

Mense, Andreas

Conference Paper

The Value of Energy Efficiency and the Role of Expected Heating Costs

Beiträge zur Jahrestagung des Vereins für Socialpolitik 2017: Alternative Geld- und Finanzarchitekturen - Session: Environmental Economics, Natural Resources and Climate Change III, No. F17-V1

Provided in Cooperation with:

Verein für Socialpolitik / German Economic Association

Suggested Citation: Mense, Andreas (2017) : The Value of Energy Efficiency and the Role of Expected Heating Costs, Beiträge zur Jahrestagung des Vereins für Socialpolitik 2017: Alternative Geld- und Finanzarchitekturen - Session: Environmental Economics, Natural Resources and Climate Change III, No. F17-V1, ZBW - Deutsche Zentralbibliothek für Wirtschaftswissenschaften, Leibniz-Informationszentrum Wirtschaft, Kiel, Hamburg

This Version is available at:

<https://hdl.handle.net/10419/168212>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

The Value of Energy Efficiency and the Role of Expected Heating Costs

Abstract

The German Energy Performance of Buildings Directive requires sellers on the housing market to provide detailed information on expected yearly energy consumption per square meter (energy performance, EPS). This paper uses variation in local fuel prices and climate, fuel types, and building ages to analyse the relationship between expected energy cost savings from energy efficient building structure and house prices in a data set of listing prices from all regions of Germany. Results suggest that heating cost considerations are less relevant than previously thought.

Keywords: climate, energy efficiency, heating fuel prices, house price capitalisation.

JEL Codes: R3, Q4, Q5

1 **1. Introduction**

2 According to the so-called “energy paradox” (Hausman, 1979; Jaffe and Stavins, 1994) price differences
3 do not fully reflect expected savings on energy costs for homes, home appliances, auto-mobiles, and other
4 products. Up to date, there is an open debate about the interpretation of such results. In principle, inatten-
5 tion to energy costs could be rational if information acquisition is sufficiently costly or potential savings are
6 small (Sallee, 2014), but it could also be a sign of consumer myopia (Gabaix and Laibson, 2006). In this re-
7 spect, housing and auto-mobile markets are perfect test-beds because inattention to energy consumption can
8 be relatively costly. However, two recent attempts to settle the issue interpret their results in fundamentally
9 different ways (Allcott and Wozny, 2014; Busse et al., 2013). Without doubt, the answer depends on expecta-
10 tions about the future that are formed by the marginal buyer. Typically, papers in the area attempt to estimate
11 reasonable discount rates, lifetime expectancies of goods, and expectations about future fuel prices in order
12 to calculate a “true” value of expected energy cost savings that can be compared to the difference in product
13 prices. This procedure involves several deliberate decisions to be made by the researcher. Altogether, this
14 weakens any conclusions derived from estimation results.¹

15 In theory, the willingness to pay (WTP) for energy efficiency should equal the present discounted value
16 of expected savings from energy expenditures. Existing literature that deals with energy efficiency in build-
17 ings has focussed on the question whether there is a correlation between house prices or rents and energy
18 efficiency labels (Brounen and Kok, 2011; Deng et al., 2012; Fuerst et al., 2015; Harjunen and Liski, 2014;
19 Högberg, 2013; Hyland et al., 2013; Kholodilin et al., forthcoming; Walls et al., 2013). To date, it is diffi-
20 cult to assess whether this correlation stems from a marketing effect, unobserved quality bias, or the present
21 discounted value of expected energy cost savings.

¹Table 9 in Busse et al. (2013, p. 245) exemplifies this dilemma. It displays a range of plausible assumptions about discount rates and demand elasticities. As interpreted by the authors, this table supports their conclusion that myopia are absent. Allcott and Wozny (2014, p. 782, Fn. 9) use the same table to show that their own results *and* the results of Busse et al. (2013) support the presence of myopia.

22 The present paper analyses a large and detailed data set of residential houses offered for sale on German
23 online real estate market places from April 2015 to July 2016. Since May 2014, the German “Energy
24 Performance of Buildings Directive” (Energieeinsparverordnung, EnEV) requires that energy performance
25 scores (EPS) have to be provided when residential dwellings are sold or rented out (§16ff EnEV). The EPS
26 gives very detailed information about expected energy consumption per square meter and year ($kWh/[m^2 \cdot a]$)
27 and is calculated based on the characteristics of the property (insulation, heating technology, etc.).

28 In contrast to simpler “green” labels, EPS allow a more detailed interpretation. We exploit this advantage
29 in three ways: First, we argue that the interactions of EPS with variation in local climate and local heating
30 gas prices are exogenous to house prices. All else equal, informed, rational consumers should be indifferent
31 between saving one Euro on energy costs because of a milder climate or a lower price of heating fuel.

