GREEN PREMIUM AND BROWN DISCOUNT: A QUANTITATIVE META-ANALYSIS OF THE ENERGY EFFICIENCY PREMIUM IN EUROPEAN HOUSING MARKETS

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1. Introduction

In 2022, the share of the residential building sector in Europe's total final energy consumption reached above 26.8%, and its share of total energy-related carbon emissions exceeded 21.4%. Improving energy efficiency of the residential building stock could help both reduce energy demand and decarbonize energy supply, not to mention the increased vulnerability of residents to energy crises in the context of recent geopolitical tensions.

The EU has set a target to fully decarbonise the buildings sector by 2050 and has reaffirmed its commitment to ensure transparency of residential building energy efficiency. Economic theory suggests that this transparency should enable the capitalization of energy efficiency in real estate prices both in the sales and rental markets. The resulting price difference is the so-called energy efficiency premium: a green premium for more energy efficient homes denotes a higher price, while a brown discount for energy inefficient homes denotes a discount due to energy efficiency compared to a home of medium energy efficiency.

However, since the lack of energy efficiency of dwellings can be a major factor for low-income households, policy-making must be able to know whether such a premium really exists, and if it does, what its magnitude is.

Evidence on the consistency and magnitude of the green premium and the brown discount across different European countries remain mixed, with several studies confirming the price premium for more energy efficient buildings while others finding no significant effect, or contraintuitive results (green discounts and brown premia). Market stakeholders also have mixed takes on the subject which is made evident by the thin market penetration of green mortgages, or noted expressly by real estate agents claiming a lack of trust and thus reliance on EPCs or buyers not listing energy efficiency among their top concerns [see Pasek (2014), Pascuas et al. (2017) or Benyak et al. (2024)].

In the last ten years, a few studies have been conducted to synthesize the vast and growing evidence on the green premium. However, most of these reviews have not adopted a systematic review approach or limited their purpose to carry out a scoping review (Ou et al., 2025), and the one Europe-focused meta-analysis on the green premium found inconclusive evidence for the effect (Cespedes-Lopez et al., 2019). Moreover, the global quantitative meta-analyses that were conducted have not been able to account for the geopolitical tensions and green energy uptake of the last five years and their potential impact on the energy efficiency premium.

This paper aims to address the gap and conduct a meta-analysis on how much of a price premium do more energy efficient homes command in European housing markets. The research questions are: 1 (a) Is there a green premium for energy efficient residential buildings in Europe? 1(b) If yes, what is the magnitude of the green premium? 2(a) Is there a brown discount for energy inefficient residential buildings in Europe? 2(b) If yes, what is the magnitude of the brown discount?

To address the research questions, results of various quantitative studies are filtered by objective selection criteria and their results are extracted and pooled. Then, random effects models are conducted with the DerSimonian & Laird (DL), Hedges and Olkin (HO) and restricted maximum likelihood methods.

Results show that there is a statistically significant green premium and a statistically significant brown discount as well, confirming research questions 1(a) and 2(a). The magnitude of the green premium is estimated to range from 8% to 12% using the three random effects models, whereas the magnitude of the brown discount is estimated to range from -2% to -10%. The finding in the literature that energy efficiency premia are higher in the sales market than the rental market are corroborated.

The thesis will be structured as follows. Section 2 will provide a literature review on the concept of the green premium and the brown discount, the various ways energy efficiency is measured in Europe, and an overview of the empirical literature, including the meta-analyses conducted thus far. Methodologies and key findings of the empirical literature will be showcased, also highlighting the differences in the magnitude of the green premium found across studies, as well as the key factors that influence the green premium. Section 3 will outline the methodology followed for the systematic review, including the literature scoping steps, inclusion criteria for studies, filtering criteria and the data extraction process. Then, after an introduction to the main meta-analysis approaches, the random effects models best suited to the context of the analysis will be chosen. Section 4 will present the results of the random effects meta-analyses and some subsample analyses. Section 5 discusses the interpretation of quantitative results and practical and policy implications, as well as limitations of the study and future research areas.

2. Literature Review

The building sector has been one of the greatest contributors to greenhouse gas emissions and energy use for decades, and measures to achieve heating and energy efficiency has been identified as one of the cost effective options already in the 1990s (Ankamah-Yeboah & Rehdanz, 2014). Buildings with low energy requirements mean lower running costs for energy, so if markets were perfect, there would be a clear theoretical case for the capitalization of energy efficiency benefits, that is, the expected savings on energy and heating bills would be reflected in a price differential. A green premium is commonly defined as a price premium of properties with high energy efficiency compared to their counterparts of an EPC band D, while the price discount of comparable properties with low energy efficiency is called a brown discount.

The policy case for making energy efficiency disclosures mandatory has been articulated due to information asymmetry on the housing market in this regard: if the energy efficiency of homes is unknown to a potential buyer/renter, the market will be less efficient in valuing energy efficiency, thus reducing the incentive for owners to make energy efficiency retrofits (Frondel et al., 2020). There is also convincing evidence that disclosure bias would increase over time if there were no compulsory disclosure, as the upward-shifting energy efficiency distribution will increasingly punish energy inefficient properties with a brown discount, so owners of such brown properties will be incentivized to conceal their „type" (Cornago & Dressler, 2020; Wilkinson & Sayce, 2020).

