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Green Clientele Effects in the Housing Market

BY FRANZ FUERST*, ELIAS OIKARINEN**& OSKARI HARJUNEN***

Abstract

This study investigates how the energy efficiency ratings mandated by the European Union affect house prices. Using a sample of several thousand apartment transactions from Helsinki, Finland, we test whether higher ratings were significantly associated with higher prices. In addition to a large number of property and neighbourhood characteristics, this dataset contains information on building-level energy usage which allows us to distinguish between the 'pure' price effects of energy consumption and the value of more intangible factors associated with the energy label. The hedonic model yields a statistically significant 3.3% price premium for apartments in the top three energy-efficiency categories and 1.5% when a set of detailed neighbourhood characteristics are considered. When maintenance costs containing energy usage costs are added, a robust and significant price premium of 1.3% persists whereas no differentiation is found for the medium and lower rating categories. These findings may be indicative of segmented demand for energy-efficient buildings where price premia will only be observable for the top tier of energy ratings due to a 'green clientele effect'. However, a high energy rating did not appear to speed up the sales process in the analysed market.

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Introduction

Despite its large size and obvious relevance for both the general economy and sustainable development, the pricing of energy-efficient residential buildings has been a largely understudied topic. The reasons for this lack of empirical evidence are not clear, but the greater fragmentation of investors and lower fraction of professional or institutional investment compared to the commercial real estate market may be a contributing factor. Also, residential property markets are highly regulated and prone to market inefficiencies. Generally, the more inefficiently a market operates, the more difficult it will be to isolate a hedonic price signal of an individual characteristic. Moreover, green financial instruments are still not used widely in the residential sector, which makes capitalisation into the lump-sum house price the only channel for economic rewards of sustainability in many cases. As this poses a significant risk for any upfront investment in energy efficiency, 'green value' might not be readily observable in housing markets.

Nevertheless, the existing evidence on the residential market points to a significant green premium in a number of countries. Hausman (1979) was among the first to discuss the trade-off between the additional upfront capital cost and the potential savings from energy-efficient household appliances. Another early study by Dian and Miranowski (1989) showed that increasing energy efficiency increases housing prices in the U.S. Banfi et al. (2005) published findings indicating that rental housing tenants are prepared to pay up to 13% higher rent for buildings that have adopted energy-saving measures in the U.S. More recently, Burfurd et al. (2012) and Fuerst et al. (2015) reported similar findings. The latter authors found a price effect of higher energy performance in the U.K. housing market in the 1995-2011 period, indicating a 14% premium of the highest band of energy ratings over the lowest band. Burfurd et al. (2012), in turn, used laboratory experiments to show that information on the energy efficiency of a dwelling – either mandatory or voluntary – improves the market efficiency and increases investment in energy efficiency in the housing rental market, while the lack of information can give rise to an undesirable ’lemons market’ outcome.

Furthermore, Wameling (2010), reported higher selling prices for dwellings with lower primary energy demand in the German housing market, and Kahn and Kok (2014) arrived at similar conclusions in their study of the Californian housing market. Based on data for Stockholm in Sweden, Mandell and Wilhelmsson (2011) concluded that there is a positive willingness to pay for environmental attributes and this willingness it is greater for those households who state that they are environmentally aware. The results by Harjunen and Liski (2014), in turn, indicate that the heating energy costs capitalise in prices in the Helsinki single-family housing market in Finland. Similar observations have been reported for Asian markets as well: Zheng and Kahn (2008) and Zheng et al. (2012) found significant price premia for green housing in China, and Deng et al.

(2012) observed substantial economic returns to green housing in Singapore. Finally, Thorsnes and Bishop (2013) showed that an otherwise similar house insulated to basic code levels sells at a premium that exceeds the cost of insulation installation at construction.

This study aims to provide more knowledge on the influence of energy ratings on the value and liquidity of housing, including new information on the willingness to pay for being green and on signalling ones green values to the peers. We use a dataset for the Helsinki metropolitan area in Finland for the period 2009-2012 that includes the transaction price, energy rating, and a great number of other variables describing the quality and location for each transacted unit. The cold climate of the study area makes the case study interesting also because the cost savings from insulation and thus from heating energy may be substantial. A greater number of heating-degree days has been consistently linked to higher energy demand in the residential sector (e.g. Considine, 2000; Moustris et al., 2014) which in turn means a higher savings potential for more energy-efficient dwellings.

In addition to giving information regarding a market with higher requirements regarding insulation, the dataset is valuable because it contains information on the actual maintenance costs, including energy consumption, and on the time on market of each unit in our sample. Hence, the data give us the opportunity to contribute to the literature by examining whether the energy rating has its own independent impact over the maintenance cost information on housing values and liquidity. While e.g. Brounen and Kok (2012) showed that higher energy label induces a price premium and low-grade labels a price discount in the Netherlands, no study (to the best of our knowledge) has investigated whether the rating affects prices after the value of energy cost savings is taken into account in the estimated equation. Furthermore, while time on market was included in previous studies of energy efficiency capitalisation in house prices – for example by Kholodilin and Michelsen (2014), where this indicator is used as a control variable to adjust asking prices that are set too high by the landlord – there appears to be no previous evidence on the direct link between time to sale and energy efficiency.

Helsinki also is an interesting case market because of the detailed information on neighbourhood characteristics. In particular, the data enable us to account for these characteristics more carefully than in the previous related studies and thereby to extract the influence of energy grades more accurately. In addition, our analysis is based on an actual consumption-based rating unlike in extant studies. Based on our conceptual framework, we derive three hypotheses that we test empirically: 1) due to a ‘clientele effect’ that arises from signaling values, the higher-tier ratings induce a premium in house prices, whereas the below average classes do not sell at a discount compared with the average energy efficiency dwellings, 2) the high-tier energy ratings affect the housing values even when controlling for the observed maintenance costs that include the energy costs, and 3) the estimated premium for energy efficient housing units decreases as confounding factors, detailed neighbourhood characteristics and maintenance cost in particular, are included in the price equation. Furthermore, we argue that high energy rating can influence the expected time on market either positively or negatively, or the influence on the expected selling time can be negligible, i.e., the impact of energy ratings on housing liquidity is essentially an empirical question.