32 In a similar fashion, the fuel price per kWh varies across heating types. Typically, it is excessively
33 costly to alter a house’s heating type. If buyers and sellers expect fuel price differences to be persistent, this
34 influences greatly the present value of the house’s EPS. We compare houses with district, gas, and electricity
35 heating. To deal with the fact that there are substantial (observable) differences between houses of different
36 heating types along other dimensions, we rely on propensity score weighting.

37 Third, we propose an approach that allows to estimate remaining lifetimes and the ratio of the expected
38 energy price increase to the discount factor directly from the data by estimating separately the valuation of
39 EPS for houses in different age groups. In theory, building age influences the net present value of energy cost
40 savings through the building’s remaining lifetime (i.e. time until rehabilitation becomes optimal). While this
41 does not necessarily solve the identification problem, it is still useful because a coherent pattern is compatible
42 with the notion that agents in the market understand the investment character of energy efficiency.

43 The results suggest that local climate and gas prices are not taken into account in the valuation of EPS,
44 which contrasts with comparable findings for the valuation of fuel economy in auto-mobile markets (Allcott
45 and Wozny, 2014; Busse et al., 2013; Sallee et al., 2015). A potential explanation is that, compared to buying

46 a house, consumers visit gas stations quite frequently. Similarly, the value of EPS does not correspond to the
47 price of the heating fuel used in a given house when comparing district-, gas-, and electricity-heated houses
48 – despite substantial differences between the three heating fuel prices. In contrast, when looking at different
49 building age groups, a clear pattern emerges: The younger a building, the higher is the valuation of EPS.
50 The pattern implies that personal discount factors are large, in line with recent survey evidence (Newell and
51 Siikamäki, 2015), and that the net present value of energy efficiency is be much lower than what is suggested
52 by direct cross-section estimates.

53 The next section briefly summarises related literature that deals with the valuation of energy efficiency
54 in real estate and auto-mobile markets. Section 3 develops the theoretical relationship between the WTP
55 for energy efficiency and prices or rents and discusses issues of identification. Section 4 describes the data,
56 Section 5 shortly discusses the empirical strategy. Empirical results are presented, interpreted and compared
57 to previous estimates in Section 6. The paper closes with a discussion of implications for future research and
58 policy.

59 **2. Related literature**

60 *2.1. Capitalisation of energy performance certificates*

61 The more recent literature on capitalisation of energy efficiency labels into property prices follows up
62 on an earlier series of papers that started in the 1980s (cf. Dinan and Miranowski, 1989; Halvorsen and
63 Pollakowski, 1981, inter alia). For instance, Halvorsen and Pollakowski (1981) find significant responses of
64 house prices with oil-fired heating systems to the 1973 oil price shock. More recently, the impact of *Energy*
65 *Star*[®] and *Leadership in Energy & Environmental Design* eco-labels on prices of office buildings has been
66 studied by Eichholtz et al. (2010, 2013) and Fuerst and McAllister (2011).

67 Eco labels for residential housing markets have been studied in Australia, the US, Singapore, and Europe
68 (Brounen and Kok, 2011; Deng et al., 2012; Fuerst et al., 2015, 2016; Högberg, 2013; Hyland et al., 2013;

69 Kahn and Kok, 2014; Soriano, 2008). The type of labels differs across studies, but all authors find positive
70 relationships. Again, identification is based on observables in ordinary least squares (OLS) or Heckman se-
71 lection regressions and on propensity score weighting techniques. Kahn and Kok (2014) find weak evidence
72 that climate influences the size of the eco premium and a considerable effect of Toyota Prius registrations
73 (i.e. attitudes toward the environment). This suggests that part of the effect can be attributed to “green”
74 marketing. However, only a tiny share of houses (4321 of approx. 1.6 million observations, or 0.3%) is
75 eco-labelled in the sample. This makes it difficult to assess the external validity of the results.

76 In contrast to binary labels, efficiency bands have the considerable advantage that both efficient and
77 inefficient homes are labelled. This changes the “default” from non-labelled to some intermediary grade
78 which in itself might influence consumer choices (Allcott and Mullainathan, 2010). Even more information
79 is provided by the German scheme of EPS that give an assessment of energy use in kilowatt hours per
80 square metre and year ($kWh/[m^2 \cdot a]$). One goal of this paper is to show that participants in the market
81 for real estate rely on such fine-grained information in calculating their willingness to pay for a house. In
82 that case, ‘notched’ policies, i.e. binary labels or efficiency bands, should be dismissed because they can
83 lead to product design distortions (Newell and Siikamäki, 2014; Sallee, 2014, p. 32). EPS thus provide
84 an opportunity to test more rigorously to what extent and in which ways agents in the real estate market
85 value energy efficiency *because of reduced heating costs*. Thus far, the German scheme has been studied by
86 Kholodilin et al. (forthcoming) with a focus on differences between landlords and tenants.