The release of the first Energy Performance of Buildings Directive in 2002 (EPBD-Directive 2002/91/EC), and its subsequent updates (EPBD-Directive 2010/31/EU; EPBD-Directive 2018/844/EU) aim to promote energy efficiency improvements in buildings, including a requirement that an energy performance certificate would be made available to a prospective buyer or tenant by the owner. Consequently, national Energy Performance Certificates (EPCs) have been designed and implemented in all member states, and in several other European countries as well (e.g., Norway, Switzerland, UK).

The exact implementation of the EPC mandate is in a member state jurisdiction, so there are differences in the way energy efficiency is calculated in each country. Most use an Energy Efficiency Rating based on the energy costs associated with energy usage – the approach in line with the costs savings narrative of energy efficiency premiums described above – but so-called Environmental Impact Ratings are also applied, which are based on the annual CO2 emissions associated with energy use. This latter method also highlights another channel through which energy efficiency premiums may emerge – although arguably to a lesser extent. Some prospective buyers/tenants may have a higher valuation of energy efficient properties solely due to their smaller carbon footprint, as green or climate-conscious consumers.

In addition to non-uniform EPC calculation methodologies, countries also use different cutoffs of energy efficiency for each EPC band and their nomenclature also differs (see European DataWarehouse). However, as Ou et al. (2025) argue, and also evidenced by Sejas-Portillo et al. (2025), the difference in band cutoffs is unlikely to be an issue when pooling data to estimate the overall green premium for various EPC bands. Most consumers are unlikely to have a thorough understanding and evaluation of the exact methodology for finding a property's EPC band values, it is rather the salient ABCDEFG qualifications that they would consider.

Since the seminal paper of Brounen & Kok (2011), a growing empirical literature assessing the price premium of energy efficiency has started to emerge. Some of the literature focus more on discussing whether these labels have been effective in enhancing the flow of information (see e.g. Olaussen et al. (2021), Aydin et al. (2020)) at all, but that will not be the subject of this study. Decoupling the energy efficiency premium from other property characteristics is challenging due to the high number of cofounders (e.g. quality, build year, location, quality, etc.), so studies aim to control for all relevant factors in order to isolate the impact of energy efficiency, or aim to exploit quasi-experimental settings.

Observational studies aiming to control for all relevant cofounders generally rely on the hedonic price model, the industry standard in real estate economics, as developed by Rosen (1974). For the purposes of this study, consider the below simple, general characterization:

$$\log(P) = \alpha + \boldsymbol{\beta x} + \boldsymbol{\gamma EPC} + \varepsilon$$

where the logarithm of sales or rental price is regressed on a constant, a set of control variables $\boldsymbol{x}$, a categorical explanatory variable EPC for each EPC band and an error term. Only studies in this semi-logarithmic form will be considered for comparability, as elaborated in section 3.

Several studies have confirmed that there is a lower price premium in the rental market than in the sales market (e.g. Fuerst et al., 2016; Gerassimenko et al., 2025; Hyland et al., 2013). Cajias et al. (2019) argue that as opposed to the owner-occupied market, the private rental market faces a „split incentive problem", a kind of public goods issue: the costs and benefits of energy efficiency investment affect different stakeholders without any mechanism of redistributing costs and benefits fairly. Tenants usually pay for electricity and heating bills directly but the cost of renovation burdens the landlord primarily.

However, in spite of numerous studies having found positive significant impacts for green premia and negative significant impacts for brown premia, as expected, quite a number of studies have produced some counterintuitive results or no significant relationship between energy performance ratings and rental and sales prices (e.g. Cespedes-Lopez et al., 2020; Fregonara et al., 2017; Fuerst & McAllister, 2011; Marmolejo-Duarte & Chen, 2019a, 2019b; McCord et al., 2020; Olaussen et al., 2021).

Ankamah-Yeboah & Rehdanz (2014) did a global meta-analysis of the literature available in 2014, however due to the nascent state of the literature at the point (30 studies were considered, out of which twelve were unpublished), after exluding studies with incomparable efficiency classes, 205 feasible observations remained. They found effect sizes to be very heterogeneous and ran a meta-regression analysis using a multi-level model, getting a global average premium of 7.6%. Europe is found to have the highest premium, a premium of around 22%. In order to be able to pool results from all around the world, they condensed energy efficiency premia into a single variable they called „premium", and used that as the independent variable in a regression to quiantify the isolated impacts of various factors.

Cespedes-Lopez et al. (2019) have a fairly recently conducted meta-analyses to aggregate results from the literature. However, Cespedes-Lopez et al. (2019) limited the scope of their meta-analysis to asses whether the oresence of an energy efficiency label has an impact on prices. They point out that the primary reason for the lack of conclusive meta-analyses in Europe is due to the fact that there is no consensus on the energy efficiency letter base to be used as reference for comparisons, thereby generating small comparable samples. In spite of their call for later studies to avoid qualification letter groupings and that the reference qualification should be identical, ideally EPC band D (p. 56), later studies continued to show heterogeneity.

Fizaine et al. (2018) did a global random effects meta-analysis using restricted maximum likelihood and clustered OLS models. They show a major publication bias in their collection of findings on the price premium , correcting for which halves their first pooled estimation of the green premium, yielding their final result for a green premium to be 3.5-4.5% of the price.

Fregonara & Irene (2021) focused their review on the European literature and assessed and compared methodological choices of each empirical study. Their pool of studies was not a result of a systemic review, they rather had covering as much heterogeneity in approaches as possible in mind. Wilkinson & Sayce (2020) also aimed to have a wide scope in covering the European literature, mostly in terms of geography. They found that a brown discount is more likely to be the long-term trend than a green premium, a finding in line with Cornago & Dressler (2020) and Cajias et al. (2016).

