = a + \beta E + \delta X + e \qquad (1)$$

A study qualifies to be included in our dataset if it estimates the parameter β which can be interpreted as the premium ($\beta * 100$) received for the energy efficient attribute of the building. A negative value indicates a discount. Variants of the functional form from the primary studies were considered if only they reported enough information to convert their estimated parameters to a comparable β else they were omitted.[2]

The information reported on energy efficiency differs by country and includes premia for a building with energy label on a continuous or categorical scale and premia for buildings with different classes of energy efficiency. Categorical scales are designed to take on ordinal alphabets for e.g A-G while continuous scale provides continuous numbers usually the amount of energy consumed or some continuous scores. For example, the Energy-Star and LEED ratings are based on a continuous scale of the U.S. HERS[3] Index. The Energy Performance Certificate of the UK has been designed to take on categorical metric scales. These and further examples are presented in Appendix A1.

Primary studies had multiple observations hence a total of 392 observations were reported from 30 studies. Out of the total number of studies, eighteen were published while the remaining twelve were unpublished. About 178 observations were excluded because efficiency classes were not comparable. Most studies generally report the overall average premium for a labelled building and then also estimate for different classes of efficiency. We observed premia for the different classes were not comparable due to the way they were introduced in the regression models. For example, estimated premia for different buildings labelled A-G depended on which class is omitted from the regression model. These were excluded. Nine observations from Kok

[2] Two studies, Cerin et al (2012) and Bonde and Song (2013), used the double log functional form but were dropped due to provision of limited information to undertake the conversion.
[3] Home Energy Rating

and Kahn (2012) had sample sizes between 500,000 and 1,600,000; these were seen as outliers in our data and so were also dropped.[4] For the premium estimates reported in EC (2013), it is known that each country operates on a specific EPC scheme. One needs to be cautious in comparing between countries. For the countries using the categorical scale (e.g. A-G), one could interpret the premium estimated as a one letter improvement in energy efficiency. Belgium uses a continuous scale and so the energy efficiency was introduced in the hedonic regression as a continuous variable. To be able to compare between countries, one can interpret the premium as a 100-point improvement in CPEB by multiplying the premium estimate by a factor of 100.[5] A similar approach was applied to the estimates from the UK by multiplying by a factor of 10 when the authors introduced the energy efficiency scores instead of the alphabetical categories.

After omitting outlying observed premia, we were left with 205 feasible observations. Information on the sample size and standard errors were also collected alongside the effect size estimates, β. The lists of studies included in this paper are displayed in Table 1.

[4] Inclusion of these observations did not make any changes to our conclusion though they slightly changed the parameter magnitudes.

[5] This becomes equivalent to the A-G seven point scale. CPEB refers to *certificate de performance énergétique*. Refer to EC (2013) for further details.

Table 1: Primary Studies included in the Meta-Analysis

Study	Sampled Period	Country of Study	Market Type	Cert. Year Introduced	Certificate. Name[a]	Metric Scale	# of Obs.
Addae-Dapaah and Chieh (2011)	2005-2009	SGP	Sales	2005	Green Mark Certificate	Categorical	4
Brounen and kok (2009)	2008-2009	NLD	Sales	2008	Energy Performance Certificate	Categorical	2
Brounen and Kok (2011)	2008-2009	NLD	Sales	2008	Energy Performance Certificate	Categorical	3
Chegut et al (2011)	2000-2009	GBR	Rent, Sales	1990	BREEAM	Categorical	10
Chegut et al (2014)	2000-2009	GBR	Sales, Rent	1990	BREEAM	Categorical	8
Das et al (2011)	2007-2010	USA	Rent	2000	LEED	Continuous	4
Deng and Wu (2013)	2000-20110	SGP	Sales	2005	Green Mark Certificate	Categorical	20
Deng et al (2012)	2000-2010	SGP	Sales	2005	Green Mark Certificate	Categorical	2
EC(2013)	2008-2012*	AUT, BEL, FRA, IRL, GBR	Rent, Sales	2008	EPCenergieausweis, EPC, DPE , BER , EPC	Categorical	21
Eichholtz et al (2008)	2007	USA	Rent	2000, 1995	LEED, Energy Star	Continuous	6
Eichholtz et al (2009)	2004-2009	USA	Sales, Rent	2000, 1995	LEED, Energy Star	Continuous	8
Eichholtz et al (2010)a	2009	USA	Rent	2000, 1995	LEED, Energy Star	Continuous	10
Eichholtz et al (2010)b	2004-2009	USA	Rent, Sales	2000, 1995	LEED, Energy Star	Continuous	8
Fuerst and McAllister (2008)	2004-2007	USA	Rent, Sales	2000, 1995	LEED, Energy Star	Continuous	8
Fuerst and McAllister (2011)a	199-2008	USA	Rent, Sales	2000, 1995	LEED, Energy Star	Continuous	7
Fuerst and McAllister (2011)b	2011	GBR	Rent, Sales	2002, 1990	EPC, BREEAM	Categorical	
Fuerst and McAllister (2011)c	1999-2009	USA	Rent, Sales	2000, 1995	LEED, Energy Star	Continuous	12
Hogberg (2013)	2009	SWE	Sales	2009	Energy Performance Certificate	Continuous	2
Hylland et al (2013)	2008-2012	IRL	Rent, Sales	2007	BER	Categorical	1
Jafee et al (2012)	2001-2010	USA	Sales	1995	Energy Star	Continuous	6
Kok and Jennen (2012)	2005-2010	NLD	Rent	2008	Energy Performance Certificate	Categorical	1
Kok and Kahn (2012)	- 2010	USA	Sales	2000, 1995	LEED, Energy Star , Green Point	Continuous	14
Kok and Kahn (2013)	2007-2012	USA	Sales	2000, 1995	LEED, Energy Star , Green Point	Continuous	7
Miller et al (2008)	2004-2008	USA	Sales	2000, 1995	LEED, Energy Star	Continuous	1
Pivo and Fisher (2010)	1999-2008	USA	Rent, Sales	1995	Energy Star	Continuous	1
Reichardt et al (2012)	2000-2010	USA	Rent	2000, 1995	LEED, Energy Star	Continuous	15
Soriano (2008)	2005-	AUS	Sales	1993	EEStar Rating	Categorical	6
Wiley et al (2010)	-2008	USA	Sales	2000, 1995	LEED, Energy Star	Continuous	4
Yoshida and Sagiura (2010)	2002-2009	JPN	Sales	2002	Tokyo Green Building Program	Categorical	6
Yoshida and Sagiura (2013)	2002-2009	JPN	Sales	2002	Tokyo Green Building Program	Categorical	8

[a] LEED-Leadership in Energy Efficiency Design, BREEAM - Building Research Establishment Environmental Assessment Methodology, EE Star Rating -Energy Efficiency Star Rating, DPE - Diagnostic de Performance Energetique, BER - Building Energy Rating, * countries have different sampling periods within this range.