We find evidence in support of each of the three hypotheses. First, a statistically significant price premium only exists for the highest (ABC) energy ratings and no impact is found for below average ratings. This implies that only a fraction of households are energy-aware and willing to pay a premium for more energy efficient housing. Second, the premium exists even when the maintenance costs are included in the model as a control. That is, the energy rating system has independent pricing effect and provides additional information for valuation purposes. Third, while the valuation impact for high-rated units is significant in all model specifications, adding more careful neighborhood controls and maintenance costs substantially decreases the estimated premium. In contrast with the price effects, we do not detect any influence of energy ratings on the liquidity of housing.

The next section describes a conceptual framework to consider the pricing effects of housing energy efficiency ratings. A brief presentation of the Helsinki market is provided and the dataset used in the empirical analysis is delineated in section three. After that, we present the estimation approach and report the empirical results. Summary and conclusion, including a discussion of policy implications, are provided in the final section.

A conceptual model of energy efficiency and house prices

Every house purchase decision also entails an implicit or explicit decision about the desired level of energy efficiency. Leaving aside the rich literature on limitations to rational decision-making for the moment, it is hence straightforward to assume that the utility a household derives from owning a dwelling can be written in Cobb-Douglas form:

$$E(U_n) = \alpha \sum_{n=1}^{N} (e_n^{\beta} + x_n^{\gamma}) \quad (1)$$

where $E(U_n)$ is the total utility of a dwelling n which comprises energy efficiency (e) and all other characteristics of the dwelling (x). Each homebuyer then faces the decision of choosing the levels of energy efficiency and other characteristics with weights β and γ respectively that maximize their utility according to their individual preferences. The choice of a level of energy efficiency is thus part of a larger bundle of characteristics of a property such as size, location, state of repair etc. and potentially correlated with these factors. For example, properties with state-of-the-art energy efficiency levels may be found in more affluent locations and also be larger and better maintained than properties with lower energy ratings. Matisoff et al (2014) posit (albeit in the context of firm production functions) that higher *e* is not only associated with cost savings via lower energy consumption but also creates a competitive advantage via a 'green' signal to consumers from environmentally friendly investment. In the housing context, green consumers will increase their status within their peer group by buying an energy-efficient home.

The utility of energy efficiency can be assumed to rise with each level of the energy rating albeit at an increasing marginal rate. The concept of increasing marginal utility in relation to social and economic status gains has been developed by Friedman (1953), Lommerud (1989) and corroborated by more recent work, for example by Ray and Robson (2010). While the cost savings associated with higher energy efficiency can be viewed as quasi-linear, the signalling value of energy ratings increases in non-linear fashion. In other words, all dwellings above the lowest grade show energy cost savings, but only the above-average rated dwellings will have additional signalling value attached to them that allows households to visually demonstrate their environmentally conscious values and behaviour to their peers. Thus, the utility derived from the energy efficiency level of a dwelling is a combination of the linear utility of the cost savings (*cs*) from energy efficiency and the convex utility of the signaling value (*sv*).

$$e_n = cs_n + sv_n^{\partial} \qquad (2)$$

The willingness to pay for a given step increase in energy efficiency equals then the total marginal utility increase from linear cost savings and the non-linear signalling value.

It is important to note that demand for the higher tier of energy efficiency investments may not be distributed equally across all home buyers. Some buyers may derive higher utility from living in greener dwellings than others because of their intrinsic environmental values and preferences and/or the collective environmental attitudes of their peer group to which they may signal housing consumption that is in line with these attitudes by buying 'greener' apartments. This may give rise to a ‘green clientele effect’ where only a fraction of households are willing to pay a premium for superior energy performance while most households do not place any value on energy ratings.

Based on the above conceptual framework, three hypotheses can be developed and tested empirically: 1) the clientele effect, which arises from signalling values, increases demand for the high-rated dwellings inducing a price premium for them, whereas the below average classes do not sell at a discount compared with the average energy efficiency dwellings, 2) the higher-tier energy ratings affect the housing values and liquidity even when controlling for the observed maintenance cost that include the energy costs, and 3) the estimated premium for energy efficient housing units decreases as confounding factors, notably location, maintenance cost and dwelling condition are included in the price equation.

There are some intervening factors that may lead to non utility maximising outcomes, particularly with regard to the potential cost saving part of the utility function. Gillingham et al (2006) identify a number of market failures that lead to suboptimal investment levels in energy efficiency. More recently, Szumilo and Fuerst (2014) report a 'green operating expense puzzle', i.e. the total operating expenses of eco-certified commercial properties are higher, not lower, than those of comparable non-certified properties. The complexity of the interaction between the intrinsic energy efficiency of a property and behavioural factors governing actual energy demand may act to further confound the simple relationship between energy efficiency levels and observed pricing mechanisms. Finally, an absence of a price premium on energy savings may also indicate high discount rates of these future savings due to uncertainty and other factors such as a generally low rate of 'energy literacy' among homebuyers reported by Brounen et al. (2012). Studies of individual differences in discount rates also show that cognitive ability plays an important role. For example, Warner and Pleeter (2001) find that individuals with higher mental test scores have lower implicit discount rates, possibly because of a larger capacity to understand intertemporal choices and long-term investment decisions. These differences at the individual level may then lead to observable differences in the pricing of energy efficiency among different groups of buyers despite the seemingly identical and linear cost savings associated with energy efficiency levels.

Helsinki Dataset and the Finnish energy efficiency rating system

This study is based on transaction level housing sales data for the Helsinki metropolitan area (HMA) from 2009 to 2012. The HMA contains Helsinki, the capital of Finland, and the two municipalities surrounding it (Espoo and Vantaa), and is by far the largest metro area in Finland with its 1.1 million inhabitants. These HMA data are used to investigate the influence of energy ratings on housing sales prices and time on market.

Our data consist of second-hand transactions of privately financed apartments. That is, the data exclude newly built dwellings. There are good reasons to focus on the privately financed (i.e. non-subsidized) sector only: In Finland, privately financed housing can be bought and sold at market prices without any restrictions, whereas selling prices and rental prices are controlled in the publicly regulated (i.e. subsidized) sector. Furthermore, the data consist only of apartments, since data on apartments are more reliable than data on the other housing types in the HMA. Apartments are the dominant housing type in the area (75% of dwellings are apartments) and a substantially more homogenous group in their characteristics than the other housing types. Moreover, a notably greater number of transactions take place in the apartment market than in the market for other housing types. Therefore, the use of apartment data diminishes the heterogeneity complication that may be associated with housing price analysis even when hedonic modelling techniques are applied. A similar rationale applies to energy consumption which would be problematic to compare across different house types and regions due to the interaction with multiple confounding factors (Heinonen and Junnila, 2014). In 2012, the total number of permanently occupied apartment units in the HMA was 417 900, while the whole housing stock included 554 000 occupied dwellings.

