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Opinion paper

Valuation of energy performance certificates in the rental market – Professionals vs. nonprofessionals

Aras Khazal *, Ole Jakob Sønstebø

NTNU Business School, Norwegian University of Science and Technology, Trondheim, Norway

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ABSTRACT

The implementation of Energy Performance Certificates (EPCs) is expected to reduce energy consumption and carbon emissions by providing actors with information that can be used to make better-informed decisions. This paper is the first to investigate EPCs in the Norwegian residential rental market. Applying the hedonic multilevel approach using information from some 440,000 rental contracts over the period of 2011–2018, we find that labeled dwellings have a premium compared with non-labeled dwellings, and that the premium is increasing with a higher EPC-label. We further define two classes of lessors – professional (real estate agents) and nonprofessionals (homeowners) – to study potential heterogeneity in EPC valuation and find that professionals assign higher rents compared with nonprofessionals. Dwellings with high energy efficiency are associated with a higher premium if rented out by a professional, a significant part of which stemming from higher EPC valuation. The results are robust to a number of heterogeneity analyses and after controlling for sample selection bias and unobserved locational heterogeneity. The findings of this paper signify the necessity to increase awareness and public dissemination regarding the EPC policy.

1. Introduction

The adverse effects of climate change have created one of the most important and debated issues of recent decades. The EU Commission has developed a number of measures to prevent or minimize the potential damage caused by energy consumption and carbon emissions. For example, the EU initiated the Energy Performance of Buildings Directive (EPBD) in 2002, which in turn led to the implementation of Energy Performance Certificates (EPCs) across the European Union. According to the International Energy Agency, the residential sector accounted for about 20 percent of the final energy consumption in Norway for 2017 (INTERNATIONAL ENERGY AGENCY, 2019). The EPC is an important instrument to enhance the energy performance of buildings by providing information for actors involved in the real estate market, solving issues regarding asymmetric information and achieving a higher pricing accuracy. Since rational actors are expected to have a higher willingness to pay for a marginal increase in energy efficiency, EPCs are assumed to create incentives to invest in the improvement of energy efficiency of buildings.

The EPBD is the EU's main legislative instrument to improve the energy performance of buildings. Although Norway is not part of the EU, it is also the basis for the Norwegian regulations on energy use in buildings. The EPC was introduced for the first time in the EPBD in 2002, and in 2010, the EPBD was recast to add a set of new requirements to improve the quality, usability and public acceptance of EPCs. The certificates were implemented in most European countries from 2006 and fully implemented in Norway on July 1, 2010. The Ministry of Petroleum and Energy and the Ministry of Local Government and Regional Development share the responsibility for implementation of the EPBD in Norway. The Norwegian Water Resources and Energy Directorate and Enova provide the managing body for the certification and inspection schemes.1.

This paper is the first to investigate the impact of EPCs on the residential rental market in Norway, adding to the existing EPC literature. Further, to our knowledge, we are the first to study potential heterogeneity in EPC valuation among market actors by defining two lessor types – professionals (real estate agents) and nonprofessionals (homeowners). We apply the hedonic multilevel approach on a highly representative dataset of some 440,000 observations over the whole of Norway for the period 2011–2018, and find that labeled dwellings are associated with a premium compared with non-labeled dwellings; green labels (A, B and C) have a premium of 5.8 percent and non-green labels

* Corresponding author.
E-mail address: aras.khazal@ntnu.no (A. Khazal).

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Table 1
Overview of literature on EPCs in European residential markets.

Reference	Country	Dep. var.	Sample size	Main findings
BROUNEN and KOK (2011)	Netherlands	Sales price/m^2	31,993	Premium of 10% for A-label and 5.5% for B-label compared with D-label.
CAJIAS and PIAZOLO (2013)	Germany	Market value and sales price/m^2	2615	Premium of 0.45% (sales) and 0.08% (rentals) per 1% increase in energy savings.
HYLAND et al. (2013)	Ireland	Listed sales and rental prices	15,060 (sales)/ 20,825 (rentals)	Price premium of 9.3% (sales) and 1.8% (rentals) for A-label, and 5.5% (sales) and 3.9% (rentals) for B-label compared with D-label.
FEIGE et al. (2013)	Switzerland	Rent/m^2	2453	Positive association between sustainable features and rental prices.
Högberg, (2013)	Sweden	Sales price	1073	Price premium for energy efficiency.
CERIN et al. (2014)	Sweden	Sales price	64,753	Energy performance associated with a price premium.
FUERST et al. (2015)	England	Sales price/m^2	333,095	A/B-rated dwellings achieve a premium of 5% compared to D-rated dwellings.
DE AYALA et al. (2016)	Spain	Sales price	1507	Price premium of 5.4 (ABCD-labeled) - 9.8% (ABC-labeled) compared to lower labeled dwellings.
FUERST et al. (2016b)	Finland	Sales price	6194	Price premium for ABC-labeled dwellings.
CHEGUT et al. (2016)	Netherlands	Sales price/m^2	17,835	Highly energy efficient dwellings sell for 2.0–6.3% more than similar dwellings with low energy efficiency.
STANLEY et al. (2016)	Ireland	List prices	2792	Energy efficiency has a positive effect on residential property list prices.
WAHLSTRÖM (2016)	Sweden	Market value	69,698	No price premium for energy efficient housing.
HÅRSMAN et al. (2016)	Sweden	Sales price	69,698	No additional premium associated with the label itself.
FUERST et al. (2016a)	Wales	Sales price/m^2	62,464	Premium of 12.8% for A/B-label compared with D-label.
OLAUSSEN et al. (2017)	Norway	Sales price/m^2	2066	No premium for labeled dwellings.
KHOLODILIN et al. (2017)	Germany	Asking price/m^2 and rental price/m^2	7298 (sales)/13,366 (rentals)	Energy savings are generally capitalized in prices and rents.
DRESSLER and CORNAGO (2017)	Belgium	Rental price/m^2	6262	Highly energy efficient dwellings achieve a premium of 4.8% compared to inefficient dwellings.
FREGONARA et al. (2017)	Italy	Sales price	879	No label impact on prices.
TALTAVULL et al. (2017)	Romania	Sales price	16,420	Premiums of 2.2–6.5% for retrofitted green dwellings.
AYDIN et al. (2017)	Netherlands	Sales price	30,036	Energy efficiency is capitalized into prices, but not the labeling itself.
CAJIAS et al. (2019)	Germany	Asking rents	1,029,202	Small but significant rental premium for green dwellings.

(D, E, F and G) have a premium of 2.5 percent. When we instead consider each label separately, premiums are increasing with higher EPC rating, with 5.1, 6.6 and 6.9 percent higher rents for C-, B- and A-labels, respectively. Comparing only labeled dwellings, improvements in energy efficiency from a G-label to an A is expected to yield a rental premium of about 5.9 percent. Further, for dwellings with the same characteristics and EPC-label, we find that professionals assign higher rents compared with nonprofessionals. Dwellings with high energy efficiency are associated with a 5.0 percent higher premium if rented out by a professional, where 1.8 percent is the difference in green-label valuation. The results are robust to a number of robustness checks and provide implications for policy makers.