Figure 1 presents the weighted study averages of the energy efficiency premia by location of study. Aggregating premia on continental basis shows that EU on average has the highest premium followed by North America (solely the US). At the disaggregated locational level, the UK and Austria showed the highest premia of about 22 and 13 percent respectively followed by Belgium and France with a premium of approximately ten percent. The least observed were the premia in Australia and the Netherlands.

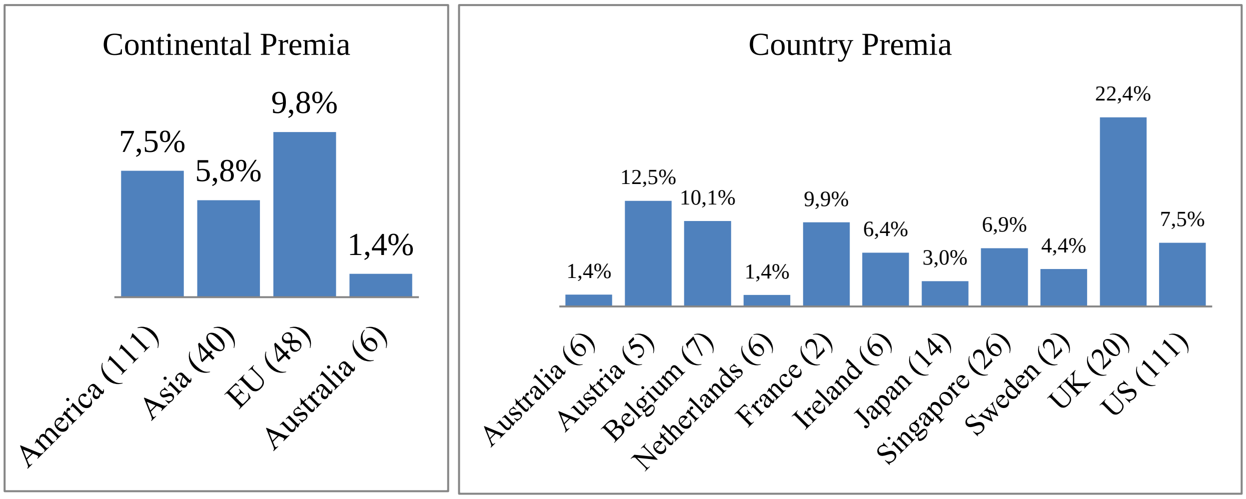

Figure 1: Premia by Continent, Premia by Country.
Note: Values in parenthesis represent the number of observations for each continent or country.

A challenge observed was that not all studies reported the standard errors of their estimates especially due to reduced information and brevity in published studies. So we subjected the effect sizes to homogeneity test based on Cochrane's Q statistics for observations with the reported standard errors (used as input for the test). This was necessary to inform us of the need for moderator variables and the selection of functional forms. The chi-square statistics and alternative measure are shown in Table 2 below.

Table 2 Heterogeneity test

Test Stat.	
Cochrane Q	65000
Pr-value (Q)	(0.000)
I^2 (%)	100
df(Q)	177

Note: Estimated with observations with reported standard errors.

The Q statistic rejects the null hypothesis of homogeneity for the overall effects sizes reported by the studies. The I-squared calculated from the Q statistic indicates the variation in effect size that is attributed to heterogeneity. The test results are sufficient to conclude that the effect sizes are heterogeneous; indicating effect size estimates from primary studies are not all estimating the same population effect, which is often inevitable in economic studies (Nelson and Kennedy, 2009).

The effect sizes were heterogeneous hence prompting the need to search for moderator variables to explain the variation in study estimates. The dependent variable in the meta-regression model is the effect size measured by the parameter β as defined previously. The moderator variables that might explain the variation in effect sizes are discussed below and presented in Table 3.

The categories of moderator variables included are the study and the energy efficiency certificate characteristics. There appear to be controversy about the comprehensiveness of the metric scale of the various energy certification schemes. Energy efficiency labels have unique designs but are mostly designed to have either a distinct categorical scale or a continuous scale (Appendix A1 for examples). Since markets tend to value what they understand, we include the metric scale in our model and expect the categorical scale to be valued more than the continuous scale. We also expect the regulation strategy (voluntary or mandatory) of the energy efficiency scheme to have effect on the extent of valuation and so we include this as a variable. We hypothesize the voluntary scheme to lead to higher valuation of energy efficiency due to its selection of efficient buildings and the associated positive branding of those buildings.[6]

[6] Refer to IEA (2010) for more discussion on the selection process between the two strategies.

Table 3 Description of Variables Used in the Meta-Regression

Variables	Description	Mean	SD	Min	Max
Premium	Coefficient estimate for the energy label (the effect size or premium)	0.08	0.10	-0.1	0.4
Categorical Scale	= 1if the measuring scale for EEC is categorical, = 0 for continuous	0.41	0.49	0.0	1.0
Voluntary	= 1if the EEC is voluntary in a country, = 0 for mandatory	0.67	0.47	0.0	1.0
Sales Market	= 1 if the effect size is with respect to sale price, = 0 for rental value	0.61	0.49	0.0	1.0
Age of Cert Scheme	The age of the EEC since introduced in a country (= ”study year” – ”year introduced”)	15.28	5.32	5.0	24.0
Residential Sector	= 1 if the ECC effect is with respect to the residential sector, = 0 for commercial sector	0.47	0.50	0.0	1.0
Compares to non-labelled	= 1 if effect size measures premium over non labelled houses, = 0 otherwise	0.72	0.45	0.0	1.0
Published	= 1 if effect size is from published study, = 0 unpublished	0.49	0.50	0.0	1.0
No of Authors	The number of authors involved conducting the study	2.55	0.69	1.0	4.0
Year of Study	The year of study	2011	1.75	2008	2014
Method of Estimation	= 1 if the study uses OLS, = 0 otherwise	0.65	0.48	0.0	1.0
Crossectional Data	= 1 if study uses crossectional data, = 0 panel data	0.88	0.32	0.0	1.0
Sampsize	The sample size from which effect size was estimated	41856	86399	83	323840
Asia	Singapore, Japan	0.20	0.40	0.0	1.0
Europe	Austria, Belgium, Netherlands, Ireland, Sweden and UK	0.23	0.42	0.0	1.0
Australia	Australia	0.03	0.17	0.0	1.0
N_America	U.S.	0.54	0.50	0.0	1.0

Note: EEC is Energy Efficiency Certification

Primary studies that fall within the objective of this paper estimate premia separately for the sales and rental markets[7] and we expect the sales market to value energy efficiency labels more than the rental market. This is motivated by the fact that premium estimates reported in the literature tend to be higher for the sales market.[8] We also set a control variable for estimates related to the residential and non-residential sector since primary studies distinguish them and the effect is also expected to take any direction. We again expect the age (since introduced in the country of study) of the certification scheme to increase with premium estimates, since it often takes time for a policy to be understood, adopted and then valued if necessary. The study characteristics included are the sample sizes from which observations were estimated, the type of data used (cross-sectional or panel), number of authors, the year of study and the method of estimation (whether it uses a simple OLS or other forms). Countries where the studies were conducted are shown in the bottom of Table 3 and are aggregated at the continental level.