From a construction company's / developer's point of view, it would be particularly interesting to know the value of energy efficiency regarding new housing construction. The study excludes new builds, though. Nevertheless, even the data on secondary market transactions is expected to reveal important information concerning the value of newly built housing, since new dwellings and older stock can generally be considered as close substitutes for each other – the same hedonic pricing principles and values must largely apply to newly built housing as to the existing housing stock.

The housing transaction data are provided by the private real estate agency Kiinteistömaailma. The data include all the apartment transactions made using this agency's services, i.e., approximately 25% of all the transactions in the area during the sample period. The data contain detailed information on the characteristics of each transacted unit, such as age, size, address etc. Our sample consists of 6203 observations with an energy efficiency rating, of which 9 were excluded from the analysis as obvious price anomalies with more than three standard deviations from the mean price per square metre. The selection of key characteristics that we include in the analysis is presented in Table 1.

According to data provided by the Finnish Real Estate Federation, the distribution of energy ratings in our sample is largely in line with the energy rating distribution in the whole stock of apartments in Helsinki. We report the characteristics separately for four different energy efficiency groups, since we use this grouping in the econometric estimations. As the number of A (23) and B (102) rated observations is very small, we combine the three high-tier bands so that the top-tier energy efficiency group (ABC) comprises 631 observations. In line with the overall Helsinki apartment stock, the share of the ABC group is some 10% of our sample. We consider this the target group of dwellings for green consumers in our clientele effect hypothesis. This also reflects the fact that it is hard to achieve higher than the average energy efficiency rating in the Finnish market. We also combine the two lowest ratings, i.e. F and G, because separately especially G would have too small a number of observations (101) for a reliable analysis. As shown in Table 1, most of the units are either D or E rated. The most common rating is D with 44% of the overall sample being rated in this medium category.

Table 1: Summary statistics

	Energy ABC		Energy D		Energy E		Energy FG	
	N=631		N=2731		N=2379		N=453	
	mean	std.dev	mean	std.dev	mean	std.dev	mean	std.dev
Apartment and building charateristics								
Price (€/m^2) [A]	3 656	1 181	3 343	1 211	3 414	1 208	3 694	1 139
Maintenance costs (€/m^2)	3,08	0,75	3,33	0,76	3,64	0,78	3,74	0,91
Size (m^2)	63,9	24,1	59,1	21,6	53,7	20,7	50,8	21,1
Age	30,1	29,0	42,0	24,6	50,2	19,8	54,2	17,8
Condition								
-very good	0,20	0,40	0,09	0,29	0,06	0,23	0,05	0,21
-good	0,58	0,49	0,54	0,50	0,50	0,50	0,48	0,50
-satisfactory	0,20	0,40	0,35	0,48	0,41	0,49	0,44	0,50
-bad	0,02	0,14	0,03	0,16	0,03	0,17	0,03	0,18
Sauna (dummy)	0,52	0,50	0,25	0,43	0,12	0,32	0,09	0,29
Floor	3,31	2,03	3,09	1,78	2,96	1,76	3,08	2,01
Maximum floor	5,67	2,39	5,24	2,12	4,90	2,01	4,94	2,41
Penthouse (dummy)	0,18	0,38	0,21	0,41	0,23	0,42	0,25	0,44
Road distance to CBD (km)	12,3	6,30	11,6	6,46	10,0	5,93	8,56	5,36
Travel time to CBD (minutes) [B]	28,4	10,1	27,1	10,6	25,3	10,0	23,3	9,66
Neighborhood characteristics								
Homeownership rate	0,53	0,19	0,52	0,18	0,52	0,16	0,52	0,15
Mean income per capita (€/year)	27 896	5 637	25 968	4 632	24 928	3 942	25 046	3 822
College degree	0,31	0,12	0,28	0,12	0,27	0,11	0,29	0,10
Unemployment rate	0,05	0,03	0,06	0,04	0,07	0,04	0,06	0,03
Pensioner share	0,18	0,08	0,21	0,09	0,23	0,09	0,23	0,11
Share of families with children	0,18	0,09	0,16	0,08	0,14	0,08	0,12	0,07
Service jobs/capita	0,19	0,38	0,30	0,81	0,32	0,93	0,38	0,95
Number of buildings	19,1	10,4	18,1	10,1	18,5	11,0	19,2	11,4
Mean dwelling size (m^2)	63,7	11,2	59,5	10,9	56,2	11,3	54,2	11,8
Population	687	421	735	510	735	530	721	521

Notes: [A] Prices are deflated to year 2013 using consumer price index. [B] Travel time using public transportation.