87 With the exception of Eichholtz et al. (2013) and Harjunen and Liski (2014), existing studies have in
88 common that they neglect the role of fuel types and local prices. To some extent, the effect of local climate
89 has been studied by Kahn and Kok (2014), but in an ad-hoc fashion that does not allow to interpret estimates
90 in the way intended in this paper. None of the papers has considered the role of building age. Another issue
91 that is acknowledged but addressed only partly in other papers is identification of relevant coefficients. The
92 present paper seeks to exploit exogenous sources of variation that allow to identify coefficients if market

93 participants react to these sources.

94 2.2. Fuel economy on auto-mobile markets and consumer myopia

95 Comparable identification strategies have been applied in another strand of the literature that is closely
96 related to the present paper. It originates from the seminal contribution of Hausman (1979) and deals with the
97 valuation of energy efficiency in consumer decisions more generally. Recently, the great potential of more
98 energy-efficient technology coupled with an extraordinarily low cost-benefit ratio of information provision
99 has aroused interest in the issue (Allcott and Greenstone, 2012; Allcott and Mullainathan, 2010). To design
100 optimal policies, it is crucial to understand whether observed choices are the outcomes of *irrational* or
101 *rational* inattention (Allcott and Mullainathan, 2010; Gerarden et al., 2015; Sallee, 2014, inter alia). In other
102 words: Are consumers myopic even in high-cost situations such as house or car purchases, or are they not?²

103 As noted in the introduction, three recent papers that study car sales on the auto-mobile market come up
104 with conflicting answers: While Busse et al. (2013, p. 221) “find little evidence that consumers ‘undervalue’
105 future gasoline costs when purchasing cars”, Allcott and Wozny (2014, p. 780) report that “auto consumers
106 appear to be willing to pay only \$0.76 in purchase price to reduce discounted future gasoline costs by \$1.00.”
107 Besides differences in the identification strategy, these interpretations are based on assumptions about dis-
108 count rates and expectations of consumers with respect to changes in gasoline prices, lifetime of the car, and
109 travel distances. In a recent working paper, Sallee et al. (2015) use the relationship between (remaining)
110 auto-mobile mileage and the present value of fuel cost savings as identification strategy. The authors argue
111 that their results support the views of Busse et al. (2013). These mechanisms have analogues in the housing
112 market and are studied in this paper. Furthermore, we develop an approach that allows to estimate remaining
113 lifetimes and implicit assumptions about discount rates/future prices directly from the price data.

²For instance, there is evidence of uninformed consumer choices in low-cost situations if part of the price information is visible and part of it is hidden (see Chetty et al., 2009, inter alia).

114 **3. Theoretical considerations**

This paper relies on the hedonic pricing framework (Rosen, 1974). The per-period WTP for one square metre of a specific dwelling can be seen as a function of its structural (s) and locational (l) characteristics:

$$\text{WTP} = W(s, l) \tag{1}$$

115 Note that s may include energy performance as a *characteristic* of the house that has a specific value to
 116 the buyer. Previous authors have indeed included EPS in s and have estimated the WTP for EPS as a
 117 characteristic of the house. In that interpretation, EPS is a *value-increasing* factor that provides utility to
 118 the buyer of the house, e.g. because he or she cares about the environment and enjoys living in an efficient,
 119 modern home. On the other hand, EPS is *cost-reducing*: Arguably, it is possible to have a warm living room
 120 in any modern house, no matter how inefficient the insulation, but costs vary with energy efficiency. In this
 121 sense, the price of the warm living room is higher for inefficient homes, not its utility.

Assume that the WTP is constant over time. Furthermore, time is discounted by a factor $1 + r \geq 1$. Since the individual cares about total expenditures, the monthly payment she is willing to make for the dwelling at time t can be decomposed as $R_t = \bar{R}_t + C_t \times (1 - \text{CF}) \times \text{EPS}$, where C_t is the per-unit energy price, CF is the climate factor that reflects energy requirements due to a difference between local climate and the baseline (CF = 0) and \bar{R}_t is net rent. If net rents and the yearly growth rate of energy prices e are constant ($\bar{R}_t = \bar{R}$; $C_t = (1 + e)^t C$), the willingness to pay given a remaining lifetime of the building T can be expressed as follows:

$$\sum_{t=1}^T \frac{W(s, l)}{(1 + r)^t} = \sum_{t=1}^T \frac{R_t}{(1 + r)^t} = \sum_{t=1}^T \frac{\bar{R} + (1 + e)^t C \times (1 - \text{CF}) \times \text{EPS}}{(1 + r)^t}. \tag{2}$$

The expression for prices can be obtained easily from eq. (2) by assuming that buyers care about the net present value of the dwelling so that $P = \text{NPV} := \sum_{t=1}^T (1 + r)^{-t} \bar{R}$, with reservation price P . From (2), this

leads to

$$P = \sum_{t=1}^T \frac{W(s, l)}{(1+r)^t} - \delta(T) \times C \times (1 - \text{CF}) \times \text{EPS}. \quad (3)$$

122 where $\delta(T) := \sum_{t=1}^T (1+e)^t (1+r)^{-t}$. Very importantly, eq. (3) suggests that a log-log or semi-log specifi-
123 cation will not capture price differences that are related to energy cost savings adequately. More precisely,
124 rents or prices per square metre are linear in expected energy costs $C \times (1 - \text{CF}) \times \text{EPS}$. Furthermore, pre-
125 vious studies have estimated $\delta(T) \times C \times (1 - \text{CF})$, which clearly depends on heating types, fuel costs, local
126 climatic conditions, and the building age distribution in the sample.