The remainder of the paper is structured as follows: Section 2 offers a literature review, Section 3 explains the EPC policy, Section 4 describes the data, Section 5 outlines the methodology, Section 6 presents the results and, finally, Section 7 concludes.

2. Literature review

The relation between energy efficiency and capitalization have been subject to several studies with contradictory conclusions in both the commercial and residential real estate markets. In the US commercial office market, EICHHOLTZ et al. (2010) conducted a study on the impact of green labels on rents and sales prices, and found that green buildings earned a rental premium of 3–7 percent, and a sales premium of 16 percent. EICHHOLTZ et al. (2013) also found increased energy efficiency to be fully capitalized into rents and asset values. WILEY et al. (2010) found that green buildings achieved superior rents and a significant premium for the selling price of eco-certified properties. As FUERST and MCALLISTER (2011a) argue, these results need to be treated with caution, due to limitations in locational controls in their hedonic model. After controlling for actual submarkets' locational effects, FUERST and MCALLISTER (2011a) found that buildings with an eco-certificate obtained both rental and sales premiums. Notwithstanding, Fuerst and McAllister (2011b), conducted a study on commercial property assets from the main UK regions, such as London West End and London City, and found no evidence of a relationship between EPCs and rental values. In contrast, KOK and JENNEN (2012), in a study of commercial leasing transactions in the Netherlands over the 2005–2010 period, found that energy-efficient buildings enjoyed a premium compared with inefficient, but otherwise similar buildings.

Table 1 offers an overview of the EPC literature in European residential markets. While the majority find that there is a premium associated with energy efficiency for both sales and rental prices, several studies conclude that there are no positive price premiums. SALVI et al. (2010) conducted a study in Zürich and argued that both Swiss owner-occupiers and renters are willing to pay a significant premium for green buildings. In the Netherlands, BROUNEN and KOK (2011) found that buyers are willing to pay a price premium for dwelling labeled as energy efficient. HYLAND et al. (2013) examined the effect of the Irish system of energy efficiency ratings on both house prices and rents and concluded that the energy efficiency has a positive effect on both sales and rental prices of properties, but that the effect is stronger for the sales segment. In the German market, CAJIAS and PIAZOLO (2013) found that energy-efficient homes have higher rents than otherwise comparable inefficient homes when considering town-fixed effects. KHOLODILIN et al. (2017) investigated the energy performance ratings on the rental market across Berlin's city districts by looking at energy savings and provide evidence that energy savings are generally capitalized in prices and rents. CAJIAS et al. (2019) also found a small but significant premium associated with German green rental dwellings. CHEGUT et al. (2019) find that energy efficiency is capitalized into assessed values of rental housing in England and the Netherlands.

Conversely, Murphy (2014), conducting an online survey in the Netherlands, suggests that EPC has a weak influence, especially pre-purchase. In the Dutch market, AYDIN et al. (2017) document that the signaling effect of the EPCs is non-significant, when controlling for actual energy consumption and a wide variety of observable dwelling characteristics. OLAUSSEN et al. (2017) applied a hedonic time dummy model and a fixed effect model on sales price observations from the Norwegian capital, Oslo, and found no evidence of a price premium. In the Swedish market, Högberg, 2013 and CERIN et al. (2014) find premiums for energy efficiency and performance, while WAHLSTRÖM (2016) and HÅRSMAN et al. (2016) find no additional premium related to the label itself.

3. Background

The EPC is a legal document produced during certification and includes an energy performance rating scale, A to G, where A indicates very efficient and G indicates very inefficient. The Norwegian EPCs are identical for both sales and rental dwellings, and similar to the certificates in the EU. The aim is to provide stakeholders with the information they need to make better decisions and integrate energy efficiency into their decision-making processes. The information from EPC should also provide an incentive for stakeholders in this market to invest in energy efficiency because it is expected that improving the energy efficiency of a building may lead to higher transaction prices and rents on the market.

The EU Commission required that certificates must be included in all advertisements in commercial media when a building is announced for sale or rent. While there were 11,810 registered homes in Norway with an EPC in July 2010, the number increased to 993,298 by December 2019, which amounts to about 40 percent of total dwellings (Energimerking.no, 2020, STATISTICS NORWAY, 2019a). However, in the rental market, there is still a substantial percentage of dwellings advertised without an EPC rating; in fact, more than 75 percent of observations in our data are non-labeled. One reason for this may be poor diffusion of information about EPC policy by the managing body. Another reason may be related to the penalty system – although certification of dwellings for sale or rent is mandatory, there is no effective system in place to enforce this requirement. In order to detect owners who do not label, supervision from the managing body is necessary if there are no complaints from consumers, and it seems that buyers demand certifications to a greater extent than tenants. Additionally, imposing fines for failing to meet requirements regarding technical facilities and heating systems are prioritized over imposing fines for lack of certification (Ministry of Petroleum and Energy, 2010).

Owners of existing apartments and buildings have a cost-free self-assessment option under the Norwegian scheme of certification. The owner inputs data on the Internet to the Energy Certification System, including year of construction, number of bedrooms, area, and building type among other attributes. These data generate typical values for the parameters needed for the calculation, and the certificate is instantly produced. Whereas the quality and precision of the self-assessment option is trust-based, a qualified expert is required for certification of new buildings. However, the legal responsibility for ensuring that the certification is correct is always on the homeowner. The certificate can be updated at any time and is valid for 10 years. Because of technical building regulations, all new buildings will normally achieve at least the energy grade C, while A- and B-labels are normally reserved for buildings with better energy quality than required (Isachsen et al., 2011).

Normally, dwellings are rented out either by a real estate agent or the homeowner, by posting advertisement on Finn.no with a date for the showing. Since bargaining is not common in the Norwegian rental market, contract prices are usually equal to posted prices. The legal framework for setting prices allows for only two ways to raise rents after the contract is signed (Ministry of Local Government and Modernisation, 2000). First, the rent can be adjusted at the earliest after twelve months in accordance with the Consumer Price Index (CPI) (provided by Statistics Norway) if a written one month's notice is given, and then changed only once a year. Equivalently, the tenant has the right to demand a reduction if the CPI decreases. Second, after a three-year residency the rent can be adjusted to the common (market) rent if requested by either the landlord or the tenant, comparing similar rental dwellings and contracts in the same area. The tenant only has to pay the contracted rent, as all other expenses are the homeowner's responsibility, e.g. maintenance costs and property insurance.

4. Data and descriptive statistics

The data is provided by Norway's largest and most popular online advertisements site, Finn.no, with a market share of property sales advertisements close to 100 percent and a majority of rental advertisements. Finn.no is the most commonly used data source for housing studies in the Norwegian market. The dataset contains information about the dwellings, such as posted rental price per month, issue date of advertisement (year and quarter), size, number of bedrooms, floor location, information about age, type of dwelling (apartments, detached, semidetached and townhouse), energy labeling, whether the lessor is a professional or a nonprofessional, and whether the dwelling is furnished, has a balcony, includes broadband and is centrally located. Location information is specified at three hierarchical levels: county, municipality, and zip code. However, the data does not contain street level address information and is therefore treated as cross sectional, since we are unable to follow the same unit over time. The sample contains 441,123 observations over the period from January 2011 to January 2018 and comprise the whole of Norway.[2]

While the majority of Norwegians own their homes, about 18 percent of the population or 23 percent of households live in rented dwellings (STATISTICS NORWAY, 2019b). The data used in this study is highly representative for the rental market, with all 18 counties, as well as 97.5% of the country's municipalities and 70.3% of the country's zip codes represented. Some 23% of the observations are energy labeled, while 77% include no energy performance information. Comparing labeled and non-labeled dwellings (Table 2), the average size, number of bedrooms, proportion of ads containing age information and distribution of dwelling type are similar, while labeled dwellings have a higher average rental price of EUR 1151 compared with.