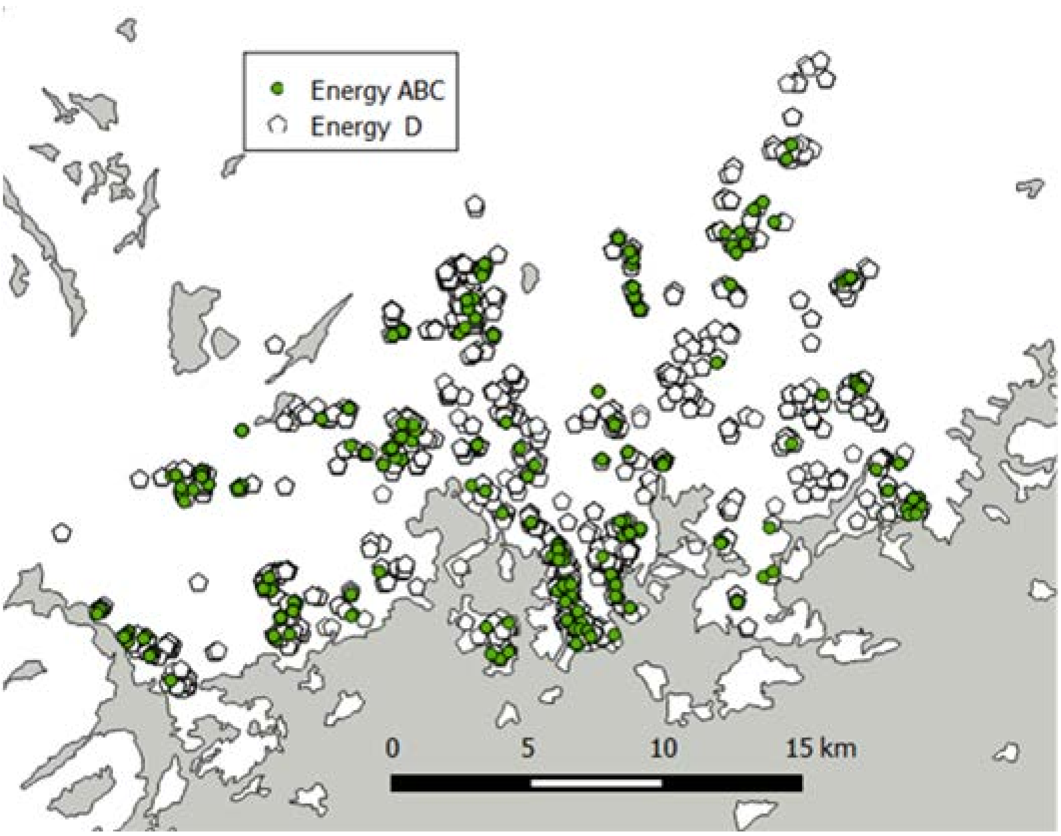
The average transaction prices are in line with market observations as reported by Statistics Finland. The characteristics considered here include the standard hedonic characteristics such as age, size and location as well as a number of more specialised features. For example, a sauna is considered to add value to a housing unit in the Finnish context due to their importance in Finnish cultural tradition. A notable share of apartments includes a sauna. Note also that the data allow us to include detailed variables on the floor and building height, and importantly on both the road distance to CBD and the travel time to the CBD using public transportation obtained from MetropAccess (2014) Travel Time Matrix.

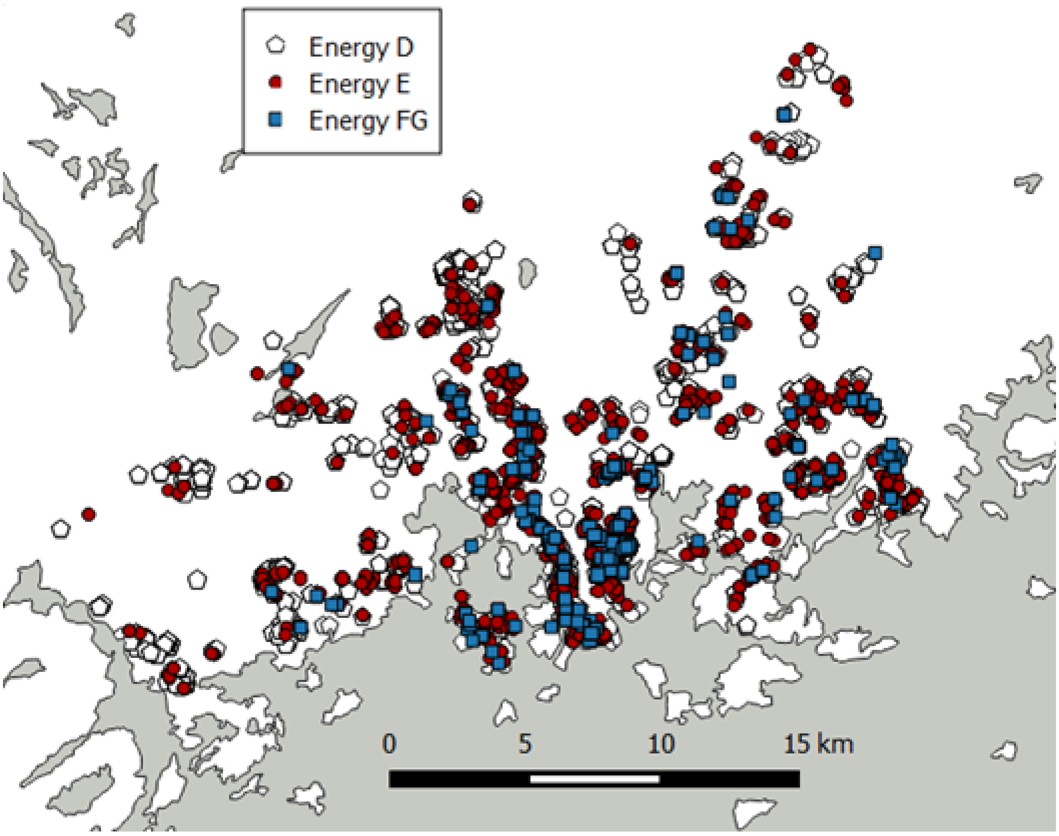
Our neighborhood measures are obtained from Statistics Finland's grid database 2010. This database is based on 250 x 250 meter grids and includes a number of relevant variables for housing values, in addition to grid coordinates. These variables contain information about the socioeconomic structure and the housing stock of the neighborhoods. In Helsinki, as in many other cities around the world, neighborhoods can be quite small in area, and there can be 'good' and 'bad' neighborhoods in close proximity. Thus, it is important to be able to include detailed neighborhood information in the hedonic analysis as pointed out in several seminal papers (e.g. Rosen, 1974; Bartik, 1987; Malpezzi, 2003). The lower part of Table 1 contains key descriptive statistics for the neighborhood measures used in the analysis.

With respect to most characteristics, the differences across the three energy efficiency classes are only small. The average per sqm selling price of the high-rated (ABC) units is somewhat greater than that of the D and E rated units. However, the average transaction price is the highest for the low energy efficiency class (FG). The high-rated apartments are a bit larger than the other ones, on average. Generally, the ABC rated units are located slightly further away from the CBD, which is in line with the fact that they typically are newer. The most notable differences across the groups concern the dwelling condition and sauna variables: the mean values indicate that the high-rated units are in substantially better shape and are much more likely to include a sauna than the lower-rated ones.

Figure 1 shows the geographic distribution of observations for each of our four energy classes. In this figure, grey coloured areas are water. While the big picture regarding the locational distribution is similar for each class, there are some differences across the classes. Most notably, the number of FG observations is very small in the western part of HMA. In any matter, we control for the locational factors in great detail in the econometric analysis.