[7] Sales and rental markets reflect whether property tenure is freehold or leasehold.
[8] Further explanation is given in the interpretation of the Meta regression output.

The last four columns of Table 3 show the summary statistics of all included variables. It can be seen that the average global premium was about eight percent and while some labelled houses receive a discount of about ten percent, the maximum observed premium was approximately 40 percent. The maximum premium was observed from the study of Chegut et al. (2011) where the authors investigate the financial performance of BREEAM[9] certified office buildings in the UK. Following various specifications, premia ranging from 23.3 – 29.6 percent were estimated for the rental market while a corresponding range of 27.1 – 43.3 percent were estimated for the sales market. Yoshida and Sagiura (2013) report the discounts observed at the other extreme in their analysis of the effect of green factors (e.g. energy and resource efficiency, long life span and planting) on condominium prices in Tokyo. The authors found that the Tokyo Green Building certificate attracted a discount of about ten percent but transacted at a premium as the building ages if a green building has a higher life-cycle cost and a longer economic life. A larger fraction of the moderator variables are coded to be binary dummy variables. The earliest study included in the study was conducted in 2008 and the oldest of the certification schemes was the BREEAM certification scheme used in the UK.

3. Methodology

Given that the effect size estimates are heterogeneous, we explain the heterogeneity in effect size estimates through a multivariate meta-regression analysis as recommended by Nelson and Kennedy (2009). The modeling choice is often set between fixed-effect-size (FES) and random-effect-size (RES) models. In the presence of homogeneous effect size estimates, the FES applies as it is assumed that primary studies estimate a common population effect. However, when primary studies (or group of studies) estimate different population effect sizes as evident in our data, then the RES model becomes the certain choice. Following Brander and Koetse (2011) and Brander et al. (2007) we use a multi-level model (MLM) to estimate the meta-regression where the formulation is represented as

$$\hat{\beta}_{ij} = \alpha_0 + \alpha_1 x_{ij1} + \ldots + \alpha_K x_{ijK} + \mu_j + \varepsilon_{ij} \qquad (2)$$

and without any explanatory variables, reduces to the null model

$$\hat{\beta}_{ij} = \alpha_0 + \mu_j + \varepsilon_{ij} \qquad (3)$$

The use of MLM allows overcoming some violations of assumptions that would arise with the use of OLS. Moreover, MLM allows relaxation of the common assumption of independent observations and

[9] Building Research Establishment Environmental Assessment Methodology

allows examining the hierarchies within the data, such as similarity of estimates produced by the same author (Brander et al., 2007). By incorporating data hierarchies into the analysis, MLM ensures that standard errors of parameter estimates are correctly estimated and significance of explanatory variables accurately assessed (Bateman and Jones, 2003).

In equations (2) and (3) above, the subscript i takes values from 1 to the number of observations (i.e. first level: observed effect size estimates) and j also takes on values from 1 to the number of clusters which is the second level (i.e. study level). There are K parameters to be estimated denoted α_i *(i=1, 2…K)* from the moderator variables and a constant α_0. ε_{ij} is the error term at the first or observational level and μ_j is the second or study level residual error. It is assumed that ε_{ij} and μ_j follow a normal distribution with means zero which are uncorrelated so that it is sufficient to estimate their respective variances σ_{ε}^2 and σ_{μ}^2. According to Brander and Koestse (2011), differences in precision of the underlying effect sizes are controlled by weighting with either the square root of the sample size or the standard errors. Though the sample size weighting has been found to be less efficient, it is less biased than the alternative (Sanchez-Mecca and Marin-Martinez, 1998; Marin-Martinez and Sanchez-Mecca, 2010). Weighting the observed effect-sizes does not have substantial effect on the estimated coefficients but does reduce the standard errors. A counter argument on the issue of weighting from Shuster et al. (2010) and Shuster (2010) is that weighting results in undesirable properties such as biasedness, incorrect standard errors and inconsistency among others which do not exist for the unweighted approach. Hence the authors recommend that all previous and future approaches should be estimated without weighting. In this study, we overcome this controversy of precision by including the sample size as an explanatory variable in explaining the heterogeneity of effect sizes between studies as suggested by Nelson and Kennedy (2009).

4. Results of the meta-regression analysis

The results for the regression explaining the variability in energy efficiency premia are presented in Table 4. We begin by first estimating the null model in the column labelled 1 followed by models with the inclusion of the moderator variables and their interactions. The intercept in the null model (0.076) is the weighted grand or global average of the estimated premia; thus labeled energy efficient buildings receive about 7.6 percent of the value (rental or sales) of buildings.

We examined the influence of study effects on estimated values using the likelihood ratio test by testing the null hypothesis that $\sigma_\mu = 0$. In this test, we compared the restricted model to the unrestricted model. This produced a likelihood ratio statistic of 92 (p-value = 0.00) which is chi-square distributed with 1 degree of freedom. We conclude from here that the mean estimates produced by the different studies are heterogeneous; thus value estimates from a particular study tend to be more similar than estimates drawn from different studies. Since the study effect is not equal to zero, it also justifies the need to use a random effect model over a fixed effect model.

We also computed the intraclass correlation coefficient (ICC)[10] which indicates the percentage of total variance in the premia that can be attributed to differences between studies for the null model to be about 50 percent. To reduce the incidence of heteroskedasticity[11], we transformed the sample size and age of the certification scheme to logarithms and reported the robust standard errors for our estimated models. The Wald test statistic reported in the bottom of the table shows chi-square values that reject the null hypothesis of restricted explanatory variables jointly equal to zero. To explain the heterogeneity in energy efficiency premia in buildings, we estimate models 2 and subsequent models in Table 4 where the subsequent models differ from model 2 by the presence of significant interaction effects. Model selection by the Bayesian Information Criterion (BIC) selects model 5 as our best model given its lower BIC value. Computation of the pseudo r-squares indicates that the proportional reduction in study variance is almost 100 %, that of the within variance is about 30% while the total variance reduction is about 64%.