EUR 1029 for non-labeled dwellings over the sample period. The dwelling types represented in the sample consist of apartments, freeholds detached, freeholds semidetached, and townhouses, where apartments count for 85% of the total observations. The shares of labels seem to be relatively equally distributed both within and across dwelling types (see Appendix Table A1).

Fig. 1 reports the yearly average rents for Norway and the four largest cities including the capital Oslo over the sample time period. As expected, rents are higher in the largest cities compared to the national average. We observe that the rental market follows the general trends in the real estate transaction market: Stavanger, the oil capital, had the highest boom after the financial crisis, but falling oil prices led to a significant bust after 2013 and rents are actually lower than the national average after 2016. Oslo has had a persistent boom market each year, while the boom in Bergen and Trondheim peaked in 2014 and 2013, respectively, followed by a relatively stable trend.

5. Methodology

We employ the hedonic model developed by COURT (1939) and ROSEN (1974) to explicitly investigate the impact of market actor heterogeneity on rental prices. The hedonic model implies that the rental price of a dwelling can be modeled as a function of its characteristics to determine how each characteristic uniquely contributes to the total unit rent. To control for all locational levels, we apply the multilevel approach, also known as the Hierarchical Linear Model (HLM) or the Random Intercept Mixed Model, dated back to GOLDSTEIN (1986). This method became popular within educational research, in which students were nested within school classes, which again were nested within schools. While the assumption of independence of units is breached in such data because of nesting in the ordinary regression models, the HLM models provides the opportunity to incorporate the variance in the dependent variable measured at the individual level, by examining information from all levels of analysis. The hedonic function can be formulated as a four-level HLM:

Table 2
Summary statistics of labeled and non-labeled dwellings.

	Labeled		Non-labeled	
	Mean	St. Dev.	Mean	St. Dev.
Rental price (€)	1150.92	391.08	1029.41	378.97
Size (m^2)	70.91	31.87	69.51	31.00
Floor	1.47	1.73	1.16	1.55
Bedrooms	1.83	0.95	1.79	0.96
Energy label (percent)				
A	17.09			
B	12.88			
C	16.73			
D	16.87			
E	11.00			
F	8.94			
G	16.49			
Furnished (percent)	15.81		15.86	
Balcony (percent)	41.27		33.93	
Broadband (percent)	46.93		40.81	
Centrally located (percent)	42.99		44.46	
Age information (percent)	0.56		0.64	
Dwelling type (percent)				
Detached	8.75		10.08	
Apartment	85.42		84.81	
Townhouse	1.92		1.38	
Semidetached	3.91		3.73	
Lessor type (percent)				
Professionals	22.78		7.52	
Nonprofessionals	77.22		92.48	
Year of transaction (percent)				
2011	5.62		12.47	
2012	8.86		12.32	
2013	12.78		12.42	
2014	16.35		13.80	
2015	19.01		15.41	
2016	18.35		16.32	
2017	18.07		16.27	
2018	0.95		0.98	
Hierarchical location (N)				
Zip-code	2636		3314	
Municipality	366		411	
County	18		18	
Number of observations	101,484		339,795	

Note: Conversion rate: 1 NOK = 0.10 EUR (nominal exchange rate per February 17, 2020). Rental prices are averaged over the whole sample period. Size in square meters (1 m^2 = 10.8 sq. feet).

$$p_{ijkl} = \alpha + \beta_m X_{ijklm} + \gamma_n E_{ijk\ \ln} + e_l + v_k + u_j + \varepsilon_{ijkl}, \quad (1)$$

where the dependent variable, p, is the natural logarithm of the rental price for dwelling i located in zip-code j in municipality k in county l. X_m is a set of M hedonic characteristics, dummies for year and quarters to capture seasonal effects. E_n refers to green labeled (A, B and C) and non-labeled dwellings, where the reference group is non-green labels (D, E, F or G). Alternatively, E_n refers to the specific label ranging from A to G and non-labeled dwellings, where the reference group is the D-label.

The multilevel equation consists of two parts: the *fixed effect part*, denoted by the parameters α (the overall mean intercept), β and γ, and the *random effect part* denoted by e, v, and u that refer to the error terms for the county, the municipality, and the zip-code levels, respectively, while ε is the model's overall error term (individual level). The error terms are assumed to be normally distributed and uncorrelated with all independent variables. The advantage of equation (1) is the additional ability to provide estimates of the variances (σ_e^2, σ_v^2, σ_u^2, and σ_ε^2) of the error terms, using *Maximum Likelihood* (ML).[3] To assess the necessity of the inclusion of each level, we determine the proportion of the total variability in the rental prices that is attributable to each level by calculating the *Variance Partition Coefficient* (VPC), also called the *Interclass Correlation Coefficient*. For example, the VPC of the zip-code level is the variance σ_u^2 divided by the sum of variances ($\sigma_e^2 + \sigma_v^2 + \sigma_u^2 + \sigma_\varepsilon^2$). A rule of thumb implies that a VPC higher than 5 percent should not be ignored (Mehmetoglu and Jakobsen, 2016).

Since labeling itself may be subject to self-selection bias, we use the Heckman two-step selection method when we estimate equation (1) using the labeled-only subsample (HECKMAN, 1979). In the first step we estimate a Probit equation where the dependent variable is a dummy that takes the value 1 if labeled and 0 otherwise, as a function of all explanatory variables in equation (1) and the number of quarterly new labeled dwellings at the municipality level. In the second step we run equation (1) including robust estimates of the inverse Mills ratio ($\hat{\lambda}$) from the first step to control for any potential selection bias.

6. Results

6.1. The impact of EPCs on rents

Table 3 reports four specifications of the HLM estimations of equation (1). In columns 1 and 2 we consider the whole sample (N =