127 4. Data

128 This study uses listing prices of houses from all regions of Germany, offered for sale on three large
129 online real estate websites, *Immonet.de*, *ImmobilienScout24.de*, and *Immowelt.de*. The data were collected
130 from April 2015 to July 2016. Due to the approach taken in this paper, it is important to use a short time
131 window in order to rule out changes in price expectations within the sample period. Naturally, this reduces
132 the number of observations, but the sample is still large enough to study separately sub-groups such as
133 district-, gas- and electricity-heated houses.

134 Listing price data have been used to study EPS certificates before (Hyland et al., 2013; Kholodilin et al.,
135 forthcoming), with results comparable to other studies that rely on similar estimation methods and trans-
136 action prices (Fuerst et al., 2015). While transaction data are preferable, listing prices seem to be a very
137 good substitute (Dinkel and Kurzrock, 2012; Henger and Voigtländer, 2014; Knight, 2002; Knight et al.,
138 1994; Malpezzi, 2003; Merlo and Ortalo-Magné, 2004; Semeraro and Fregonara, 2013). One result that
139 emerges from this literature is that mis-pricing houses systematically is quite costly for house sellers because
140 it increases time on the market and decreases the final price (Knight, 2002; Knight et al., 1994; Merlo and
141 Ortalo-Magné, 2004).

142 Two papers report hedonic regressions of matched listing and transaction data. In Knight et al. (1994),
143 only one of four coefficients of housing characteristics is significantly different across regressions, even
144 though t-values are very large (6.68 to 99.2). Coefficients in Semeraro and Fregonara (2013) hardly differ
145 across regressions.³ Closely related, three papers regress the relative difference between listing and trans-
146 action prices on covariates, but find no to marginal explanatory power of housing characteristics (Dinkel
147 and Kurzrock, 2012; Henger and Voigtländer, 2014; Semeraro and Fregonara, 2013). Taken as a whole,
148 this suggests that potential sellers – on average – do not systematically mis-price housing characteristics. If
149 the reader is willing to accept this reasoning, results can be interpreted as being close to market outcomes.
150 Otherwise, the regressions are still informative about seller behaviour.

151 The data contain information on offered prices, the zip code, EPS, and a long list of quality and structural
152 attributes. A potential problem of the data source are missing values on several important variables, in
153 particular EPS, year of construction and lot size. We chose to drop these observations because these variables
154 have great influence on the value of the house. Implications for the estimation method are discussed below.
155 Furthermore, the sample was restricted to observations with at least $50m^2$ lot size and living area, a listing
156 price per m^2 between 200 and 10,000 Euro, and three to 20 rooms that were constructed in the year 1800
157 or later. For the samples analysed in Sections 6.1 to 6.3 observations with EPS greater than 500 were also
158 discarded. These observations were regarded as outliers.

159 Summary statistics for the sample of gas-heated houses for which EPS information is available, as well
160 as a short description of the covariates, can be found in Table 2. The sample is analysed in Section 6.1.
161 Throughout, we focus on houses that hold a "projection-based" EPS certificate because these certificates do

³It is not possible to decide whether there are statistically significant differences because the authors only report significance levels and also do not indicate the type of covariance matrix that was used in their calculation.

162 not depend on past user behaviour.⁴

163 **[Table 2 about here]**

164 Each observation was observed in a specific month and zip code. Duplicates were removed within
165 each zip code, based on a comparison of the most important variables (lot size, living area, room, year of
166 construction, EPS). The price of heating gas per kWh was calculated from a data set of heating gas contracts
167 obtained from a website for gas price comparisons, *tarife.de*. Specifically, the zip code's default supplier's
168 default contract was used as the measure of this zip code's gas price, while fixed payments were excluded
169 altogether. Climate factors (CF) were provided on the level of zip codes by the German Weather Service.
170 They are defined as $CF_i = HDD_i/HDD_r - 1$, where HDD_i and HDD_r are heating degree days at zip code i
171 and at the reference location. Positive values indicate below-average temperatures, so that more heating is
172 required than at the reference location. Compared to the reference location, the climate is 3% milder in the
173 sample on average, with a standard deviation of 6%.

174 **5. Empirical strategy**

175 *5.1. Sources of variation*

176 It has been argued that a simple regression of P on EPS suffers from endogeneity if structural or locational
177 attributes of the dwelling are correlated with EPS, but not captured adequately by the available variables. In
178 particular, it is very likely that interior and structural quality are correlated with EPS, e.g. because newer
179 homes tend to have better EPS and building materials; retro-fitting that aims at improving EPS at the same
180 time improves quality, and so on. Similar arguments have been made by Brounen and Kok (2011); Deng

⁴For houses older than three years, a "consumption-based" EPS can be calculated which is based on energy use in the past three years.