Ou et al. (2025) were the first in the literature to conduct a systemic review of studies in the European market. Although they only presented the ranges of premia they found without any meta-analysis, their addition to the review literature is very valuable and unique in its systemic nature, European focus and the vast range of new findings that have emerged recently.

The recent heating price hikes the Russian invasion on Ukraine brought in 2023 have increased the green premium in affected nations in Europe, as shown for Hungary by Fekete & Baranyai (2024). If the expectations of homebuyers for energy prices or energy price volatility can be characterized as diagnostic expectations [see e.g. Bordalo et al. (2019) or Bordalo et al. (2022)], such price shocks may increase the salience of expected energy costs when purchasing new real estate, so attention to the energy performance of considered homes could increase.

3. Data and Methodology

The field of systematic reviews and metaanalyses has been developed with the most care in the field of medical sciences in order to be able to integrate the findings of randomized control trials [see e.g. the Cochrane Handbook (Higgins et al., 2019) and Borenstein et al. (2021)]. Although the nature of the field differs, the highest standard of economic meta-analysis also strives to follow these protocols and apply them as much as possible to our field. The primary source used in this paper discussing meta-analysis in the social sciences will be Irsova et al. (2023). A generally accepted set of guidelines is provided in the 2020 update of the PRISMA statement (Page et al., 2021) that will be followed. M. F. Cespedes-Lopez et al. (2019) will also be consulted as they have conducted a meta-analysis to aggregate the assessments on the impact of the presence of an EPC label.

3.1. Literature scoping

As there have been a significant number of review papers on the green premium literature, all these will be reviewed to gather primary sources. Ou et al. (2025) provided a scoping review on the European green premium literature very recently, and not only took a remarkably transparent and systematic approach to identify and screen available papers but made them publicly available and encouraged building on them in future research. Therefore, one of the primary sources for data will be their collection of papers. Due to the up-to-date nature of their collection, the parts of the literature that they had in scope will not be directly searched beyond the extraction of studies from the rest of the secondary literature.

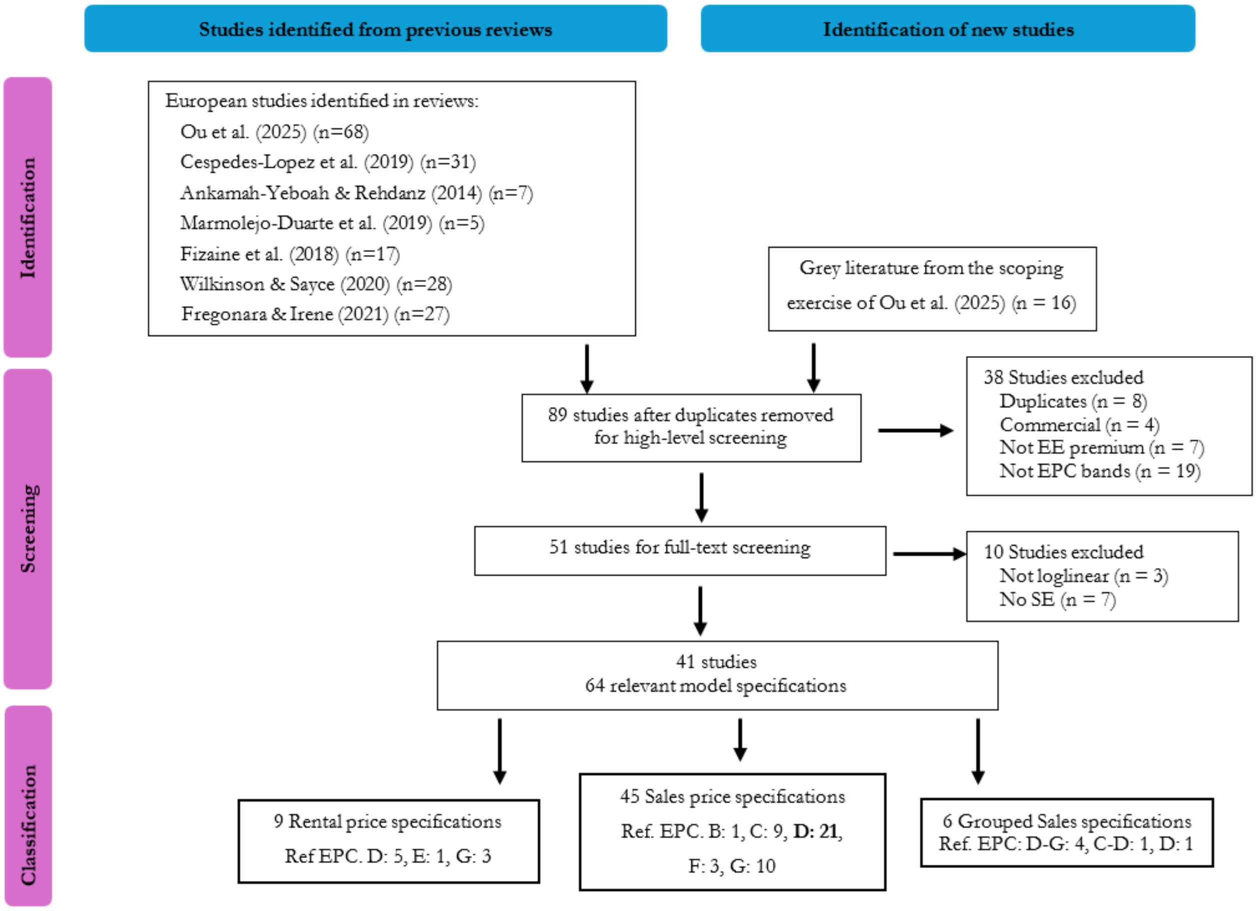
One of the major shortcomings of Ou et al. (2025) is that they only included peer-reviewed academic sources to „improve consistency and trustworthiness" of the literature they'd cover, in spite of a consensus against such an approach in most relevant meta-analysis handbooks. The Cochrane Handbook argues that „including studies reported in all types of publication will generally reduce bias" (Higgins et al., 2019, p. 60, 178), particularly non-reporting bias and advocates for including unpublished, partially published and grey literature. Borenstein et al. (2021, pp. 315-316) provide a compelling argument for the inclusion of gray literature due to the fact that researchers working for government agencies and think-tanks generally publish their findings in reports instead of academic papers, as well as pointing to the possibility for high quality theses and dissertations that would later not be submitted for academic publications.