As one can observe from our selected model (i.e. model 5), we find that the categorical metric scale (*Categorical Scale*) of the building energy efficiency label has a weakly significant positive impact on the building value (with an estimated premium of two percent). This implies that people value the energy efficiency labels designed to take distinct categorical scale over the alternative continuous metric scales. It also reflects the extent of comprehensiveness between the two metric designs. Since markets value what they understand, the use of categorical scales would provide incentives for producers to supply more energy efficient buildings which could lead to greater energy savings. This finding is in line with the European Union research from Backhaus et al. (2012) who report that the continuous scale proves to be more confusing to home owners in Europe than the categorical scale, raising the need to consider how information on the label can be presented to the understanding of investors. Other studies

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[10] $ICC = \frac{\sigma_\mu}{\sigma_\mu + \sigma_\varepsilon}$ i.e. the ratio of between variance to the total variance.

[11] We avoided transforming the dependent variable into logarithms due to the presence of negative values.

such as Egan and Waide (2005), Consumer Focus (2012) and Heinzle and Wuestenhagen (2009) provide supporting evidence for this outcome in the consumer appliance labels.

The impact of the sales market also discriminates between the residential and non-residential sector as denoted by the variable *Sales Market*. Here, we also observe that the sales market has a positive marginal effect on the value of the energy efficiency value both in the residential and nonresidential sector. However, we observe the marginal effect is greater in the non-residential (with a contribution of 9.7 percent of the premium) than the residential sector (which contributes 2.2[12] percent of the premium). The positive valuation of the sales market is motivated by the theory of amenity valuation by tenure type (buying or renting). According to Lyon (2012), the difference in valuation of amenity is motivated by search cost and buyer lock-in concerns which make buyers care about wider range of amenities than renters. Renters reach their search threshold sooner and so restrict their willingness to pay for amenities while buyers care about future access to amenities due to fixed supply which can lead to overcapitalization. Moreover, buyers are prepared to value amenities if they believe it will contribute to future capital gains. Our findings in the two markets are in line with the findings from the literature (Hylland et al., 2013; Eicholtz et al., 2010) where valuations in the rental market are estimated to be weaker than the sales market.

[12] Marginal effect of sales market in the residential sector was computed as: 0.097-0.075=0.022

Table 4 Meta-Regression Output

VARIABLES	(1)	(2)	(3)	(4)	(5)
Categorical Scale		0.017	0.017	0.021*	0.020*
		(0.014)	(0.013)	(0.012)	(0.012)
Voluntary		0.057***	0.055***	0.230***	0.217***
		(0.012)	(0.012)	(0.049)	(0.049)
Sales Market		0.079***	0.096***	0.081***	0.097***
		(0.026)	(0.027)	(0.026)	(0.028)
Compares to Non-labeled		0.005	0.013	-0.011	-0.002
		(0.026)	(0.026)	(0.027)	(0.027)
Year of Study		-0.031*	-0.031*	-0.032*	-0.032**
		(0.016)	(0.016)	(0.016)	(0.016)
Log (Age of Cert. Scheme)		0.101***	0.099***	0.124***	0.121***
		(0.032)	(0.031)	(0.032)	(0.031)
Method of Estimation (OLS)		0.014	0.014	0.014	0.014
		(0.013)	(0.012)	(0.013)	(0.012)
Residential Sector		-0.116***	-0.051	-0.103***	-0.043
		(0.038)	(0.042)	(0.038)	(0.043)
Number of Authors		-0.044***	-0.047***	-0.041***	-0.044***
		(0.010)	(0.010)	(0.010)	(0.011)
Published		0.026	0.027	0.027	0.028
		(0.020)	(0.020)	(0.020)	(0.021)
Crossectional Data		-0.041*	-0.049**	-0.047*	-0.054**
		(0.023)	(0.024)	(0.024)	(0.025)
Log(Sample Size)		0.009	0.008	0.011*	0.011
		(0.006)	(0.006)	(0.007)	(0.007)
Asia		0.101***	0.099***	0.056*	0.057*
		(0.033)	(0.033)	(0.031)	(0.031)
Europe		0.267***	0.261***	0.223***	0.221***
		(0.041)	(0.041)	(0.039)	(0.039)
Australia		-0.085	-0.084	-0.153**	-0.148**
		(0.062)	(0.061)	(0.066)	(0.065)
Log(Age of Cert)*Voluntary				-0.084***	-0.078***
				(0.023)	(0.023)
Residential*Sales			-0.080**		-0.075**
			(0.035)		(0.037)
Constant	0.076***	61.638*	62.747*	63.707*	64.609**
	(0.015)	(32.881)	(32.402)	(32.840)	(32.355)
σ_μ	0.005	1.58e-18	2.36e-16	1.25e-16	6.74e-23
σ_ε	0.005	.0038073	.0036793	.0036767	.0035655
Observations	205	205	205	205	205
Number of groups	28	28	28	28	28
Wald-Chi2		336.34***	355.18***	355.57***	373.05***
BIC	-446.15	-464.44	-466.13	-466.28	-467.25

Note: Dependent variable is the premium. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Source: Authors estimations from data

In terms of the regulation strategy enacted for a particular scheme in a country, we find that the voluntary scheme (*voluntary*) has a significant positive impact on the extent to which energy efficiency labels are capitalized in building values (about 22 percent of the effect size). The main difference between the two strategies according to the IEA (2010) is that the voluntary strategy is considered as a type of ‘positive branding’ for builders keen on advertising the high energy efficiency performance of their buildings. Hence, builders with low performance buildings would opt out of the scheme causing selection effects where only the high efficiency buildings are identified. The mandatory schemes on the other hand identify the most inefficient buildings and force them to adopt efficient measures. In the end a greater number of buildings become efficient in the mandatory regulation scenario leading to larger energy savings and carbon dioxide reductions. In terms of valuation, the voluntary scheme leads to higher valuation due to its positively branded characteristic. One should also note that the impact of the voluntary scheme decline with the age of the certification scheme as captured by the variable (*Log(Age of Cert)*Voluntary*). That is, the overall impact of the voluntary scheme declines annually by 7.8 percent; implying the effect vanishes within a period of thirteen years.

The residential sector does not generally differ from the nonresidential sector as indicated by its insignificant negative effect (*Residential Sector*). However, discriminating the residential sector by the type of markets reveals a different story. We observed a significant declining effect of 7.5 percent in the sales market (i.e. the marginal effect of residential sector in the sales market would decline by about 12 percent) compared to the rental market (marginal effect of the residential sector in the rental market declines by 4.3 percent). Also, the age of the energy efficiency certification scheme since introduced into the country has a significant positive impact on the value of buildings. This meets our expectation given the time lag between policy implementation, understanding and subsequently adoption. As discussed earlier, the age and the regulation strategy depend on each other, thus a dampening effect is observed when interacted; confirming a reduction in voluntary scheme’s valuation over time.