181 et al. (2012); Fuerst et al. (2015, 2016); Högberg (2013), inter alia. Observable quality characteristics from
182 different data sets suggest that the issue should be taken seriously: Energy efficient buildings are younger
183 and of higher quality (Deng et al., 2012; Eichholtz et al., 2013; Kahn and Kok, 2014).

184 Because e , r and T are not known, it is difficult to decide to what extent an estimate for δ falls short of
185 (or exceeds) energy cost savings for the dwelling's residents. One obstacle in this way is the dependence of δ
186 on T . Hence, in order to be able to compare estimates for δ from different sources of variation it is necessary
187 to balance the building age structure of the sample. We approach the problem in three complementary ways.
188 (i) As noted in the introduction, variation of heating fuel prices over space and, because EPS is climate-
189 normalised, spatial variation of climate can be used in order to test whether participants in the market are
190 aware of the relationship stated in Eq. (3). (ii) The value of EPS should depend on fuel type if (future and
191 present) fuel costs differ. Under the assumption that prices of different fuel types are expected to increase
192 with the same rate, δ should be equal across fuel types in a regression of prices on expected energy costs, as
193 long as building age is taken into account. (iii) Needless to say, the functional form of δ is interesting in itself
194 (cf. Sallee et al., 2015). According to its definition, δ should be greatest for young buildings and decrease
195 strictly with building age, up to the point where buildings are retro-fitted. We exploit the dependence of δ
196 on T and estimate T and $d := (1 + e)/(1 + r)$ directly from the data.

197 (i) *Local fuel prices and climate.* The theoretical argument laid out above explicitly takes into account that
198 energy costs are related to fuel costs via C and local climate via CF . We argue that variation in $\text{EPS} \times$
199 "local fuel prices" and $\text{EPS} \times$ "local climate" is not subject to quality bias. The most important underlying
200 assumption is stability over time of the geographical pattern of prices and local climate.

201 Variations in fuel prices over time and space have been exploited by Allcott and Wozny (2014) and Busse
202 et al. (2013) in their studies of the auto-mobile market. Note that in the present context time variation is less
203 useful because it strengthens the reliance of the results on discount rates and remaining lifetimes. However,
204 the immobility of houses allows to use variation over space more effectively. Figure 1a shows substantial

205 spatial variation of gas prices in German zip codes in mid-2016. To the extent that these differences are
206 permanent, the implied heating cost differences are considerable.

207 **[Figure 1 about here.]**

208 Variation in climatic conditions (CF, see Figure 1b) over space is useful in the present context because
209 EPS are climate-standardised. Obviously, energy use depends on local climatic conditions via EPS. In terms
210 of the model, CF is one factor that influences l in Eq. (1) (cf. Potepan, 1996, inter alia). Similarly, the
211 normalised energy performance of a building could be one of the determinants of s , the structural quality of
212 the building. In other words, a cross-sectional comparison of EPS across buildings might capture differences
213 in building design, but EPS is related only indirectly to energy consumption. If other quality characteristics
214 correlated with EPS are not controlled for adequately, this term will also reflect general building quality.

215 Table 1 summarises the distributions of projected yearly energy costs per square metre for gas-heated
216 houses in the sample (excluding fixed payments). In gas-heated houses, residents have to spend 9.7 Euro/ $[m^2 \cdot a]$
217 $a]$ for heating at the median (EPS = 150 kWh/ $[m^2 \cdot a]$). In houses at the first and fourth quartiles of the
218 EPS distribution (80 kWh/ $[m^2 \cdot a]$ and 219 kWh/ $[m^2 \cdot a]$, respectively), energy costs differ substantially (5.2
219 Euro/ $[m^2 \cdot a]$ and 14.2 Euro/ $[m^2 \cdot a]$). Looking at variation over space (local prices), the interquartile range
220 is 0.9 Euro/ $[m^2 \cdot a]$, and the difference between the 9th and the first decile is 2.6 Euro/ $[m^2 \cdot a]$. In a house
221 with a living area of 140 m^2 (median), this implies yearly cost differences across ZIP codes of 126 and
222 364 Euro per year. The interquartile range of energy cost differences from local climate is slightly smaller,
223 0.7 Euro/ $[m^2 \cdot a]$, or 98 Euro per year. Even though these numbers are relatively small compared to yearly

224 down-payments for typical a 140 m^2 house, they are not negligible.

225 **[Table 1 about here.]**

226 (ii) *Fuel types.* Four main fuel types are used in Germany⁵ gas (49.3%, including liquid gas and bio-gas),
227 light heating oil (26.8%), district heating (13.5%), and electricity (2.9%). Taking gas as the baseline, Figure
228 2 plots the relative costs per kWh of each of these four fuel types. Whereas the price of light heating oil
229 increased relative to the price of natural gas, the cost ratios of electricity and district heating to natural gas
230 have been quite stable over the past 24 years. If consumers rely on this type of information to form their
231 beliefs about the cost relationship between the four fuel types, their the valuation of EPS should reflect
232 these cost-ratios. A simple statistical test could be built around differences between EPS coefficients across
233 heating types. However, identification issues are much more prevalent in this case.