Figure 1: Geographic composition of the observed transactions





Energy efficiency rating and maintenance costs

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

A: 0-100 kwh/m^2/year
B: 101-120
C: 121-140
D: 141-180
E: 181-230
F: 231-280
G: 281-

Due to the cold winter in Helsinki with subzero long-term average lowest daily temperatures from November until March, buildings generally require good heat insulation regarding walls, floor, ceiling, loft, and windows to receive a high energy efficiency rating. A typical building that meets the requirements of building regulations set in 2008 is generally D rated. Ottelin et al. (2015) show that the emissions from housing energy are generally much lower in new buildings compared with the old stock in Finland, as expected.

Because the average outside temperature – and thereby the heating energy usage – can vary across years, the heating energy consumption is 'normalized'. The normalization takes into account the difference between the average temperature of the year during which the energy consumption is observed and the long-term average annual temperature.

The rating is the same for all the apartments within the same building, as the rating is given at the housing company level. Practically all apartments in Finland are part of a housing company. A potential complication with the rating system is that the observed energy consumption is dependent on the habits of people living in the building, not only on the building characteristics. Another complication is caused by the varying number of people per sqm living in different buildings, as the energy consumption is normalised only with respect to the floor area. Fortunately, the energy consumption that influences the energy rating is not largely dependent on the number of people staying in the building. This is because 1) the heating and cooling energy are typically only slightly affected by the number of dwellers and 2) electricity consumption used in the rating computations does not incorporate the electricity usage inside apartments – it only includes general building level electricity usage (heating, outside lighting, stairway lighting, and various building level machinery such as lifts, pumps etc.). The within-unit electricity consumption, i.e. lighting and various appliances such as TV and washing machines, is billed to each household separately: As this consumption is largely dependent on a given household's size and habits, it does not enter the energy efficiency calculations apart from inside-unit water heating. The fact that the share of this energy consumption of the overall heating energy usage is generally only small – in 2011 the share was 17% in Finland according to Statistics Finland – diminishes the potential influence of this complication on the results.

In Finland, each dwelling in a housing company is charged the same per square meter maintenance fee. Typically, the maintenance fee is charged monthly. While information on the maintenance costs are not available for most countries, in the Finnish context the company form of housing ownership allows for the recording of maintenance costs for practically all the apartment transactions. In the housing company form of housing ownership – which quite closely corresponds to the housing cooperative structure in some other countries – ownership of a certain set of shares of the company confers the right to use a certain part of the building owned by the company, and a transaction of shares refers to a sale of shares entitling right to use a given dwelling owned by the company. The owners pay a monthly fee towards maintenance costs. The maintenance cost fee is public information. One advantage of the housing company structure is risk pooling among the individual households owning units through shares. Another attractive feature is the economies of scale (with respect to maintenance) provided by a company owning a number of dwellings.

The maintenance costs charged by housing companies include the aforementioned company level energy consumption costs as well as several other expenditures including administration, cleaning services, refuse disposal, insurances, and real estate tax. Similar to the energy rating calculations, the company level maintenance costs do not incorporate the within-unit electricity consumption, as these electricity bills are charged separately from each household. According to Statistics Finland, the average share of heating energy expenditure of the overall maintenance costs of Helsinki area apartment stock was 20% in 2010-2011. Corresponding values for electricity and gas was 3%, and 7% for water (including sewage). The relatively small share of gas and electricity can be explained by the fact that a great majority of the buildings are heated through central/district heating. According to Statistics Finland, 86% of heating energy of the whole Finnish stock of apartments came through district heat in 2011. While our maintenance cost variable incorporates costs stemming from the building level energy usage, separate data on the actual energy consumption or costs are not available, unfortunately.

In any matter, our main aim is to study whether the ratings contain independent pricing information in excess of the maintenance costs including prevailing energy usage costs, and information affecting the liquidity of apartments. For this purpose, the before-mentioned caveats should not cause notable complications. In particular, a finding that the energy ratings have pricing information even in a model including maintenance costs would indicate that the ratings contain independent value and information.

The summary statistics in Table 1 provide an indication of the link between the energy performance rating and average maintenance cost. The top section of Table 1 shows that average monthly maintenance costs per square metre are €3.08 for the ABC class, €3.33 and €3.64 for D and E rated units respectively, and €3.74 for the lowest energy efficiency class (FG). Since this difference in maintenance costs may be due to not strictly energy performance related factors, for example deteriorating building substance, higher replacement and redecoration requirements etc., we also provide a regression for the maintenance costs in Table 2. This regression that controls for other factors potentially affecting the maintenance costs, confirms that the costs are lower in the more energy efficient buildings. In other words, higher energy performance is associated with lower maintenance costs even when comparing buildings with a similar condition, that are of similar age, that have similar location, etc. The omitted energy class in the regression is D.

Table 2: Regression estimates for maintenance costs

Dependent variable: log of maintenance costs per sqm	
Energy class ABC	**-0.029****
	[0.014]
Energy class E	**0.048*****
	[0.012]
Energy class FG	**0.057*****
	[0.026]
R-squared	0.33
N	6,194
Year quarter fixed effects	**yes**
Postal code fixed effects	**yes**
House characteristics [A]	**yes**
CBD distance [B]	**yes**
Neigh. Characteristics [C]	**yes**

Notes: The omitted energy class is D. Estimated coefficient is statistically significant at *** 1% level, ** 5% level, * 10% level. Standard errors are clustered within postal code area, number of clusters is 118. [A] House characteristics include: age in second power, dummies for condition (bad, satisfactory, good, very good), dummy for sauna, dummies for floor (less than 4, 4 to 6, 7 to 9, more than 9) dummies for maximum floor (less than 4, 4 to 6, 7 to 9, more than 9) and dummy for penthouse. [B] CBD distance is measured in road distance and in travel time using public transportation. [C] Neighborhood controls include: share of homeowners, log of mean income, share with college education, share of unemployed, share of pensioners, share of families with children, number of buildings, log of mean house area and population.