Ou et al. (2025) also exclude non-English literature. There is evidence that even without such deliberate restriction, there can be a risk of a so-called „language bias" for English-language databases and literature which can lead to an oversampling of statistically significant studies (Egger et al., 1997; Jüni et al., 2002, as cited by Borenstein et al., 2021, p. 316), so the inclusion of non-English studies is desirable. In fact, Irsova et al. (2023, p. 1150) advise that it is better not to exclude any studies *ex ante* due to a suspicion of lower quality or because of being unpublished, but rather suggest performing sensitivity tests as part of the analysis. Therefore, the literature scoping of Ou et al. (2025) will be revisited, and grey literature studies and non-English sources that they have excluded will be readded to the pool of studies considered. This way, 16 studies will be reconsidered in addition to the 68 studies they identified (see Figure 1).

As discussed in section 2, there have been six other scoping reviews of the energy efficiency premium literature [M. F. Cespedes-Lopez et al. (2019), Ankamah-Yeboah & Rehdanz (2014), Marmolejo-Duarte et al. (2019), Fizaine et al. (2018), Wilkinson & Sayce (2020), Fregonara & Irene (2021)], who identified 31, 7, 5, 17, 28, and 27 primary empirical studies respectively that considered European markets. Needless to say, there were many papers present in several of these reviews, but many checks were taken and a thorough documentation followed to enhance the quality of literature scoping. Combining all these papers and removing duplicates resulted in a set of 89 studies.

3.2. Screening and processing

A round of high-level screening and a round of full-text screening was conducted. The high-level screening process involved reading the abstract and identifying the data sources. **Hiba! A hivatkozási forrás nem található.**, a PRISMA flowchart following industry standard guidelines



details the exclusions for each round.

Figure 1. PRISMA flowchart of the searching and selection process of studies and the classification of registers. The chart follows the PRISMA 2020 guideline (Page et al., 2021, p. 4) for sytematic reviews.

Eight papers have been excluded as they have been identified as duplicates of other papers in the sample. Due to the inclusion of non-published papers, a few have been identified as working paper versions of studies that were later published. One of the non-English papers were also excluded for this reason, as the same regression results s already published in Spanish were used in a later publication in English. Finally, there were a few cases in which the data used in an earlier study was a subset or was identical to the sample used in a later one.

Four studies discussed the commercial market, and seven discussed something other than a quantitative assessment of an energy efficiency premium. The latter included three papers that assessed the impact of the presence of an energy efficiency label, two policy recommendation pieces, a survey on the reliability of EPCs according to real estate agents and a theoretical discussion.

The fourth exclusion criterion is probably the most problematic one in this round of screening, both due to the number of studies that had to be discarded and the valuable results they contain. Limiting the sample to EPC bands was however necessary in order to have a homogenous explanatory variable to enable aggregating impacts. A few studies from Eatern Europe exploited quasi-experimental settings of an energy efficiency renovation, or applied an input-output methodology to assess potential impacts. Six studies used a continuous measure of energy efficiency, some directly used log energy consumption, while some treated EPC bands as an ordinal measure (equating bands to numbers from 1 to 7 for instance, and including it in regressions as a continuous variable).

Finally, the 47 remaining studies were screened to assess the exact methodology applied and to gather results for each specification. In this round, three studies in which the independent variable was not in logartihmic form, and seven studies that did not report standard errors for EPC bands were discarded. Although some imperfect approximations do exist for transforming regression results that do not come from a semi-logarithmic functional form, only one of the studies (Gerassimenko et al., 2025) had a linear specification with standard errors reported. In this case, an attempt was made to make the transformation but standard errors were so small (<2e-16), that it has become a clear outlier among the others, and the weight for its results (see section 3.3) would have significantly skewed results.

A study may have more than one specification, but only one model run will be considered for each specification. These specifications represent different subsamples of the data due to assessing the premium (i) for both the sales and rental market, (ii) in different locations, (iii) for different construction types or (iv) for different periods of time. Finally, specifications were classified according to EPC reference bands and letter groupings when relevant.

Due to the limited number of studies found with EPC reference bands B, E and F, as well as the difficulties in pooling grouped EPC band results with individual band estimates, the primary metaanalyses specifications will be three meta-analysis estimates calculated from specifications with reference bands C, D and G respectively[1].