234 **[Figure 2 about here.]**

235 (iii) *Building age.* Assume that $\delta(T)$ takes on the functional form as defined in eq. (3) and consider a regres-
236 sion of price per square metre on EPS and covariates, where the coefficient of EPS is estimated separately for
237 three building age groups (A: 0-7 years, B: 8-15 years, C: 16-23 years). Intuitively, $\delta(T)$ can be estimated
238 by the ratio of differences between the EPS coefficients for the three age groups. Section C in the appendix
239 shows that this is indeed the case if the building age distributions within each age group are similar. For-
240 mally, let $p_i^k \in [0, 1]$ ($i = 1, \dots, 8$) and $\sum_{i=1}^8 p_i^k = 1$ for $k \in \{A, B, C\}$. p_i^k is the share of observations with the
241 i^{th} youngest age in group k . Then, it is necessary to impose $p_i^A = p_i^B = p_i^C \forall i$.

⁵Figures reported by the German Association of Energy and Water Industries (BDEW), “Beheizungsstruktur des Wohnungsbestandes in Deutschland 2014”

242 Since the estimated $\delta(T)$ is calculated from differences of coefficients, the identifying assumptions are
243 less strict than in previous papers. Let $\text{EPS} = \gamma_0 + \gamma_1 Q + v$ for all three age groups, with an omitted variable
244 Q . If $P_k = \alpha + \beta_k C \times \text{EPS} + \bar{\beta} Q + \eta$ in age group k , and P_k is regressed on EPS, we have $E[\widehat{\beta}_k C] = \beta_k C + \bar{\beta} \gamma_1$,
245 so that $E[\widehat{\beta}_k C] - E[\widehat{\beta}_l C] = (\beta_k - \beta_l)C$. In other words, if quality bias is present but takes on the same form
246 in each age group, the approach still yields unbiased estimates. This relaxes the assumption made by other
247 papers, namely $\bar{\beta} \gamma_1 = 0$. A similar argument can be made w.r.t. approach (ii) described above.

248 5.2. Coherent behaviour

249 The analysis of different sources of variation allows to take a second look at the EPS valuation problem
250 by focussing on the coherence of estimated patterns. Previous authors have attempted to directly answer
251 the question whether present values of energy cost differences match price differences on the market. This
252 presupposes that individuals calculate energy cost differences correctly even if cost differences stem from
253 different sources (such as local climate or fuel prices). Eq. (3) shows that – if energy costs are calculated
254 correctly and the age structure is accounted for – regression estimates of the “present value coefficient”
255 $\delta(T)$ should be equal for different sources of variation. This can be seen as a test of the preconditions for
256 reasonable present value calculations.

257 The comparison of different sources of variation brings in another aspect that is highly relevant for the
258 design of EPS certificates: Including climatic conditions into the present value calculation is relatively dif-
259 ficult because the relationship between climate and heating costs is highly technical. Similarly, information
260 on local fuel prices is not necessarily salient to the house buyer because the local default provider will send a
261 default contract to the house owner automatically. In contrast to local climatic variation the relationship be-
262 tween energy costs and prices is linear in EPS. Finally, if market participants consider the impact of building
263 age on the value of EPS, it is very likely that they understand the investment character of energy efficiency
264 improvements. This can be the case even if they do not take into account more subtle variation, such as local
265 fuel prices or climate.

266 5.3. *Other issues*

267 Previous authors have identified another problem that is related to the availability of information on EPS.
268 Conditional on reporting year of construction, lot size, and heating type, only 56% of all observations include
269 EPS information, even though it is mandated by law to display EPS in online real estate offers (see Table 3).
270 Potentially, defiers can report EPS in their offers, but without using the forms provided by the websites—in
271 these cases, the certificate does not appear in the data. There is an exception for new buildings if the EPS
272 is not available yet. Indeed, the share of reported EPS increases to 66.4% if building age is greater than 1.
273 Conversely, only 15.8% of the observations with at least one missing value among the year of construction,
274 lot size, or heating type variables report EPS.

275 **[Table 3 about here]**

276 It has been argued that dwellings offered without information on energy efficiency are systematically
277 different from other dwellings. These objects might have higher EPS and lower quality than comparable
278 buildings. For that reason, previous papers have estimated selection models (Brounen and Kok, 2011; Hyland
279 et al., 2013; Kholodilin et al., forthcoming). However, reporting rates were much lower in these papers (18%
280 in Brounen and Kok (2011) and Kholodilin et al. (forthcoming), and 5% in Hyland et al. (2013).