Empirical strategy and results

In line with other studies in this topic area, we estimate hedonic housing price functions (Rosen, 1974), where the dependent variable is the natural log of the transaction price while the detailed housing characteristics are used as explanatory variables that determine the value of a dwelling. This allows us to estimate a separate value for each characteristic, i.e., a separate price function for housing. As our most extensive model, we estimate the following regression specification:

$$\ln p_{ilt} = \beta ER_i + \lambda Maint_i + \gamma X_{il} + n_{il} + q_{it} + \epsilon_{ilt} \quad (3)$$

where

$\ln p_{ilt}$ = natural log of transaction price (unit i, neighbourhood l, time t)

ER_i = energy class {high-rated (ABC), E-rated (E), low-rated (FG); omitted group = D}

$Maint_i$ = maintenance costs per square meter

X_{il} = vector of house and neighbourhood characteristics

n_{il} = postal code fixed effects

q_{it}= year quarter fixed effects

e_{ilt}= error term,

β is a four-dimensional vector of coefficients on the energy classes, γ is the coefficient on maintenance costs, and λ is a vector of coefficients on the house and neighbourhood characteristics. In all model specifications, β, γ and λ are estimated using the Ordinary Least Squares (OLS) technique controlling for the clustering of model residuals. The usual assumption that e_{ilt} is iid (independently and identically distributed), is probably violated in this case with multiple observations of flat sales over time in the same locations. In the presence of clustered errors, OLS estimates are unbiased but the standard errors can be wrong, thus leading to incorrect inference. A natural generalisation is to assume clustered standard errors such that observations *within* a postal code area are correlated in some unobserved way but that there are no correlated errors *across* postal code areas (Rogers, 1993).

By including the maintenance costs and energy efficiency ratings in the group of right hand side explanatory variables, we can investigate the impact of these factors on housing prices, and examine whether the energy class has some additional independent impact on the transaction price of a dwelling. We also add quarterly time dummies in the model to account for the time-variation in the housing price level, and postal code dummies to account for unobserved time-invariant neighbourhood attributes that might be correlated with the energy label. We estimate similar model for the observed selling time, too, to examine the relationship between energy rating and expected time on market.

As explained in the data section, we use four energy rating groups in the estimations: The above average energy efficiency group (ABC), the average classes (D and E), and the low-rated apartments (FG). The aggregation of the highest and lowest energy efficiency groups is preferable as the small number of observations in the A, B and G groups could yield spurious and idiosyncratic coefficient estimates. It is reasonable to consider the ABC class as the highly-rated units for the sake of testing the clientele hypothesis.

Table 3 shows a number of alternative model specifications for the natural log of transaction price. The omitted energy efficiency group in the estimations is D. That is, the coefficients on the energy classes show the premium or discount compared with the average efficiency class.

Table 3: Regression estimates for transaction prices

Dependent variable: log of sales price

	(1)	(2)	(3)	(4)
Energy class ABC	**0.1823*** **	**0.0332** **	**0.0150** **	**0.0130** **
	[0.0392]	[0.0143]	[0.0064]	[0.0062]
Energy class E	**-0.0816*** **	**-0.0170* **	**-0.003**	**0**
	[0.0239]	[0.0096]	[0.0055]	[0.0057]
Energy class FG	**-0.0587**	**0.0073**	**-0.002**	**0.0002**
	[0.0380]	[0.0177]	[0.0083]	[0.0052]
Log(maint costs/m^2)	-	-	-	**-0.0529*** **
	-	-	-	[0.0139]
R-squared	0.074	0.857	0.932	0.933
Adj. R-squared	0.071	0.856	0.93	0.931
N	6,194	6,194	6,194	6,194
Year quarter fixed effects	**yes**	**yes**	**yes**	**yes**
Postal code fixed effects			**yes**	**yes**
House characteristics [A]		**yes**	**yes**	**yes**
CBD distance [B]		**yes**	**yes**	**yes**
Neigh. Characteristics [C]			**yes**	**yes**
Maintenance costs				**yes**

Notes: Estimated coefficient is statistically significant at *** 1% level, ** 5% level, * 10% level. Standard errors are clustered within postal code -area, number of clusters is 118. [A] House characteristics include: area in third power, age in second power, dummies for condition (bad, satisfactory, good, very good), dummy for sauna, dummies for floor (less than 4, 4 to 6, 7 to 9, more than 9) dummies for maximum floor (less than 4, 4 to 6, 7 to 9, more than 9) and dummy for penthouse. [B] CBD distance is measured in road distance and in travel time using public transportation. [C] Neighborhood controls include: share of homeowners, log of mean income, share with college education, share of unemployed, share of pensioners, share of families with children, number of buildings, log of mean house area and population.

Specification (1) only includes the energy classifications and no other explanatory variables (except for the time dummies). The point estimates indicate that the average selling price for the high-rated units is 18% higher and those for the E and FG rated units are respectively 8% and 6% lower than the mean value of D rated apartments. For the ABC and E classes the price difference also is highly statistically significant. However, the more detailed model specifications show that these observed price differences between the energy rating groups can be explained, to a major extent, by the locational and building characteristics.

The inclusion of the typical variables included in hedonic housing price models to capture the influence of location and physical attributes of an apartment diminishes the absolute values of the coefficient on high-rated units to 3.3% with a model fit of 86% (specification 2). When controlling more carefully for the locational attributes by adding postal code dummy variables and the neighbourhood characteristics in specification (3), i.e., in X in equation (1), this point estimate further drops to 1.5%, while the model fit substantially increases to 93%. That is, the inclusion of the detailed neighbourhood characteristics that are often absent in related investigations causes a significant decline in the estimated premium for the energy efficient apartments: although the premium remains statistically significant, it is less than half the size shown by specification (2). Moreover, the coefficients on E and FG classes are insignificant in specification (3). Clearly, this points to an omitted variable bias in a model where the road and time distance to the CBD are the only variables reflecting the unit location, and is in line with our *third hypothesis*. Importantly, the results also give support to our *clientele hypothesis*, according to which there is a price premium for the high-rated units, whereas there is no price discount for the low-rated compared with the average energy performance apartments.

In support of our *second hypothesis* regarding the independent informational content of the energy ratings, the inclusion of maintenance costs only slightly affects the estimated premium for the ABC class: the point estimate on the ABC group is 1.3% in model (4). Expectedly, the coefficient decreases as the maintenance costs are controlled for, but this decline is insignificant. Thus, our results provide evidence in support of all our three hypotheses.