3.3. Meta-analysis methodology

The two main parametric approaches used to combine results of individual studies are the so-called fixed-effect (FE) and random-effect (RE) models. It is important to note that these terms in a meta-analysis context do not mean using a set of cluster-specific dummies as in econometrics. Instead, a fixed-effects or common-effects model means that all studies „share the same (fixed) effect" (μ_{FE}), and all differences in observed effects are caused by sampling error (Irsova et al., 2023). Random effect models on the other hand allow for between-study heterogeneity of true effects (different θ_i with variation τ^2), not just within-study variation (v_i), that is, „effects in the studies are assumed to represent a random sample from a distribution of true treatment effects" (Veroniki et al., 2016, p. 59).

Following Veroniki et al. (2016, p. 59), a random effects model can thus be characterized as:

$y_i = \theta_i + \epsilon_i,$ where $\epsilon_i \sim N(0, v_i)$

[1] Although transforming the effect size estimates such that they are brought to the same reference category is simple given the semilogarihtmic functional form, without knowing the individual covariance of each EPC band dummy with the control variables, standard errors cannot be recalculated, only a very rough estimate could be used. Such an estimate would inflate the standard errors of the transformed results and not the non-transformed ones, introducing bias to weighting individual parameter estimates.

$\theta_i = \mu_{RE} + \delta_i,$ where $\delta_i \sim N(0, \tau^2),$ so $Var(y_i) = v_i + \tau^2,$

whereas in a FE model, τ^2 and consequently δ_i are assumed to be zero, so the only variation in y_i is in v_i, it is assumed that $\theta_i = \mu_{FE}$ for all *i*. It is therefore fairly simple and straightforward to estimate the common effect in a FE model: one simply takes the square of the standard errors of the explanatory variable from each study (v_i), and uses their inverse as weights to calculate the weighted average, whereas for a RE estimation, although the weighted average approach is identical), the weights are not readily available, as between-study variance (τ^2) is to be accounted for as well: $\mu_{FE} = \frac{\sum_{i=1}^{k} w_i^{FE} Y_i}{\sum_{i=1}^{k} w_i^{FE}},$ where $w_i^{FE} = \frac{1}{v_i},$ as opposed to

$$\mu_{RE} = \frac{\sum_{i=1}^{k} w_i^{RE} Y_i}{\sum_{i=1}^{k} w_i^{RE}}, \quad \text{where } w_i^{RE} = \frac{1}{v_i + \tau^2}$$

Numerous methods have been developed to estimate between-study variance (to be discussed in section 3.3.2) but first the choice between a FE versus a RE approach will be addressed.

3.3.1 Random effects versus Fixed effects approach

The variablility of energy prices over time and across regions, the regional variance in the number of heating degree days and cooling degree days, differences in the energy efficiency retrofitting costs and many other factors are very likely to influence the exact magnitude of an energy effiiciency price premium. The nature of the meta-analysis calls for a RE approach, nevertheless Cochran's Q-test is run as suggested in the Handbook (2019).

As developed in Higgins et al. (2003), to quantify heterogeneity, the degree of inconsistency between study results can be characterized by I^2, given as $I^2 = 100\% * (Q - df)/Q$, where Q is Cochran's heterogeneity statistic ($Q = \sum_{i=1}^{k} w_i \, (Y_i - \bar{Y})^2$), and *df* is the degrees of freedom, that is, the number of studies (*k*) minus one.

I^2 statistics	**A**	**B**	**C**	**D**	**E**	**F**	**G**
EPC ref: C	98.27%	99.18%	N/A	79.64%	79.42%	81.16%	70.30%
EPC ref: D	99.69%	99.67%	97.41%	N/A	97.49%	99.48%	99.13%
EPC ref: G	99.72%	93.42%	99.67%	99.30%	96.25%	79.61%	N/A

Table 1. I^2 statistics of the meta-analysis model specifications

Inconsistency measures I^2 are shown in **Table 1** for each EPC band under the three reference EPC specifications. As the Cochrane Handbook advises, an I^2 statistic above 75% is evidence for „considerable heterogeneity", and any value above 50% „may represent substantial heterogeneity" (2019). As all I^2 statistics fall in these ranges, we shall proceed with selecting the most suitable random effects model.

3.3.2 Model selection

There are over a dozen different random effects model estimators. Picking the right one to use is a matter of attempting to minimise bias and maximise efficiency (minimise mean squared error). Model choice for a particular sample should depend on the number of studies included, sample sizes of individual studies and the real variance between studies, as different estimator behave differently under different conditions(M. F. Cespedes-Lopez et al., 2019; Veroniki et al., 2016).

The simplest and most common random effects model has been developed by DerSimonian & Laird (1986). Their estimator of the between study variance τ^2 is given by:

$$\hat{\tau}_{DL}^2 = max\left\{0, \frac{Q-k-1}{\sum w_{i,FE} - \frac{\sum w_{i,FE}^2}{\sum w_{i,FE}}}\right\}$$

Since the DL method is considered standard in the meta-analysis literature, the DL model will be among the ones used in this paper. It has been shown however that DL is inefficient when the studies in the meta-analysis have magnitudes of different sizes and particularly when τ^2 is large. More importantly, simulation studies have also provided evidence that in case τ^2 is large, the DL estimator may produce estimates with significant negative bias (Veroniki et al., 2016). As discussed and shown in the previous section, this is indeed the case, so in order not to underestimate the standard errors of the pooled estimates, a method better suited for heterogenous effect samples is desired.