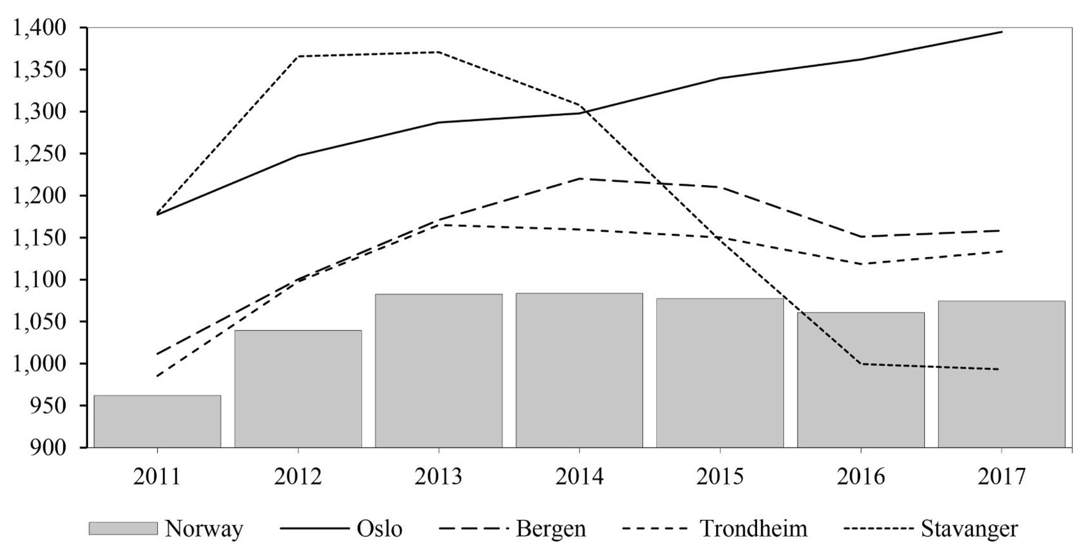

Fig. 1. Yearly average rents (EUR) over time for Norway and the four largest cities. Note: Conversion rate: 1 NOK = 0.10 EUR (nominal exchange rate per February 17, 2020). Rental prices are averaged by year.

Table 3
Main results of hedonic HLM for the whole sample and labeled-only subsample.

	Whole sample (1)	Whole sample (2)	Labeled (3)	Labeled (4)
EPC:				
Green	0.0334*** [29.71]		0.0344*** [30.32]	
Non-labeled	−0.0254*** [-430.11]	−0.0424*** [-31.28]		
Label A		0.0269*** [14.50]		0.0284*** [16.08]
Label B		0.0132*** [6.59]		0.0131*** [6.91]
Label C		0.0086*** [4.65]		0.0092*** [5.26]
Label E		−0.0243*** [-11.66]		−0.0250*** [-12.82]
Label F		−0.0321*** [-14.36]		−0.0350*** [-16.47]
Label G		−0.0236*** [-12.33]		−0.0308*** [-16.23]
Reference	Non-green	Label D	Non-green	Label D
Size	0.0097*** [248.34]	0.0097*** [248.59]	0.0094*** [98.89]	0.0095*** [99.40]
Size^2	−0.0000*** [-155.81]	−0.0000*** [-155.89]	−0.0000*** [-66.62]	−0.0000*** [-66.96]
Bedrooms	0.0948*** [206.21]	0.0948*** [206.17]	0.0813*** [85.47]	0.0814*** [85.82]
Contains age	0.0897*** [26.04]	0.0883*** [25.61]	0.2221*** [11.55]	0.2181*** [11.37]
Floor	0.0080*** [43.65]	0.0080*** [43.50]	0.0090*** [27.35]	0.0090*** [27.53]
Furnished	0.0340*** [44.25]	0.0339*** [44.18]	0.0263*** [17.03]	0.0257*** [16.73]
Balcony	0.0422*** [64.38]	0.0421*** [64.23]	−0.0059 [-1.37]	−0.0062 [-1.43]
Broadband	0.0098*** [14.86]	0.0097*** [14.80]	−0.0349*** [-10.13]	−0.0352*** [-10.23]
Central location	0.0043*** [6.49]	0.0042*** [6.23]	0.0437*** [11.26]	0.0439*** [11.33]
Apartment	0.0155*** [7.06]	0.0159*** [7.21]	−0.0307*** [-6.63]	−0.0290*** [-6.27]
Townhouse	−0.0179*** [-12.56]	−0.0175*** [-12.28]	−0.0348*** [-12.14]	−0.0326*** [-11.39]
Semi detached	−0.0264*** [-23.60]	−0.0258*** [-23.14]	−0.0079* [-2.50]	−0.0047 [-1.50]
Year effect	✓	✓	✓	✓
Seasonal effect	✓	✓	✓	✓
Selection variable ($\hat{\lambda}$)			−0.3449*** [-10.83]	−0.3418*** [-10.75]
Constant	7.9199*** [198.35]	7.9359*** [198.60]	8.6239*** [123.31]	8.6306*** [123.51]
Hierarchical variation:				
County var. [VPC]	0.0256*** [0.24]	0.0256*** [0.24]	0.0168*** [0.19]	0.0169*** [0.19]
Municipality var. [VPC]	0.0390*** [0.37]	0.0391*** [0.37]	0.0374*** [0.42]	0.0376*** [0.42]
Zip code var. [VPC]	0.0127*** [0.12]	0.0127*** [0.12]	0.0101*** [0.11]	0.0101*** [0.11]
Residual var. [VPC]	0.0287*** [0.27]	0.0287*** [0.27]	0.0241*** [0.27]	0.0240*** [0.27]
Observations	440,172	440,172	101,277	101,277
LR chi2(3) [P-value]	420000 [0.00]	430000 [0.00]	96700.1 [0.00]	96834.4 [0.00]
Adjusted R^2	0.76	0.76	0.77	0.77

Note: Rental observations are from the Norwegian market over the period of 2011–2018. Yearly and seasonal effects have been included but not reported. *Var.* stands for the variance coefficient. VPC is the *Variance Partition Coefficient* that determines the proportion of the total variability in the rental prices that is attributable to each level. *t* statistics in brackets. The number of new labeled dwelling at municipality level is included as the selection variable in the first stage Probit regression. Estimation results of the first stage are not reported. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

440,172) of labeled and non-labeled dwellings, whereas in columns 3 and 4 we consider a subsample of labeled-only dwellings ($N = 101{,}277$). The estimated model explains 76 percent of the variation of the natural logarithm of rental prices when using the whole sample in columns 1 and 2, and 77 percent for the subsample in columns 3 and 4. The coefficients of the control variables in all estimations are in line with the economic theory and previous literature in both sign and magnitude. Both year and quarterly dummies have been included to control for macroeconomic shocks and seasonal variations. We control for hierarchical locational variations across 18 counties, 415 municipalities and 3414 zip codes in the whole sample estimations, and 18 counties, 366 municipalities and 2636 zip codes in the subsample estimations.

The first specification in column 1 treats the labels as green and non-green, where the non-green dwellings is the default group. The green coefficient is positive and significant, suggesting a premium of 3.3 percent compared to non-green, and the non-labeled dwellings are associated with a 2.5 percent discount compared to non-green labeled dwellings. Hence, the premium is 5.8 percent for green-labeled dwellings compared with non-labeled.

In column 2 we treat the EPCs separately, where the D-label is the default category. The coefficients of A-to C-labels are positive and highly significant, indicating higher rents for dwellings with higher EPC ratings, whereas E−to G-labels have negative and significant coefficients, indicating a discount. The A-label is associated with a 2.7 percent higher rent, whereas the G-label yields a 2.4 percent lower rent compared with the D-label. This implies a premium of some 6.9, 6.6 and 5.1 percent for A-, B- and C-labels, respectively, compared to non-labeled. Moreover, the non-labeled coefficient is significantly lower than all EPC ratings. The non-labeled dwellings would achieve ratings from A to G if labeled today, and therefore the idea of comparing labeled and non-labeled is to identify the impact of the EPC policy as a whole, where the only difference is whether they are labeled or not. If the label itself does not have any impact on rents, one would expect the non-labeled dwellings to achieve at least the same rent as the lowest rated dwellings (non-green, or at least F- or G-labels). However, our findings imply that regardless of energy efficiency, labeled dwellings are always associated with a premium, signifying the impact of labeling itself on rents.