Although this study does not focus on the capitalisation of energy cost savings to housing values per se, a brief quantitative assessment of the obtained coefficients appears in order here. The 0.2%-point difference in the coefficient on ABC class between models (3) and (4) is not likely to provide a clear picture of the capitalisation of energy cost savings into housing value, since the age and condition variables can considerably influence the level of energy costs and may therefore be highly correlated with these costs (that we do not observe separately from the maintenance cost data). In other words, age and condition are likely to include part of the energy cost effects in specifications (2) and (3). Therefore, we re-estimate these models without the age and condition variables (Table A1 in the Appendix) and observe that the R-squared remains over 90% in these specifications. This suggests that the possible omitted variable bias stemming from excluding age and condition is unlikely to be a great concern. The model and coefficients of interests are robust to these changes in specification as the difference in the point estimate of ABC in these models (0.3% points) does not notably differ from the baseline models.

Note also that, given the point estimate of -0.05 (-0.08 in the version excluding age and condition) and the fact that on average some 30% of the maintenance costs are due to energy consumption, the results imply that a 50% drop in energy costs would have a ‘pure’ price effect (i.e. effect unrelated to the valuation impact of the energy rating) of only 1.6% (2.4%). Overall, our analysis does not confirm expected energy cost savings capitalisation but the causal effects warrant more careful investigation in follow-up research.

An inability to detect a significant capitalisation effect from the current energy cost savings is not necessarily at odds with rational behaviour. The discounted present value of the energy savings is generally only a small proportion of the overall property value. To illustrate this, let us consider the average savings of a typical energy class C unit compared with a D rated apartment. The average annual energy usage is 130kwh/m^2 and 160kwh/m^2 in C and D, respectively. The average size of an apartment in our sample is 57m^2. Annual savings, with energy price €0.068/kwh, is then € 116 per annum. Assuming a real interest rate of 2% and a risk premium of 3% (given the uncertainty of the size of savings due to uncertainty in future energy prices and consumption), the present value of energy cost savings over 25 years is about €1700. This is slightly less than 1% of the mean apartment value in our sample. The savings are more substantial at both tails of the energy rating scale. For A and G rated apartments, similar computations yield present values of €4700 and €9400, respectively, but the share of A or Grated apartments in groups ABC and FG is relatively small. Obviously, the present values are greater in absolute value if the real discount rate is smaller than 5% or if we assume that energy prices grow faster than the general price level. For instance, assuming an annual real energy price growth rate of 1%, the present values would be €5200 for A, €1900 for D, and € 10300 for G. In any case, it should be understood that our estimate of cost capitalisation effects in models (4) and (6) is only a coarse approximation.

An obvious follow-on question is why energy consumption for heating and the savings associated with higher energy efficiency do not appear to be capitalised into Helsinki apartment prices which seems to contradict the findings of a number of studies from other markets and countries. One possible explanation may be the fact that individual occupants have very little control over their heating expenses in apartment buildings as these have district heating and heating bills are split among residents according to apartment size. For example, Kyrö et al (2011) as well as Heinonen and Junnila (2014) document how this fixed-ratio splitting mechanism stimulates higher aggregate energy consumption in Finnish and Swedish apartment buildings. It would be interesting to investigate further whether purchasers pay the same attention to heating costs when buying an apartment as they would when buying a detached house or an apartment with separate metering and billing or whether the opposite is the case.

Absent energy savings capitalisation, there are several possible explanations for the observed 'independent' premium for high-rated units. First, eco-consumers typically aim to buy above average rated dwellings, thereby inducing higher demand for those units. Second, a small fraction of households may expect energy prices to grow fast so that the expected energy cost increase (or more precisely the increase *in excess of current* maintenance costs) capitalises, at least to some extent, to the dwelling price if these households choose to buy A/B/C-rated units. Third, a pricing difference also could emerge due to smaller risk with respect to future obsolescence in the higher-rated units (Falkenbach et al., 2010).

A potential complication in virtually all hedonic house price models estimated in the literature is that there can be omitted variables which could bias the point estimates and standard errors to some extent. The fit of our more detailed models is up to 93%, which indicates that no important drivers have been omitted from our specification. Moreover, in addition to the typical explanatory variables included in the previous studies the models include a number of locational characteristics that control for neighbourhood effects that would otherwise remain unobserved – another factor increasing the reliability of our results. Finally, the building and zoning regulation in Finland are very strict compared with most countries. This too suggests that the possible unobserved variation in the housing stock is likely to be relatively small.

Liquidity model

In theory, the high (low) energy efficiency rating might be associated with either shorter or longer than average expected time on market. On the one hand, there may be a larger number of potential buyers for an otherwise similar dwelling that is high energy-rated: Our clientele hypothesis and the results reported above suggest that there is a set of market participants that aim to buy only high-rated units and are willing to pay a premium for those apartments. Thus, the liquidity of the high-rated units could be better. On the other hand, many owners of high-efficiency units that are about to sell the dwelling – being themselves environmentally aware and oriented – may expect to get notable price premiums for their apartments. As most market actors do not pay attention to the energy ratings based on the comments of housing market professionals and on our price estimations, it may take a long time for the seller to match with an equally aware buyer, and the seller may eventually need to substantially drop the required green premium. These potential effects can offset each other, of course. Therefore, the possible liquidity effect is essentially an empirical question.

Table 4: Regression estimates for time on market

Dependent variable: log of time on market	
Energy class ABC	**-0.0131**
	[0.0499]
Energy class E	**0.0438**
	[0.0281]
Energy class FG	**0.0003**
	[0.0528]
Log(maint costs/m^2)	**0.1493*****
	[0.0545]
R-squared	0.013
N	6,194
Year quarter fixed effects	**yes**
Postal code fixed effects	**yes**
House characteristics[A]	**yes**
CBD distance [B]	**yes**
Neigh. Characteristics [C]	**yes**
Maintenance costs	**yes**

Notes: Dependent variable: log of saletime in days+1 (some observation that were sold the first day they were on the market). Estimated coefficient is statistically significant at *** 1% level, ** 5% level, * 10% level. Standard errors are clustered within postal code -area, number of clusters is 118. [A] House characteristics include: residual of the most extensive price estimation, log of maintenance costs, area in third power, age in third power, condition, dummy for sauna, dummies for floor (less than 4, 4 to 6, 7 to 9, more than 9) dummies for maximum floor (less than 4, 4 to 6, 7 to 9, more than 9) and dummy for penthouse. [B] CBD distance is measured in road distance and in travel time using public transportation. [C] Neighborhood controls include: share of homeowners, log of mean income, share with college education, share of unemployed, share of pensioners, share of families with children, number of buildings and log of mean house area and population.