Turning to the premia for the respective geographical locations, we estimated significantly higher valuation for energy efficient buildings for European countries (*Europe*) and a lower valuation for Australia (*Australia*) as compared to the US (with respective contributions of plus 22 percent as compared to minus 15 percent). The other variables in the model reflect controls for the study characteristics and design. The year of study, number of authors and studies using crossectional data significantly helped in explaining the variation in the observed premia while the remaining variables are insignificant.

Comparing the different effect sizes in our model for the included variables, we observed that the largest effect sizes are captured by the regulation strategy (*voluntary*) and the age of the energy efficiency certification schemes. In the case of locational characteristics, the European countries appear to capture most of the effect sizes. We attribute the high valuation in the EU over the US to their relative strength regarding energy efficiency policies not captured by our model. The strength as captured by the ACEEE (2014) report on energy efficiency scorecard/rankings for example, Germany and Italy respectively ranks first and second while the EU ranks third with France falling in the fourth place. Comparatively, the US ranks thirteenth out of the sixteen largest economies.

5. Benefit Transfer Analysis

In this section, we assess the validity of our Meta regression for benefit transfer purposes. Benefit transfer provides the means for adapting and using economic information derived from specific sites (often referred as "study sites") under certain resource and policy conditions to a site (also called "policy sites") with similar resources and conditions (Rosengerger and Loomis, 2001). This approach has gained greater interest especially in environmental valuation as it offers a shortcut to resource valuation without conducting time consuming and expensive primary valuation studies.

Benefit transfer approaches often used include the direct value transfer and the function value transfer (Brander et al., 2007 and Rosengerger and Loomis, 2001). The former involves the transfer of a single point value estimate (or in some cases the mean or median of several point estimates) from the study site to the policy site in question conditioned on similarity in characteristics between the two sites or adjusted if necessary. The latter approach however encompasses predicting the benefits from a demand function of a single study site or a meta-regression function derived from several primary studies that describe how values vary with people, places and estimation designs. As evident in our discussion in the previous sections, our focus lies on the use of the meta-analytic function transfer.

The extensive literature on benefit transfer are in consensus that this approach carries with it some errors, often termed as the transfer errors. Thus, transferred benefits frequently disagree with primary valuation studies carried out at the policy site leading to errors that arise if the characteristics of the policy site are not well represented. If we let the observed benefit at the study site be denoted by β_{ij}^{s} and the transferred benefit to the policy site by β_{ij}^{p}, then we can represent the measure of the benefit transfer error (TE) typically expressed in percentage terms,

$$TE = \left| \left[\left(\frac{\beta_{ij}^{p}}{\beta_{ij}^{s}} \right) - 1 \right] * 100 \right|$$

According to Kaul et al. (2013), the function transfers generate lower transfer errors than value transfer since one is able to adjust explanatory variable to represent the policy site. Also, the meta-analysis approach of function transfer is acknowledged to be the most accurate transfer approach since one is able to control in addition, for methodological differences (Brander et al., 2007 and Shrestha and Loomis, 2001). In meta-analysis, characteristics are often represented as dummy variables. One shortcoming is, that this approach is unable to capture accurately the actual quality and quantity differences. In practice, the meta-analysis function transfer is implemented by forecasting or predicting benefits of the policy site using the estimated coefficients from the meta-regression. The activity and site characteristics variables of the meta-regression function are activated to match the policy site and the methodological and other unknown variables could be set equal to the means of the respective meta-variables or set equal to the currently accepted best practice (Shrestha and Loomis, 2001).

We adopt a jackknife (n-1) data[13] splitting approach to evaluate the predictive properties of our meta-regression function following insights from Brander et al. (2007) and Shrestha and Loomis (2001) by comparing the model predicted values β_{ij}^{p} and the observed true values β_{ij}^{s}. Convergence between the two values demonstrates the validity of the benefit transfer from the study site to the policy site. To confirm convergence, we test whether the expected values from the predicted and observed true values are statistically the same ($H_0: \beta^p = \beta^s$) or if the mean difference is equal to zero. Implementing a student t-test for the null hypothesis presented in Table 5 shows a near zero mean difference and t-statistic with a probability value of 1. Hence, the test fails to reject the null, confirming convergence between the premia and predicted values.

A Pearson correlation coefficient (r) test also reveals the statistical correspondence between the two sets of values. Where a statistically significant positive coefficient indicates high values from the meta-regression model are estimated when the original studies produce high values and vice versa. Testing for the null hypothesis of no significant correlation ($H_0: r\left(\beta_{ij}^{p}, \beta_{ij}^{s}\right) = 0$) was rejected at the 1 percent significance level. With a correlation coefficient of about 0.79, we conclude that there is a strong positive relationship between the two values.

Table 5 Transfer Error Statistics for n-1 observations

Statistics	*Values*
Mean Transfer Error (MAPE)	71.56
Median Transfer Error	48.61
Mean Difference = 0	0.00
Pearson Correlation Value = 0	0.79***

Source: Authors own calculation

[13] For the purposes of benefit transfer analysis, observed premia with values of zero were omitted in our analysis since we could not compute transfer errors for those values.

As displayed in Table 5, we estimated a mean prediction error (MAPE) of 71.56 percent and a median value of 48.61 percent for our out-of-sample observations. Prior to arriving at our final feasible observations for the meta-analysis and this value transfers, we performed a check on the predictive properties of our sample using the inter-quartile range criterion to identify outliers (based on estimated transfer errors). A value x is classified as an outlier if it falls outside of the bound; $Q_1 - 1.5IQR < x < Q_3 + 1.5IQR$. Q_1 and Q_3 are respectively the first and third quartiles while IQR is the inter-quartile range (Q_3 - Q_1). The criterion identified studies that estimate a near zero premia to be outliers. Outliers were detected in some of the observations reported from Zheng et al. (2012), Das et al. (2012), Jafee et al. (2012), Kok and Kahn (2012), Miller et al (2008), Hylland et al. (2013) and EC (2013). In Kok and Kahn (2012) for example, the outlying value detected represented a discount of about 0.2% for green buildings in areas highly dense in greeness; indicating diminishing returns to greeness. That of Eichholtz et al. (2008) represented a low and insignificant premium of about 0.3% for LEED rated buildings in the rental market.