In order to better assess whether energy efficiency is capitalized in rents, we investigate the labeled-only subsample reported in column 3 and 4. The positive and significant green coefficient suggests a premium of 3.4 percent compared with non-green homes. Compared with the D-label, the A-label is associated with 2.8 percent higher rents and the G-label have a discount of 3.1 percent. Comparing A-to G-labels the corresponding premium is about 5.9 percent. Although the selection variable – the inverse Mills ratio – is significant and negative, providing evidence of selection bias in the subsample, the results across all specification are robust. The increasing premium with a corresponding increase in the label rating – indicating a premium for improvement in the energy efficiency of dwellings – is in line with the economic incentives proposed by the policy implementation. Our findings seem reasonable considering the premiums for energy efficiency found in the existing literature on rental markets (see Table 1).

6.1.1. Heterogeneity analyses

We conduct a number of heterogeneity analyses to address the potential omitted variable issue that may originate from unobserved characteristics. We re-estimate the specification from Table 3, column 1 over time and across the largest cities and household composition according to factors such as type of dwelling, living area and number of bedrooms. Table 4 reports the yearly estimated green premiums and non-labeled discounts over time. We also estimate the quarterly premium over time, presented graphically in the Appendix Figure A1, using the labeled sample. The results are similar to Table 3 estimations and provide evidence that the relation between rents and EPCs has been stable over time.

In Fig. 3 we graphically report the estimated green premiums from the labeled sample with 95 percent confidence intervals.[4] Panel A shows that green premiums are lower in Oslo and Stavanger compared with the other large cities and the rest of Norway. This may be due to high demand and low supply in Oslo and Stavanger, which has also been found to be the case in large German cities (Cajias et al., 2019). Hence, a sample including only the capital Oslo could lead to unreliable results for policy implications. In panel B we report estimated green premiums by dwelling type. Except for a higher premium for semidetached homes there is no pattern among the other dwelling types. The estimated green premiums seem to increase with increasing living area in Panel C. This shows that dwellings with the same energy efficiency (green) are associated with higher premiums when the living area is larger, which seems reasonable considering that energy consumption due to heating is higher for larger dwellings, increasing the importance of energy efficiency. Similarly, the premium in Panel D is increasing with the number of bedrooms. A potential endogeneity issue is the possibility that EPCs are merely measuring the unobserved dwelling quality. Although it is difficult to rule out the presence of endogeneity, the fact that the green premium is increasing in Panel C and D is indicative of the true label impact on rents, as unobserved quality is not necessarily associated with/dependent on dwelling size or the number of bedrooms.

6.1.2. Model assessment

Because ignoring location may lead to bias estimation, both LR test and result from VPCs reported in Table 3 provides evidence that the estimated HLM model is appropriate and preferred for standard estimated models without sufficient control for locations. We further estimated the HLM and predict the quarterly average rents without controlling for any location, and when including one, two and three location levels. Comparing these predictions with the actual rents (Fig. 2) we observe that when controlling for all location levels a high prediction accuracy is achieved. The importance of location is well known in the real estate universe and we argue that it is necessary to utilize a highly representative data for the whole market to investigate the policy impact. Thus, comprehensive location control is essential.

In the Appendix, Table A3 reports the HLM estimation results when drawing random subsamples of 75, 50 and 25 percent of the total. Additionally, instead of estimating the HLM by maximum likelihood we re-estimate equation (1) with OLS by applying a Multi-Way Fixed Effects model, developed among others by GAURE (2010) and GUIMARAES and PORTUGAL (2010).[5] The results of these four estimations are almost identical to the HLM results from Table 3, column 1, supporting our main findings.

6.2. Professionals vs. nonprofessionals

So far, we have investigated the overall EPC impact on rents ignoring potential heterogeneity among lessors' valuation of energy efficiency. Taking advantage of the lessor type information available in our data, we further explore whether professionals and nonprofessionals capitalize energy efficiency equally in rents. By profession, real estate agents typically have expert knowledge about the market, superior access to information and marketing skills, and we therefore define this agent group as *Professionals*. As homeowners are usually less experienced in the market, we define this group as *Nonprofessionals*. Table A2 in the Appendix presents summary statistics for professionals and nonprofessionals. Labeled dwellings account for 47 percent of the total for professionals and 20 percent for nonprofessionals. The average rent for professionals is EUR 1307 and EUR 1026 for nonprofessionals over the sample period. Average size and number of bedrooms are similar for both groups. Note that while the proportions of both A- and B-labeled dwellings are higher among nonprofessionals, the proportions of C- to G-labeled dwellings are higher among professionals. Moreover, only 1.6 percent of dwellings advertised by nonprofessionals are G-labeled, while the share is 21.3 percent for professionals. Fig. 4, Panel A shows that the yearly average rental prices of dwellings are higher for professionals than for nonprofessionals over time. Panel B shows a clear average rental price difference between professionals and nonprofessionals in each energy label category.

To shed light on this relationship, we re-estimate equation (1) including a dummy variable – taking the value 1 if the lessor is a professional and 0 if nonprofessional – to control for the overall heterogeneity, and adding interaction terms with labels in order to test whether these two groups have equal valuation of EPCs. Table 5 reports these estimations for the labeled-only subsample.

The dummy variable *Professionals* indicates that, on average, dwellings rented out by professionals have 3.9 percent higher rents than nonprofessionals. The interaction term *Green* × *Professionals* suggests that a dwelling with high energy efficiency (green) is associated with a 5.0 percent higher premium if rented out by a professional, where 1.8 percent is the difference in green-label valuation. We also include interaction terms for each label, reported in the Appendix Table A4, with consistent results. Using expected rents, the results suggest that, for instance, a non-green apartment can be rented out by EUR 1000 per month on average if the lessor is nonprofessional, while the expected rent is EUR 1032 if labeled green. Further, for the same green dwelling, the expected rent is EUR 1089 if rented out by a professional. Thus, the total difference for the green dwelling in expected rents between a professional and a nonprofessional is EUR 57, and the amount coming from the difference in EPC-valuation itself is EUR 18.

A number of factors may explain the heterogenous valuation in the *Professionals* variable, such as market experience in terms of better information, expertise and marketing. One possible explanation for the heterogenous EPC-valuation in the interaction term *Green* × *Professionals* could be that professionals use EPC labels as an additional quality indicator to raise rents. It may be argued that the average higher label premium among professionals is because they choose better

Table 4
Green premiums over time.