The Hedges and Olkin (HO) method has proven to work well when there is substantial variation between studies, and some simulations showed that in such a case, it is also more efficient than the DL estimator (Friedman, 2000, as referenced by Veroniki et al., 2016, p. 62). The between-study variance is estimated as:

$$\hat{\tau}_{HO}^2 = max\left\{0, \frac{1}{k-1}\sum(y_i - \bar{y})^2 - \frac{1}{k}\sum v_i\right\}$$

The last method that will be considered is the restricted maximulm likelihood (REML) method. As the name suggests, it was developed to correct for the negative bias in the iterative maximum likelihood (ML) method. For large τ^2, REML has been shown to also be more efficient than ML, and that it is especially desirable to use REML when large studies are included in the meta-analysis 6Friedman, 2000, as referenced by Veroniki et al., 2016, p. 62). The iterative solution is given by solving the below equation:

$$\hat{\tau}_{REML}^2 = max\left\{0, \frac{\sum w_{i,RE}^2\left(\left(y_i - \hat{\mu}_{RE}(\hat{\tau}_{ML}^2)\right)^2 - v_i\right)}{\sum w_{i,RE}^2} + \frac{1}{\sum w_{i,RE}}\right\}, \qquad \text{where } w_{i,RE} = \frac{1}{v_i + \hat{\tau}_{REML}^2}$$

4. Results

As we allow for large between-study heterogeneity, the main specification will pool parameter estimates for sales and rental prices together. Results are presented in Table 2. There are a few notable differences between parameter estimates of the restricted maximum likelihood model and the closed-form models for some of the green premium estimates in the EPC reference C (A, B) and the EPC reference G (A) categories, as well as a much larger estimated effect by the DL model for the premium of EPC band D compared to a baseline of band G. Nevertheless, in virtually all other cases, results under the three models are quite well-aligned.

	EPC Ref: C			**EPC Ref: D**			**EPC Ref: G**		
	DL	**HO**	**REML**	**DL**	**HO**	**REML**	**DL**	**HO**	**REML**
A	0.078 (0.028)	0.080 (0.023)	0.174 (0.003)	0.123 (0.023)	0.127 (0.032)	0.124 (0.026)	0.137 (0.044)	0.136 (0.042)	0.091 (0.002)
B	0.039 (0.022)	0.029 (0.040)	0.041 (0.019)	0.087 (0.015)	0.089 (0.024)	0.088 (0.018)	0.126 (0.034)	0.149 (0.066)	0.141 (0.049)
C	*Ref.*	*Ref.*	*Ref.*	0.017 (0.004)	0.017 (0.007)	0.017 (0.003)	0.034 (0.036)	0.029 (0.029)	-0.002 (0.001)
D	-0.014 (0.005)	-0.014 (0.005)	-0.012 (0.003)	*Ref.*	*Ref.*	*Ref.*	0.067 (0.024)	0.016 (0.001)	0.016 (0.001)
E	-0.022 (0.007)	-0.023 (0.008)	-0.022 (0.006)	-0.025 (0.004)	-0.026 (0.005)	-0.025 (0.004)	0.020 (0.010)	0.030 (0.019)	0.024 (0.012)
F	-0.023 (0.011)	-0.022 (0.006)	-0.020 (0.004)	-0.055 (0.011)	-0.055 (0.009)	-0.006 (0.000)	0.007 (0.006)	0.003 (0.001)	0.008 (0.007)
G	-0.045 (0.017)	-0.019 (0.006)	-0.029 (0.010)	-0.096 (0.014)	-0.097 (0.017)	-0.095 (0.013)	*Ref.*	*Ref.*	*Ref.*
k		9			26			13	

Table 2. Results of random effect models: DerSimonian and Laird, Hedges and Olkin, Restricted Maximum Likelihood. Energy efficiency estimates of the impact of each EPC band with reference EPC bands C, D and G pooled from 9, 26 and 13 specifications respectively. Pooled standard errors in parantheses.

The forest plot for each EPC band's impact compared to reference category D under the most conservative HO model is shown on Figure 2, and Figure 3 shows pooled results for the six EPC bands altogether for ease of comparison. Results confirm the presence of both a statistically significant green premium and a statistically significant brown discount. In fact, both price differentials move exactly in line with EPC bands, reaching a premium of 13.54% and a discount of -9.24%.

Results for EPC band C also provide evidence for both a green premium and a brown discount, although of somewhat smaller magnitude. It is important to note that specifications using EPC band C as reference all considered the sales market (see Figure 1). However, as section 2 discusses, due to the more limited capitalization of energy efficiency in rental prices, a sales-only subsample could be expected to show stronger impacts. To gather further evidence on this, an only-sales estimation on the EPC reference D subsample is conducted. Results shown in Table 3 and Figure 4 aligns with expectations, energy efficiency premiums in the sales only subsample (both green premium and brown discount) are indeed greater than in the pooled subsample.