To complement our discussion on the predictive powers of our model, we present in Figure 2 a plot of the predicted and observed values for the out-of-sample prediction. The smooth line on the left figure shows the original observed values in ascending order while the non-smooth line is the predicted values. As generally expected, most observations are either over-predicted or under-predicted given the gap between the observed and the predicted. At the section of the plot representing buildings that receive a discount instead of a premium, we observe that values are over-predicted while to the extreme right, premia are under predicted. In the right figure, we show a plot of the transfer errors against the observed premia and as evident, the errors tend to be large for values approaching zero.

Our prediction of MAPE compares to findings from the literature; Kaul et al. (2013) for instance conduct a meta-study on benefit transfer errors and found a range of 0% - 7496% with mean of 172% and median 39%. After removing outlying observations, the authors arrive with respective mean and median values of 42% and 33%.

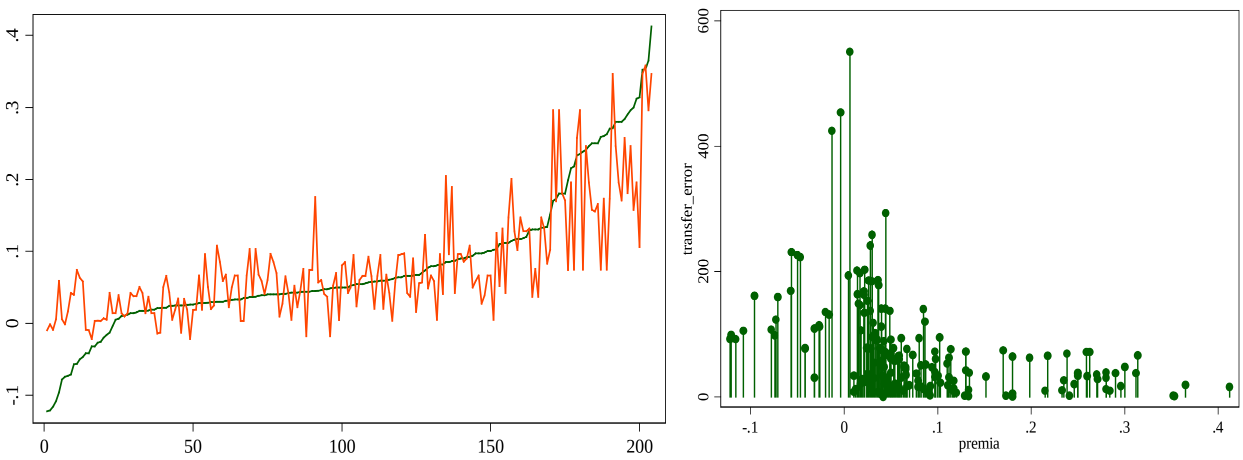


Figure 2 Predicted versus Observed Premia and Transfer Errors versus Observed Premia

6. Conclusion

This study pools together the literature on energy efficiency valuation in the built environment and quantitatively explains the heterogeneity in estimated premia for building energy efficient labels. These premia reflect the marginal willingness to pay for an energy efficient building. Studies from around the globe that estimate the premia paid on building values were collected from various databases and references. Descriptive analysis reveals that there is a positive observed global average premium of about 7.6 percent weighted by each study's contribution. A disaggregation at regional level reveals that Europe has the highest premium followed by the US with Australia having the least. Analysis of the fundamental data generation process shows that observed values are not representative of a common population. Hence we adopt the random intercept multilevel model to explain the variation in premium estimates using information on study characteristics, energy efficiency label characteristics and country policy regulation strategies and sectors of implementation.

Our results reveal that the energy efficiency labels are better valued in the sales market than the rental market which is motivated by the fact that tenure types have different valuation levels for amenities. Discriminating between the sales market, a higher valuation is observed in the nonresidential sector compared to the residential sector. In terms of the regulation strategy from a policy perspective, the voluntary strategy showed a greater impact in valuing building energy efficiency labels though the impact tend to decline with time (vanishing within thirteen years). We also observed the design of the energy certification in terms of the metric scale presented to people matters for the extent of valuation. The categorical metric scale appears to be better understood and valued than the continuous scale. The age of the energy certification since introduction into the respective countries had impact on the extent of valuation as policy usually takes time to be understood and adopted. Also, energy efficiency valuation showed were significantly higher in European countries compared to the US and significantly lower for Australia (with respective magnitudes of about plus 22 percent and minus 15 percent). We indicate the differences between EU and the US to be driven by their respective strengths regarding energy efficiency policies as captured by the international energy efficiency scorecard.

As a further step, the robustness of our meta-regression model was checked for out-of-sample value transfer purposes using an n-1 data splitting technique. Our predicted values and the observed values showed evidence of convergence and correspondence signaling a valid estimated model. We were able to estimate resulting transfer errors with respective median and mean values of 48.61 percent and 71.56 percent which are comparable with estimates from the general meta-regression literature.

Based on our findings we recommend that more policy efforts should be directed towards the design of energy labels that would improve understanding in the residential sector as well as the rental market. Ignoring the rental market could intensify the problem of split incentives and prevent energy efficiency adoption by home owners. Also, regulatory bodies should consider the adoption of mandatory label provision since the effect of the voluntary approach tend to decline with time. The use of categorical metric scales on the energy labels would better improve understanding than the continous scale though the effect is marginal.

References

ACEEE (2014). Executive Summary: International Energy Efficiency Scorecard. American Council for Energy Efficient Economies. Accessed on 23/07/2014: http://aceee.org/files/pdf/summary/e1402-summary.pdf

Addae-Dapaah, K., & Chieh, S. J. (2011). "Green Mark certification: does the market understand?." *The Journal of Sustainable Real Estate*, *3*(1), 162-191.

Backhaus, J., Tigchelaar, C., and Best-Waldhober, M. D. (2011). Key findings & policy recommendations to improve effectiveness of Energy Performance Certificates & the Energy Performance of Buildings Directive.

Bateman, I. J., & Jones, A. P. (2003). "Contrasting conventional with multi-level modeling approaches to meta-analysis: expectation consistency in UK woodland recreation values." *Land Economics*, *79*(2), 235-258.

Brander, L. M., & Koetse, M. J. (2011). "The value of urban open space: Meta-analyses of contingent valuation and hedonic pricing results." *Journal of environmental management*, *92*(10), 2763-2773.

Brander, L. M., Van Beukering, P., and Cesar, H. S. (2007). "The recreational value of coral reefs: a meta-analysis." *Ecological Economics*, *63*(1), 209-218.

Brounen D,. and Kok N.(2011). "On the economics of energy labels in the housing market." *Journal of Environmental Economics and Management*, Volume 62, Issue 2, September 2011, Pages 166-179.