	2011	2012	2013	2014	2015	2016	2017
Green	0.0359***	0.0327***	0.0293***	0.0326***	0.0307***	0.0337***	0.0377***
	[7.53]	[8.65]	[9.44]	[12.19]	[12.64]	[13.24]	[14.82]
Non-labeled	−0.0197***	−0.0277***	−0.0379***	−0.0343***	−0.0263***	−0.0223***	−0.0137***
	[-5.64]	[-10.64]	[-17.02]	[-17.26]	[-14.11]	[-11.12]	[-6.77]
Controls	✓	✓	✓	✓	✓	✓	✓
Observations	47,538	50,396	54,662	62,894	71,022	73,533	73,197
Adjusted R^2	0.77	0.78	0.79	0.78	0.77	0.76	0.77

Note: All variables from equation (1) included but not reported (*Controls*). The default is non-green dwellings. *t* statistics in brackets * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

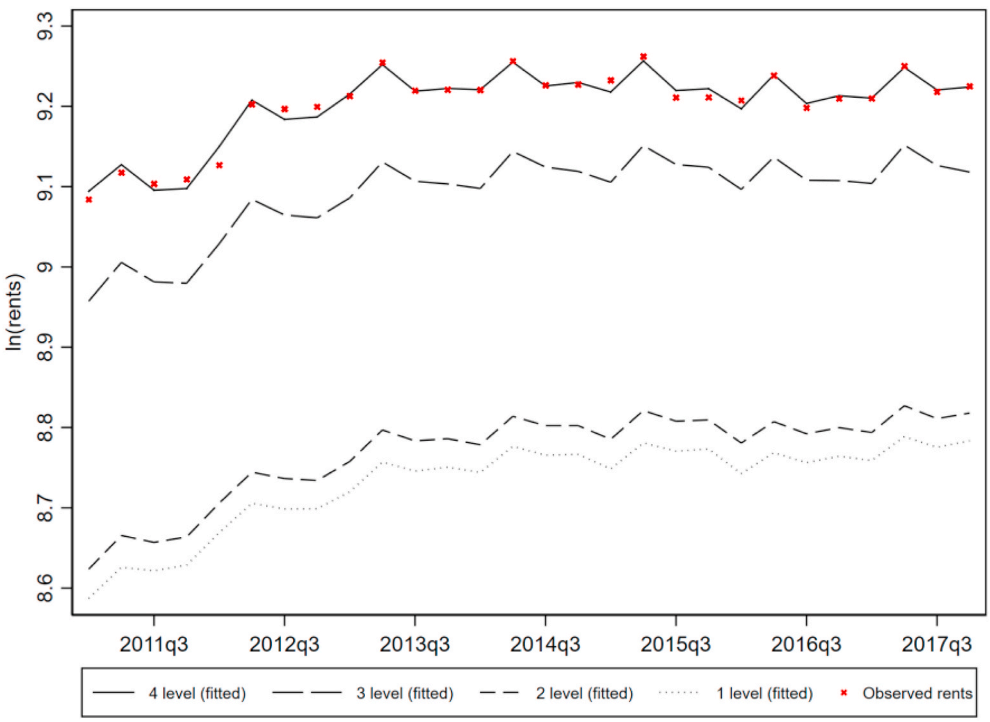

Fig. 2. Quarterly averages of observed and predicted monthly residential rents (log) from various-level HLMs over the period of 2011–2018. Note: The figure reports quarterly averages of residential monthly rents. Red crosses are observed asking rents. The dotted line is the predicted rents from the 1-level HLM, considering only the individual level. The dashed line is the predicted rents from the 2-level HLM, additionally controlling for the zip code level. The long-dashed line is the predicted rents from the 3-level HLM, additionally controlling for the municipality level. The black line is the 4-level HLM, additionally controlling for the county level. Data source: Finn.no.

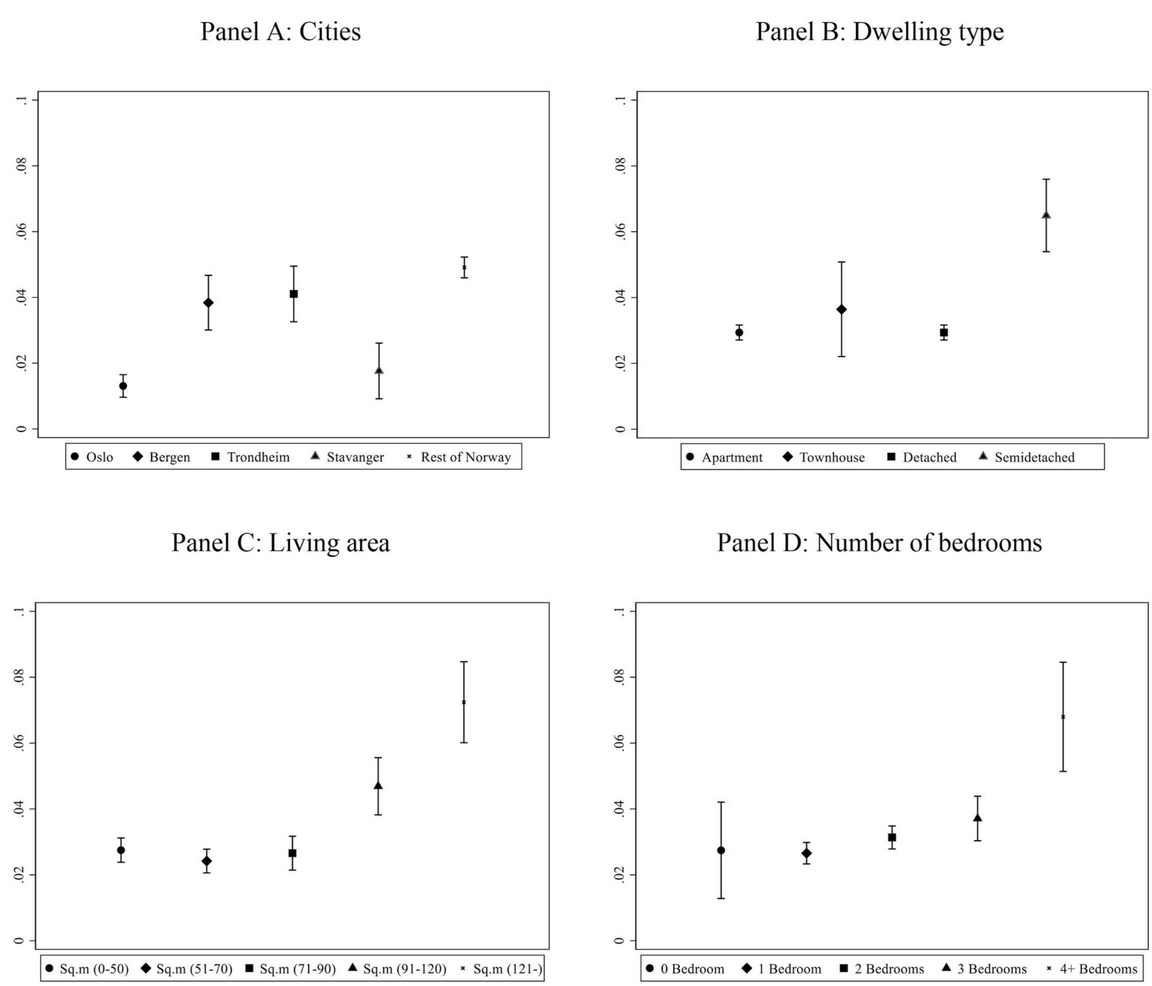

Fig. 3. Heterogeneity analyses of green premiums. Note: The figure shows the green coefficients from estimations of equation (1) for the labeled sample. The reference group is non-green dwellings. 95 percent confidence intervals.