Table 4 only reports our best model for liquidity, because the key result does not vary across model specifications. The dependent variable is the natural log of the time on market, and the set of explanatory variables contains all the variables included in the most detailed price equation (specification (4) in Table 3). In addition, we add as an explanatory variable the residual series from the price equation (4), as the deviation of the selling price of a dwelling compared with its hedonic price can notably affect the selling time based on the search theoretic models of the housing markets (e.g. Krainer, 2001; Novy-Marx, 2009).

The estimation results do not provide evidence of a liquidity effect of energy ratings. While the point estimates show a slightly shorter time on market for the high-rated units and a somewhat longer selling time for the E-rated apartments compared with the average energy class D, the coefficients are statistically insignificant. Interestingly, higher maintenance costs make an apartment somewhat harder to sell. Similar to the price model, the inclusion of maintenance costs has only a marginal influence on the parameter estimates in the time on market model. In contrast with the price models, the liquidity model explains only some 13% of the variation in the dependent variable. This implies that a major share of the variation in time on market cannot be explained, at least by the typical explanatory variables, but a bulk of the variation seems to be random across sold units rather than related to the main characteristics of the location or physical structure.

Conclusions

This study investigates how energy efficiency ratings, which are mandatory in various forms throughout the European Union, affect house prices and liquidity. Using a sample of several thousand apartment transactions in the Helsinki market in Finland, we test whether higher ratings were significantly associated with higher prices during 2009-2012, controlling for a large number of other property and neighbourhood characteristics.

We find a statistically significant price premium for the high-rated (ABC) apartments even when controlling for the maintenance costs that incorporate the housing company level energy usage. Therefore, the results indicate that energy ratings contain independent valuable information regarding housing valuation. However, the results do not show pricing effects between the low- and medium-rated units. This may arise in a situation where the majority of households do not pay attention to or may not even be aware of the energy ratings whereas environmentally aware households may pay attention to the energy ratings and subsequently target properties with good or excellent ratings. In this situation, segmented demand will arise and price premia will only become observable for the top tier of energy ratings and no differentiation within the mainstream market. We call this the ‘green clientele effect’ in the housing market. However, we do not find similar effects concerning liquidity: The energy ratings do not appear to have notable influence on the expected time on market when the other relevant variables are controlled for.

The empirical analysis provides some practical implications. We find that more careful controls (than those that are conventionally included in related analyses) in the estimations lead to a smaller price premium being observed. Nevertheless, our results imply that the energy ratings do matter, at least in the upper end of the distribution. This could be an important message given that adoption rates of energy performance certificates seem to have been low and declining over time at least in some countries within the European Union (Brounen and Kok, 2011).

Regarding construction companies and real estate agents, in turn, the results give important pricing information. For the construction sector, a price premium for higher than average energy efficiency units could potentially provide a signal that is transmitted from the investment market to the space market, subsequently causing incentives for construction companies to construct green apartments and thereby leading to an increase in the supply of green buildings and less energy consumption. However, these price effects, based on our estimations, are not large enough to give incentives to build high energy efficient housing in the area, as the costs involved with such construction are notable. Thus, the policy recommendation – in order to get more energy efficient new construction – is to either tighten mandatory requirements or to contribute to an increase in the price premium for energy efficient housing. The latter could be achieved by improving the public awareness of energy costs and energy ratings (i.e. by improving economic literacy with respect to housing costs and valuation, and by strengthening the households' green values) or by increasing the expected economic benefits of energy efficiency (through taxation or subsidies, for instance).

The findings of this paper are not necessarily generalisable to other markets located in different climate conditions. On the one hand, one might expect that higher energy efficiency will generally have a greater premium in the countries where the average energy efficiency standard of housing is notably lower and thereby the difference in the energy efficiency between the average building and the high-rated apartments is much greater – after all, Finland is a market that arguably maintains some of the highest building and energy efficiency standards in the world due to its harsh winters. That is, a gradual tightening of minimum requirements for energy efficiency over the next few years would not necessarily take away the financial incentives to build (or renovate) above average energy efficient units in countries with much less energy efficient building stock. On the other hand, the energy efficiency can be particularly relevant in a cold climate due to potentially large heating cost differences arising from the quality of insulation.

Follow-up research may explore these issues in greater depth. A particularly attractive opportunity for further analysis arises from the fact that the energy efficiency rating system was switched from a consumption-based system as reflected in this study to one that estimates the hypothetical energy requirements based on the intrinsic energy efficiency quality of a dwelling's components. This would allow to discern different capitalisation patterns of these two fundamentally different efficiency rating philosophies in future research.

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Appendix

Table A1: Regression estimates for transaction prices when age and condition are excluded

Dependent variable: log of sales price		
	(1)	**(2)**
Energy class ABC	**0.0374*** **	**0.0345*** **
	[0.0010]	[0.0096]
Energy class E	**-0.0119**	**-0.0081**
	[0.0055]	[0.0058]
Energy class FG	**-0.0143**	**-0.0098**
	[0.0102]	[0.0099]
Log(maint costs/m^2)	-	**-0.0794*** **
	-	[0.0177]
R-squared	0.907	0.909
Adj. R-squared	0.905	0.906
N	6,194	6,194
Year quarter fixed effects	**yes**	**yes**
Postal code fixed effects	**yes**	**yes**
House characteristics[A]	**yes**	**yes**
CBD distance [B]	**yes**	**yes**
Neigh. Characteristics [C]	**yes**	**yes**
Maintenance costs	**yes**	**yes**

Notes: Estimated coefficient is statistically significant at *** 1% level, ** 5% level, * 10% level. Standard errors are clustered within postal code -area, number of clusters is 118. [A] House characteristics include: area in third power, dummy for sauna, dummies for floor (less than 4, 4 to 6, 7 to 9, more than 9) dummies for maximum floor (less than 4, 4 to 6, 7 to 9, more than 9) and dummy for penthouse. [B] CBD distance is measured in road distance and in travel time using public transportation. [C] Neighborhood controls include: share of homeowners, log of mean income, share with college education, share of unemployed, share of pensioners, share of families with children, number of buildings, log of mean house area and population.