Brounen D., and Kok N.(2009). On The Economics of Energy Labels in the Housing Market. Accessed on 30/02/2014 from http://urbanpolicy.berkeley.edu/greenbuilding/brounenkok.pdf

Chegut, A., Eichholtz, P., and Kok, N. (2014). „Supply, demand and the value of green buildings." *Urban Studies*, *51*(1), 22-43.

Chegut, A., Eichholtz, P., Kok, N., and Quigley, J. M. (2011). The value of green buildings: new evidence from the United Kingdom. *ERES 2010 Proceedings*.

Consumer Focus (2012). Under the influence? Consumer attitudes to buying appliances and energy labels. Accessed on 23/06/2014 from: http://www.consumerfocus.org.uk/files/2012/12/Under-the-influence.pdf

Das, P., Tidwell, A., and Ziobrowski, A. (2011). "Dynamics of green rentals over market cycles: Evidence from commercial office properties in San Francisco and Washington DC." *The Journal of Sustainable Real Estate*, *3*(1), 1-22.

Deng, Y., and Wu, J. (2013). "Economic returns to residential green building investment: The developers' perspective." *Regional Science and Urban Economics*.

Deng, Y., Li, Z., and Quigley, J. M. (2012). "Economic returns to energy-efficient investments in the housing market: evidence from Singapore." *Regional Science and Urban Economics*, *42*(3), 506-515.

EC (2013). Energy performance certificates in buildings and their impact on transaction prices and rents in selected EU countries. DG Energy Final Report. April 19th.

Egan, C., and Waide, P. (2005). A multi-country comparative evaluation of labelling research. *ECEEE 2005 Summer study–what works & who delivers*.

Eichholtz, P., Kok, N., and Quigley, J. M. (2008). Doing Well by Doing Good? Green Office Buildings. Accessed on 15/02/2014 at http://urbanpolicy.berkeley.edu/pdf/EKQ_Green_Buildings_040808.pdf

Eichholtz, P., Kok, N., and Quigley, J. M. (2009): Sustainability and the Dynamics of Green Building. Accessed on 18/02/2014 from: http://merage.uci.edu/ResearchAndCenters/CRE/Resources/Documents/02%20-%20Kok%20Sustainability%20Dynamics.pdf

Eichholtz, P., Kok, N., and Quigley, J. M. (2010b). Sustainability and the Dynamics of Green Building. Accessed on 15/02/2014 from: http://www.usgbc.org/Docs/Archive/General/Docs7094.pdf

Fuerst, F., & McAllister, P. (2011c). "Eco-labeling in commercial office markets: do LEED and energy star offices obtain multiple premiums?." *Ecological Economics*, *70*(6), 1220-1230.

Fuerst, F., and McAllister, P. (2008). Green Noise or Green Value? Measuring the Price Effects of Environmental Certification in Commercial Buildings (No. 11446). University Library of Munich, Germany.

Fuerst, F., and McAllister, P. (2011a). "Green noise or green value? Measuring the effects of environmental certification on office values." *Real Estate Economics*,*39*(1), 45-69.

Fuerst, F., and McAllister, P. (2011b). "The impact of Energy Performance Certificates on the rental and capital values of commercial property assets." *Energy Policy*, *39*(10), 6608-6614.

Heinzle, S., and Wüstenhagen, R. (2009). Consumer survey on the new format of the European Energy Label for televisions-Comparison of a" AG closed" versus a" beyond A" scale format. *St. Gallen: University of St. Gallen*.

Hyland, M., Lyons, R. C., and Lyons, S. (2013). "The value of domestic building energy efficiency—evidence from Ireland." *Energy Economics*, *40*, 943-952.

Högberg, L. (2013). ”The impact of energy performance on single-family home selling prices in Sweden.” *Journal of European Real Estate Research*, *6*(3), 242-261.

IEA (2010). Energy Performance Certification of Buildings: A policy tool to improve energy efficiency, International Energy Agency.

Jaffee, Dwight; Stanton, Richard; & Wallace, Nancy. (2012). Energy Factors, Leasing Structure and the Market Price of Office Buildings in the U.S.. UC Berkeley: Fisher Center for Real Estate and Urban Economics. Accessed from: http://escholarship.org/uc/item/03d6w2m1 on 12/03/2014

Kahn, M. E., and Kok, N. (2012). The value of green labels in the California housing market: an economic analysis of the impact of green labeling on the sales price of a home.

Kahn, M. E., and Kok, N. (2013). ”The Capitalization of Green Labels in the California Housing Market.” *Regional Science and Urban Economics*.

Kaul, S., Boyle, K. J., Kuminoff, N. V., Parmeter, C. F., and Pope, J. C. (2013). ”What can we learn from benefit transfer errors? Evidence from 20 years of research on convergent validity.” *Journal of Environmental Economics and Management*, *66*(1), 90-104.

Kok, N., and Jennen, M. (2012). ”The impact of energy labels and accessibility on office rents.” *Energy Policy*, *46*, 489-497.

LCTU (2013). Energy Policy Toolkit on Energy Efficiency in New Buildings: Experiences from Denmark. Low Carbon Transition Unit, Danish Energy Agency.

Leipziger D. (2013). Comparing Building Energy Performance Measurement: A framework for international energy efficiency assessment systems, Institute for Market Transformation, Washington DC.

Lyons, R. (2012). Inside a bubble and crash: Evidence from the valuation of amenities. *Available at SSRN 2007530*.

Marín-Martínez, F., and Sánchez-Meca, J. (2010). ”Weighting by inverse variance or by sample size in random-effects meta-analysis.” *Educational and Psychological Measurement*, *70*(1), 56-73.

McGrath, K. M. (2013). ”The effects of eco-certification on office properties: a cap rates-based analysis.” *Journal of Property Research*, *30*(4), 345-365.

Miller, N., Spivey, J., and Florance, A. (2008). ”Does green pay off?” *Journal of Real Estate Portfolio Management*, *14*(4), 385-400.

Nelson, J. P., and Kennedy, P. E. (2009). ”The use (and abuse) of meta-analysis in environmental and natural resource economics: an assessment.” *Environmental and Resource Economics*, *42*(3), 345-377.

Pivo, G., and Fisher, J. D. (2010). ”Income, value, and returns in socially responsible office properties.” *Journal of Real Estate Research*, *32*(3), 243-270.

Reichardt, A., Fuerst, F., Rottke, N. B., and Zietz, J. (2012). ”Sustainable building certification and the rent premium: a panel data approach.” *Journal of Real Estate Research*, *34*(1), 99-126.

Rode, P., Burdett, R., & Soares Gonçalves, J. C. (2011). Buildings: investing in energy and resource efficiency (pp. 331-373). United Nations Environment Programme.