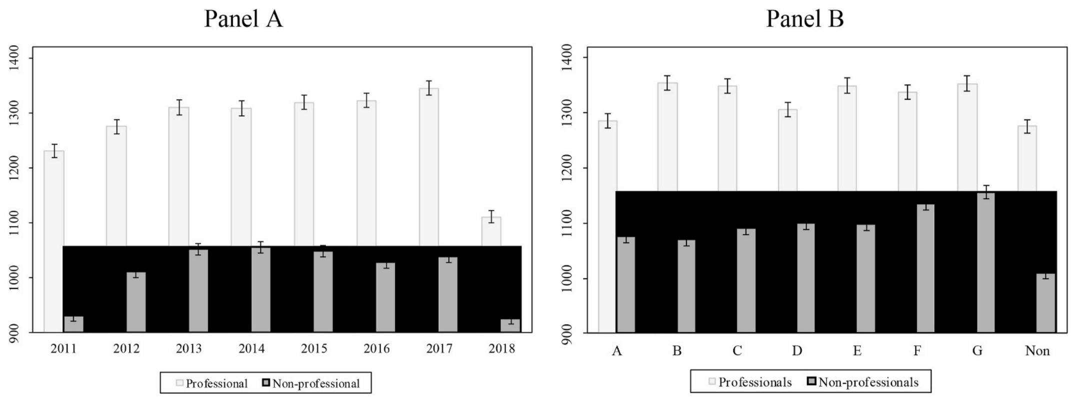

Fig. 4. Average rental prices (EUR) of dwellings for professionals and nonprofessionals over time (2011–2017), and by EPC rating. Note: Panel A reports the average monthly rents for each year for professionals and nonprofessionals. Panel B reports the average rents by EPC-labeled and non-labeled dwellings, for both professionals and nonprofessionals. Both graphs are reported with 99 percent confidence intervals. Panel A 2018 contain information only for the capital Oslo.

Table 5
Professional and nonprofessional EPC valuation.

	Labeled sample
Green	0.0321*** [26.67]
Professionals	0.0387*** [24.19]
(Green × Professionals)	0.0178*** [5.45]
Controls	✓
Observations	100,955
Adjusted R^2	0.77

Note: All variables from equation (1) included but not reported (Controls). The default is non-green dwellings.
t statistics in brackets * $p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

quality homes which are also more energy efficient. However, this does not seem to be the case when looking at Fig. 5, illustrating the distribution of labels among professionals and nonprofessionals. The figure clearly displays two different trends for agents: for professionals, the proportion of labels is increasing with a lower score, whereas the proportion is more equally distributed and with a relatively higher share of green labels among nonprofessionals.

7. Conclusion and policy implication

The implementation of energy performance certificates in European housing markets is expected to reduce energy consumption and carbon emissions by creating incentives for the actors involved to invest in improvement of energy efficiency. This paper is the first to investigate the impact of EPCs on the residential rental market in Norway, adding to the existing EPC literature. Further, to our knowledge, we are the first to analyze agent heterogeneity through EPC label valuation, applying the hedonic multilevel approach on a highly representative dataset of some 440,000 observations over the whole of Norway for the period 2011–2018.

We start by investigating the overall EPC impact on rents. Our results show that labeled dwellings have a premium compared with non-labeled dwellings, and that the premium increases with a higher EPC-label. Green dwellings are associated with a premium of 3.3–3.4 percent compared with non-green dwellings, while non-labeled dwellings have a discount of 2.5 and 5.8 percent compared with non-green and green dwellings, respectively. Considering each label separately, the finding suggests a premium of 6.9, 6.6 and 5.1 percent for A-, B- and C-labels, respectively, compared to non-labeled dwellings. The non-labeled dwellings would be expected to achieve at least the same rent as the

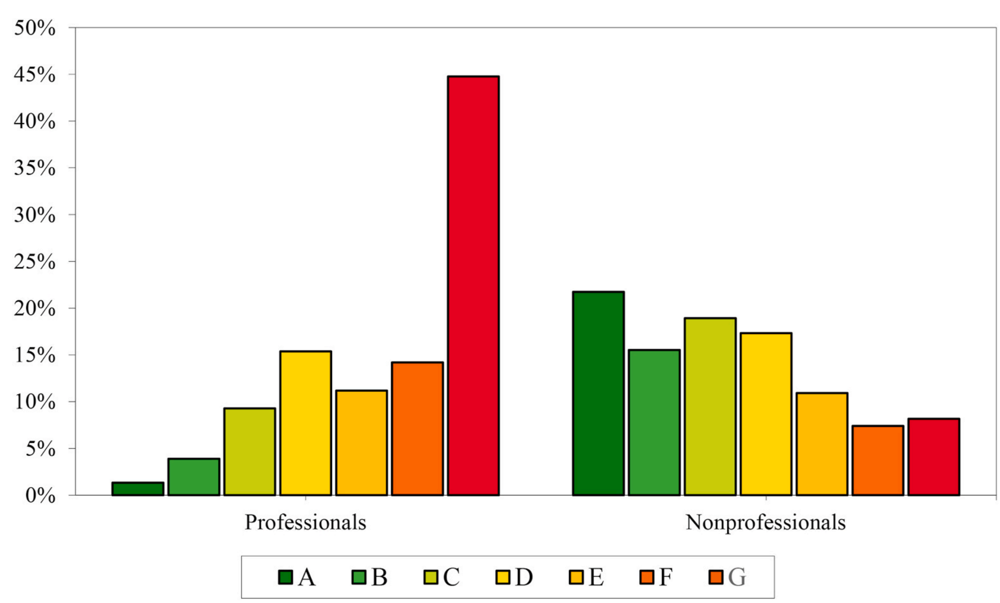

Fig. 5. Distribution of labels among professionals and nonprofessionals. Note: The distribution is the average share of labels over the sample period of 2011–2018. The high share of G-labels among professionals is explained by a combination of higher shares of both G-labels and professionals in larger cities.

lowest rated dwellings (non-green, or at least F- or G-labels) if labeled today. However, our findings imply that regardless of energy efficiency, labeled dwellings are always associated with a premium, signifying the impact of labeling itself on rents.

Further, we study potential heterogeneity in EPC valuation – taking advantage of the lessor type information available in our data, we explore whether professionals and nonprofessionals capitalize energy efficiency equally in rents. For dwellings with the same characteristics and EPC-label, we find that professionals assign higher rents compared with nonprofessionals. Dwellings with high energy efficiency are associated with a 5.0 percent higher premium if rented out by a professional, where 1.8 percent is the difference in green-label valuation.

Assessing the robustness of our findings, we control for potential endogeneity related to sample selection, unobserved locational heterogeneity, and conduct a number of heterogeneity analyses to address the potential omitted variable issue that may originate from unobserved characteristics. The results from the robustness cheeks all support our main findings. Moreover, we find that the impact of EPCs on rents is stable over time.

As the aim of the EPC implementation is to provide information for market actors and thereby creating incentives to invest in improving the energy efficiency of buildings, this paper provides important policy implications. Our findings are in line with the economic incentives proposed by the policy implementation. However, given the low proportion of labeled dwellings in the market despite the fact that labeling is mandatory and taking into account both the environmental and economic benefits of the policy's implementation, further efforts are needed from policy makers in raising awareness and streamlining the labeling process for the actors involved in the market, particularly for non-professional lessors.