281 This paper does not estimate a selection model for the following reason: If EPS information influences
282 prices, it will be more likely that non-reporters are forced to re-negotiate the price once EPS information is
283 presented. The strategy would thus lead to longer time on the market and the need for price re-negotiation
284 (Knight, 2002) because potential buyers will have a chance to check the EPS certificate even if it is not
285 presented in the offer. According to this reasoning, there are other (unsystematic) reasons why some offers
286 do not contain EPS information. Table 3 suggests that general data quality is lower for these observations.
287 It would bring in new problems if a selection model was built around these observations. In any case the

288 results will be representative for a relatively large part of the population.

289 6. Estimation results

Results for a baseline model are presented in the Appendix, Table 4. The sample consists of all observations for which information on year of construction, lot size, heating type, and EPS is available, see Table 3.

For an observation i from district d , month t , and heating type h ,

$$\log P_i = X_i\beta + \phi_t + \psi_d + \delta \times EPS_i + \eta_i. \quad (4)$$

290 P_i is the price per square metre of house i , EPS_i is its energy performance score, and X_i is a vector of housing
291 characteristics, including heating type (base category: gas heating). ϕ_t and ψ_d are time and district fixed
292 effects. Table 4 contains the results. In column (1), the log price is the dependent variable, and the EPS
293 coefficient is negative and highly significant.⁶ It implies a reduction of the price by approx. 0.11% as EPS
294 increases by 1% (at sample mean). In column (2), the dependent variable is the price per square metre. The
295 EPS effect is slightly smaller (-0.07% at sample mean) and model fit is somewhat worse. Nevertheless, eq.
296 (3) suggests that a linear form captures heating cost effects more accurately. Potentially, the difference can
297 be attributed to the effect of unobserved building quality. A jump from an A-rated building ($30 < EPS < 50$)
298 to an E-rated building ($160 < EPS < 200$) reduces the price by 10.5% (at sample mean), which is very close
299 to estimates found in other studies, e.g. 9.3% in Hyland et al. (2013) or 10.2% in (Brounen and Kok, 2011).
300 Covariates are included in the table as well. The overall picture is reasonable. Higher quality, younger,
301 detached houses on larger lots are offered at a higher price per square metre.

302 Figure 3 shows kernel density estimates for the EPS variable in different year of construction brackets.
303 Clearly, younger buildings have much higher energy efficiency, and the distribution shifts to the right from

⁶Note that a regression of log price per square metre on covariates including log living area is equivalent to the more common regression of log price on covariates including log living area.

304 the group of middle- to the group of old-age buildings. Furthermore, the distributions of older houses are
 305 much more widespread, probably because some of the older houses were retro-fitted. This points to a source
 306 of bias that should be accounted for in the analysis: If the vintage structure of buildings across space changes,
 307 so will the distribution of EPS and the value of energy efficiency (via T).

308 **[Figure 3 about here.]**

309 *6.1. Local variation in gas prices and climatic conditions*

In this section, we consider the effect of local variation in gas prices and climate on the value of EPS. The sample is restricted to gas-heated houses. The estimating equations read

$$P_i = X_i\beta + \phi_i + \psi_z + \delta(C \times EPS_i) + \gamma(\Delta_z C \times EPS_i) + \eta_i \quad (5)$$

$$P_i = X_i\beta + \phi_i + \psi_z + \delta(C \times EPS_i) + \gamma(C \times CF_z \times EPS_i) + \eta_i \quad (6)$$

310 where C is the average price of gas per kWh in the sample, $\Delta_z C$ is the deviation from that average in zip code
 311 z , and CF_z is the climate factor of zip code z . Since identifying variation lives at the level of zip codes, we
 312 include zip code fixed effects, ψ_z and use zip code-clustered standard errors. The regressions also control
 313 for an interaction of EPS and population density, to account for the possibility that construction was more

314 concentrated in densely populated areas in the past years.

315 **[Table 5 about here]**

316 Coefficient estimates for the most important variables from eq. (5) are reported in columns (1) to (4) of
317 Table 5. The main effect, δ , implies a 23 Euro reduction as heating costs per m^2 , $C \times EPS_i$, increase by 1
318 Euro. This suggests that the present value term, $\delta(T)$ in (3), is equal to 23. However, local differences in gas
319 prices do not seem to be important. The coefficient estimate for γ is close to zero and insignificant. A Wald
320 test of $\delta = \gamma$ has a p-value of 0.001.

321 Potentially, very high EPS are ignored by the market because the time until retro-fitting becomes optimal
322 might be very short for these houses. Similarly, very efficient homes might sell at an additional premium.
323 Therefore, model (2) excludes observations with EPS outside the range 50 to 300. Qualitatively, the results
324 remain unchanged. However, the main effect is significantly larger in this model.