	EPC Ref: D, sales and rent			**EPC Ref: D, sales only**		
	DL	**HO**	**REML**	**DL**	**HO**	**REML**
A	0.123 (0.023)	0.127 (0.032)	0.124 (0.026)	0.153 (0.024)	0.158 (0.039)	0.157 (0.036)
B	0.087 (0.015)	0.089 (0.024)	0.088 (0.018)	0.098 (0.019)	0.099 (0.029)	0.098 (0.023)
C	0.017 (0.004)	0.017 (0.007)	0.017 (0.003)	0.019 (0.005)	0.020 (0.008)	0.019 (0.004)
E	-0.025 (0.004)	-0.026 (0.005)	-0.025 (0.004)	-0.029 (0.006)	-0.029 (0.006)	-0.027 (0.003)
F	-0.055 (0.011)	-0.055 (0.009)	-0.006 (0.000)	-0.063 (0.014)	-0.063 (0.010)	-0.066 (0.001)
G	-0.096 (0.014)	-0.097 (0.017)	-0.095 (0.013)	-0.111 (0.019)	-0.111 (0.018)	-0.109 (0.014)

Table 3. Comparison of pooled results for sales and rent, and sales only subsample for EPC reference D specifications. Pooled standard errors in parantheses.

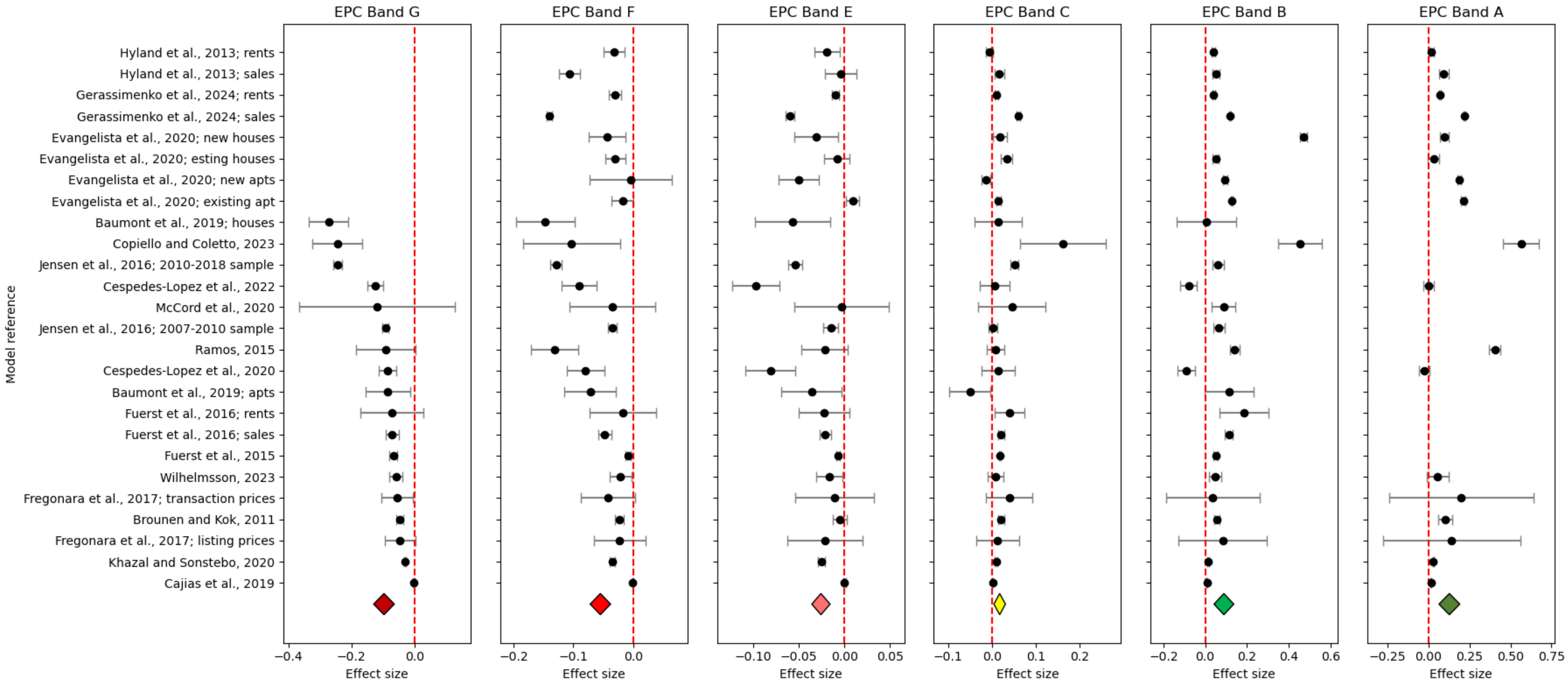


Figure 2. Forest plot with Hedges and Olkin Random Effects estimates. Reference category D. Diamond width represents 95% confidence interval.