CRediT authorship contribution statement

Aras Khazal: Methodology, Formal analysis, Writing - review & editing. **Ole Jakob Sønstebø:** Methodology, Formal analysis, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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12 Appendix

Table A1
Distribution of EPCs among types of dwelling

	Detached	Apartment	Townhouse	Semidetached
A	2.26%	4.17%	3.62%	2.84%
B	2.34%	3.00%	4.30%	3.12%
C	3.10%	3.88%	5.40%	4.52%
D	3.21%	3.93%	5.36%	4.00%
E	3.20%	2.42%	3.89%	2.72%
F	2.64%	1.92%	3.98%	2.83%
G	3.84%	3.80%	2.84%	3.81%
Non-labeled	79.41%	76.88%	70.60%	76.16%

Table A2
Summary statistics of professionals and nonprofessionals.

	Professionals		Nonprofessionals	
	Mean	St. Dev.	Mean	St. Dev.
Rental price (€)	1307.08	461.00	1026.41	362.96
Energy label (percent)				
A	0.63	7.89	4.34	20.37
B	1.85	13.47	3.10	17.33
C	4.41	20.54	3.78	19.07
D	7.30	26.01	3.46	18.27
E	5.31	22.42	2.14	14.62
F	6.74	25.08	1.48	12.06
G	21.27	40.93	1.63	12.65
Size (m^2)	68.03	33.96	70.05	30.84
Floor	1.95	1.98	1.14	1.52
Furnished (percent)	9.70	29.60	16.61	37.22
Balcony (percent)	33.70	47.27	35.86	47.96
Broadband (percent)	39.83	48.95	42.52	49.44
Centrally located (percent)	36.81	48.23	45.03	49.75
Age information (percent)	38.71	39.38		
Bedrooms	1.76	1.08	1.80	0.94
Dwelling type (percent)				
Detached	5.61	23.01	10.29	30.38
Apartment	90.77	28.95	84.23	36.44
Townhouse	1.55	12.35	1.50	12.14
Semidetached	2.07	14.25	3.98	19.56
Year of transaction (percent)				

(*continued on next page*)

Table A2 (*continued*)

2011	10.37	30.48	10.96	31.24
2012	11.49	31.89	11.53	31.94
2013	13.05	33.69	12.44	33.00
2014	14.44	35.15	14.38	35.09
2015	15.32	36.02	16.35	36.98
2016	17.13	37.68	16.75	37.34
2017	17.73	38.19	16.56	37.17
2018	0.47	6.86	1.04	10.13
Hierarchical location (N)				
Zip-code	1641		3378	
Municipality	230		414	
County	18		18	
Number of observations	48,660		392,619	

Note: Conversion rate: 1 NOK = 0.10 EUR (nominal exchange rate per February 17, 2020). Rental prices are averaged over the whole sample period. Size in square meters (1 m^2 = 10.8 sq. feet).

Table A3
Regression of Multi-way fixed effects and HLM using random sub-samples

	Multi-way fixed effects	HLM		
	Whole sample	75%	50%	25%
Green	0.0333*** [29.63]	0.0319*** [24.60]	0.0322*** [20.25]	0.0315*** [13.95]
Non-labeled	−0.0254***[-30.04]	−0.0263*** [-26.98]	−0.0262*** [-21.90]	−0.0264*** [-15.55]
Controls	✓	✓	✓	✓
Observations	439,832	330,133	220,096	110,053
Adjusted R^2	0.76	0.75	0.87	0.75

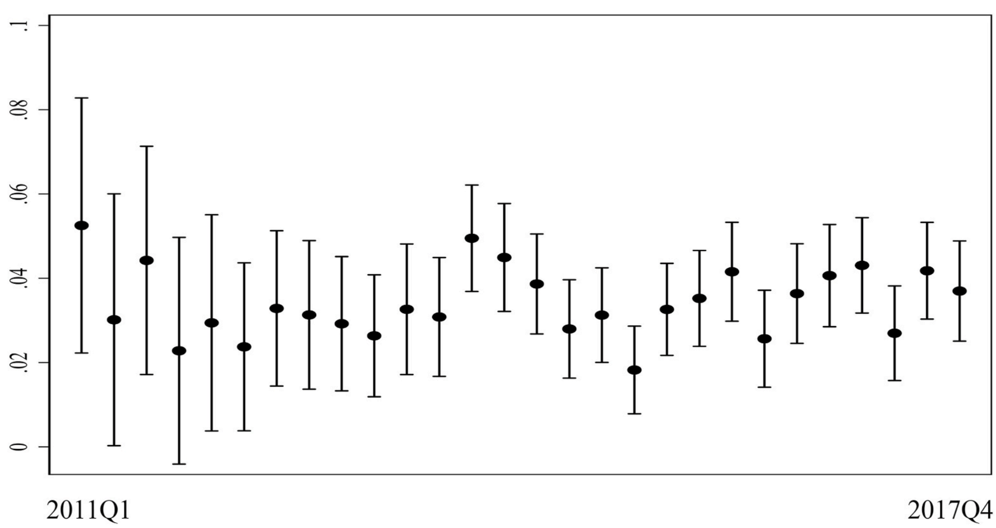

Fig. A1. The quarterly green premium over time. Note: The figure shows the green coefficients from estimations of equation (1) for the labeled sample. The reference group is non-green dwellings. 95 percent confidence intervals.

Table A4
Professional and nonprofessional EPC valuation.

	Labeled sample
Label A	0.0283*** [14.97]
Label B	0.0116*** [5.65]
Label C	0.0083*** [4.29]
Label E	−0.0272*** [-12.09]
Label F	−0.0328*** [-12.75]
Label G	−0.0272*** [-10.84]
Professionals	0.0438*** [14.18]
(Professionals × A)	0.0210* [2.10]
(Professionals × B)	0.0225*** [3.52]
(Professionals × C)	0.0131** [2.72]
(Professionals × E)	0.0023 [0.49]
(Professionals × F)	−0.0163*** [-3.49]
(Professionals × G)	−0.0154*** [-3.86]

(*continued on next page*)

Table A4 (*continued*)

	Labeled sample
Controls	✓
Observations	100,955
Adjusted R^2	0.77

Note: All variables from equation (1) included but not reported (Controls). The default is D-labeled dwellings.
t statistics in brackets * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

1 Enova is a company established in 2001, financed through government funding, and owned by the Norwegian Ministry of Petroleum and Energy. Enova's purpose is to reduce energy consumption and promote energy-efficient practices.
2 The data provided contained some 600,000 observations, but after a thorough examination we removed duplicate ads for the same dwelling over the same period and did not include bedsits and shared accommodations. To ensure the quality of the sample, we were able to retrieve the original ad online and verify the information for a random subsample.
3 While both ML and restricted maximum likelihood (REML) produce unbiased estimates for the fixed effects, ML can produce biased estimates for the random effects in some cases. Hence, in this analysis we apply both methods of estimation.
4 Full regression results are available from the authors by request.
5 This method is applicable for both panel and, in our case, cross-sectional data structures.

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