Rosen, S. (1974). ”Hedonic prices and implicit markets: product differentiation in pure competition.” *The journal of political economy*, 34-55.

Rosenberger, R. S., and Loomis, J. B. (2001). Benefit transfer of outdoor recreation use values: a technical document supporting the Forest Service Strategic Plan (2000 revision). *General Technical Report-Rocky Mountain Research Station, USDA Forest Service*, (RMRS-GTR-72).

Sanchez-Meca, J., and Marín-Martínez, F. (1998). ”Weighting by inverse variance or by sample size in meta-analysis: a simulation study.” *Educational and Psychological Measurement*, *58*(2), 211-220.

SBCI, U. (2009). Buildings and climate change: a summary for decision-makers. *United Nations Environmental Programme, Sustainable Buildings and Climate Initiative, Paris*.

Shrestha, R. K., and Loomis, J. B. (2001). ”Testing a meta-analysis model for benefit transfer in international outdoor recreation.” *Ecological Economics*, *39*(1), 67-83.

Shuster, J. J. (2010). ”Empirical vs natural weighting in random effects meta-analysis.” *Statistics in medicine*, *29*(12), 1259-1265.

Shuster, J. J., Hatton, R. C., Hendeles, L., & Winterstein, A. G. (2010). “Reply to discussion of ‘Empirical vs natural weighting in random effects meta-analysis’.” *Statistics in Medicine*, *29*(12), 1272-1281.

Soriano, F. (2008) Energy efficiency rating and house price in the ACT: Modelling the relationship of energy efficiency attributes to house price: the case of detached houses sold in the Australian Capital Territory in 2005 and 2006, Department of the Environment, Water, Heritage and Arts, www.nathers.gov.au/about/publications/pubs/eer-house-price-act.pdf.

van den Bergh, J. C. (1997). Meta-analysis in environmental economics.

Wiley, J. A., Benefield, J. D., and Johnson, K. H. (2010). ”Green design and the market for commercial office space.” *The Journal of Real Estate Finance and Economics*, *41*(2), 228-243.

Yoshida, J., and Sugiura, A. (2010). Which “greenness” is valued? Evidence from green condominiums in Tokyo. Accessed in March, 2014: http://mpra.ub.uni-muenchen.de/23124/1/MPRA_paper_23124.pdf

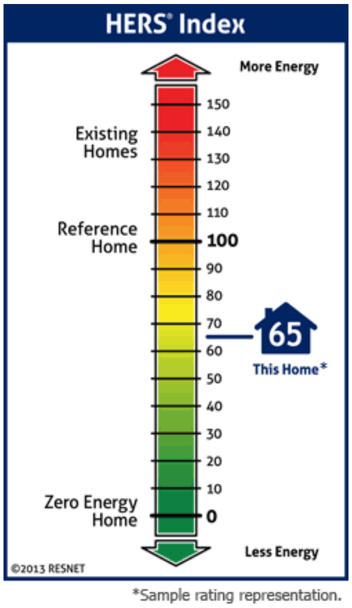
Yoshida, J., and Sugiura, A. (2013). ”The Effects of Multiple Green Factors on Condominium Prices.” *The Journal of Real Estate Finance and Economics*, 1-26.

Zheng, S., Wu, J., Kahn, M. E., and Deng, Y. (2012). ”The nascent market for “green” real estate in Beijing.” *European Economic Review*, *56*(5), 974-984.

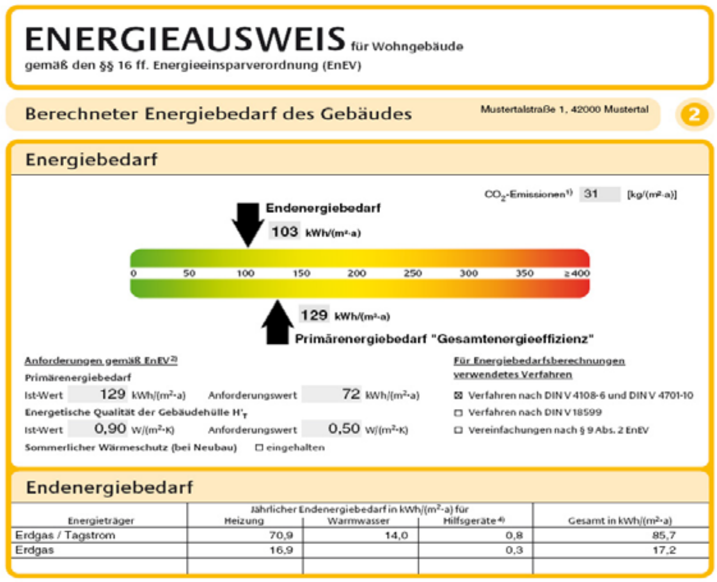
Appendix

Figure A1: Examples of Continuous (a, b) and Categorical (c) Metric Scales

a) United States

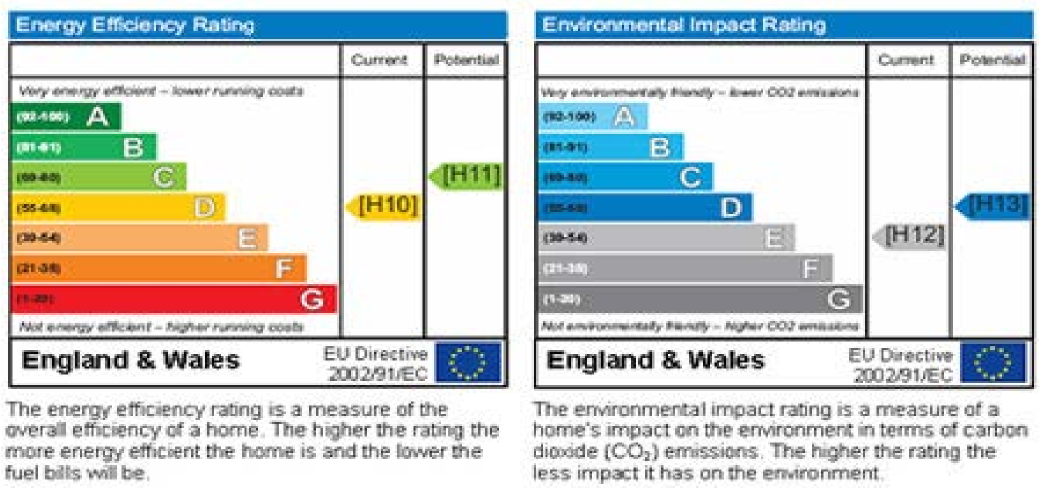


b) Germany



Source: a) www.resnet.us/energy-rating b) www.energieberatung-schupp.de/index.php/energieausweis/

c) United Kingdom



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