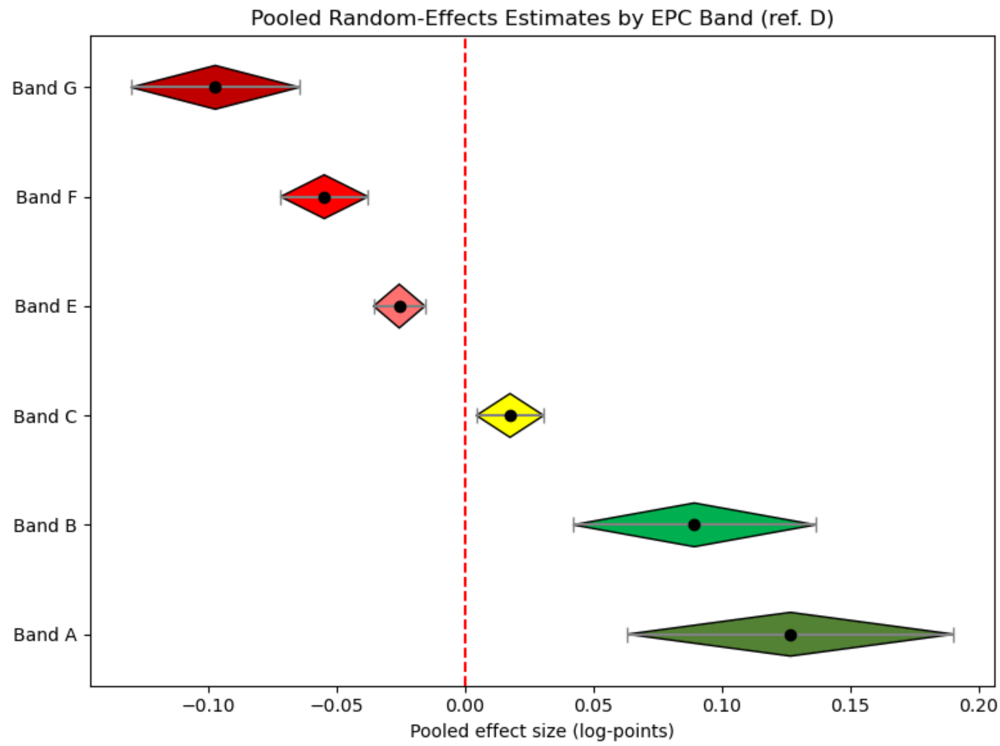


Figure 3. Hedges and Olkin Random Effects estimates. Reference category D. Pooled sales and rents subsample. Diamond width represents 95% confidence interval

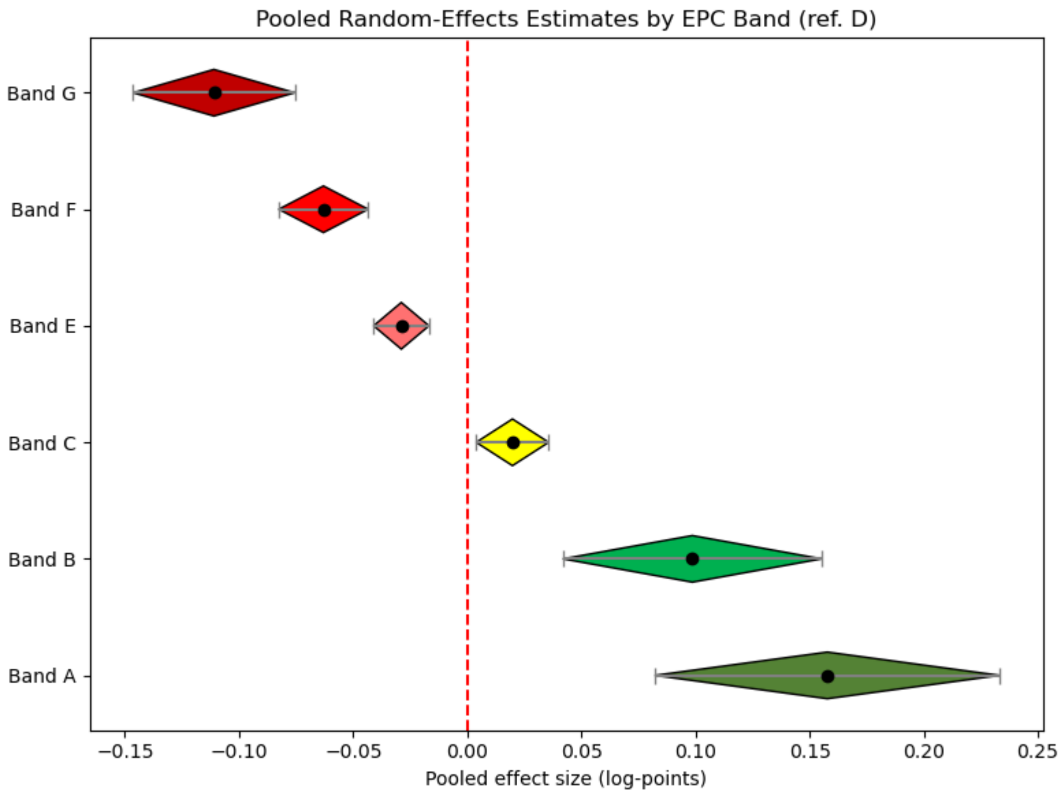


Figure 4. Hedges and Olkin Random Effects estimates. Reference category D. Sales only subsample. Diamond width represents 95% confidence interval

5. Conclusion

The results of the study show that there is a statistically significant green premium and a statistically significant brown discount as well. The magnitude of the green premium is estimated to range from 8% to 12% whereas the magnitude of the brown discount is estimated to range from -2% to -10%. Such a considerable magnitude confirms that raising awareness of energy costs and the potential benefits of energy efficieny retrofitting may in and of itself contribute to reaching the EU's decarbonisation goals, and that especially in the sales market nudges coupled with such campaigns may work effectively.

Limitations of the study include an overrepresentation of Western European countries, as the limited number of studies found for Eastern Europe did not have comparable specifications. A metaregression would be desirable as a potential further step of this analysis if more studies were available. Subject to greater resources, authors could be contacted to disclose unpublished results (e.g. standard errors), rerun analyses using specifications that are comparable so that results can be better harmonized, or their data.

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