325 A reason why local gas price differences do not play a role might be that differences are too small
326 and/or not stable over time. Furthermore, there might be considerable noise in the measurement of local gas
327 prices. We therefore restrict our attention to zip codes that share a border with a zip code where the price of
328 heating gas is lower by at least 1 *ct/kWh*. In a typical house with an EPS of 160 $kWh/[m^2 \cdot a]$, the expected
329 difference in heating costs across zip codes is at least 1,60 Euro per m^2 and year, which is substantial. For
330 each pair of zip codes, observations were matched on the the building age variable⁷ in order to control for
331 the dependence of $\delta(T)$ on the remaining lifetime of the building. Differences between the matches were
332 then regressed according to eq. (5). In order to capture local land price differences, the median house price
333 among all houses without gas heating was calculated in each zip code and included as a regressor.

334 Column (3) of Table 5 contains the results. Reassuringly, gas price differences still remain insignificant

⁷Matching was done without replacement and inexact, using the `Match` function from R package `Matching`.

335 and small, while the main effect is slightly lower than in model (1). Column (4) restricts the sample further to
 336 matches for which the EPS difference was smaller than $25 \text{ kWh}/[\text{m}^2 \cdot \text{a}]$ in absolute value. In this sample, the
 337 focus is on (energetically) similar houses across zip code borders with relatively large gas price differences.
 338 Even though this model produces the largest interaction effect (-0.09), it still remains insignificant and much
 339 smaller than the main effect (-0.16 to -0.36).

340 The remaining two models focus on variation in local climate. In column (5), the local gas price-
 341 interaction was dropped and a local climate interaction term was added, see eq. (6). The coefficient has
 342 a positive sign, suggesting that the value of EPS is slightly *lower* in colder regions. However, it is insignifi-
 343 cant. The same holds for model (6) that again restricts the sample to observations with EPS higher than 50,
 344 but lower than 300. Taken as a whole, these results do not suggest that participants in the market consider
 345 local variation in climate or gas prices when calculating an implicit price of energy efficiency.

346 6.2. Fuel types

347 Variation in heating costs that was exploited in Section 6.1 is relatively subtle. More pronounced differ-
 348 ences exist across different fuel types. Compared to gas heating (gas combustion on-site), district heating
 349 (heat delivered through a local network) was 22% more expensive on average in the past 24 years. Electricity
 350 heating is three to four times as expensive as gas heating (see Figure 2).

In this section, a sub-sample of gas-, district-, and electricity-heated houses is analysed. The estimating equation is

$$P_i = X_i\beta + \phi_t + \psi_z + H_g + H_e + \delta EPS_i + \gamma(H_g \times EPS_i) + \kappa(H_e \times EPS_i) + \eta_i. \quad (7)$$

351 H_g and H_e are dummy variables that are equal to 1 if the heating type is gas or electricity, respectively.
 352 The sample was restricted to zip codes in which all three fuel types were present in the data. In order to
 353 identify the effect properly, it is important to ensure comparability of houses across fuel types. For instance,

354 it is likely that some gas-heated houses have special features that cannot be observed in electricity-heated
 355 houses, so that these houses cannot be compared easily. As a solution, a combination of propensity score
 356 weighting and trimming was used. Table 6 displays means of all important variables for the three fuel types.
 357 Clearly, there are important differences in the unweighted samples. For instance, district-heated houses are
 358 built on smaller lots and are younger than gas-heated houses, while electricity-heated houses seem to be of
 359 lower quality.

360 **[Table 6 about here]**

361 **[Table 7 about here]**

The results from two logistic regressions are reported in Table 7. An indicator variable that is equal to 1 if a house has district-heating installed was regressed on an array housing characteristics, separately for the sub-samples of gas- and electricity-heated houses. All houses with a predicted probability of having district-heating installed, \hat{p}_i , smaller than 5 or larger than 95% were excluded. Propensity weights w_i were defined as follows:

$$w_i = \begin{cases} \min\left\{\frac{\hat{p}_i}{(1-\hat{p}_i)}, 4\right\}, & i \text{ has gas or electricity heating,} \\ 1, & i \text{ has district heating.} \end{cases} \quad (8)$$

362 The boundary at a weight of 4 was used to prevent very influential observations from driving the results. It
 363 corresponds to a propensity to be district-heated of 80%. A comparison of weighted means in Table 6 clearly

364 shows that the weights greatly increase comparability across the three heating types.

365 **[Table 8 about here]**

366 Results for the most important variables are displayed in Table 8. In the unweighted sample, column
367 (1), the main effect is significant and negative, as expected. However, the value of EPS is not significantly
368 different in gas-heated houses, even though gas is about 20-25% less expensive than district heating. The
369 value of EPS seems to be more than twice as high in electricity-heated houses, which roughly corresponds
370 to the idea that electricity is much more expensive than gas. However, this effect becomes insignificant
371 when the weighted sample is used, see column (2). Now, only the main effect is significant, suggesting that
372 differences between district and electricity-heated houses in other dimensions might be responsible for the
373 significant interaction term in column (1).

374 Overall, the value of EPS does not seem to reflect the fact that there are persistent price differences
375 between different fuel types - even though these differences are substantial: In a typical house of 150 m² and
376 an EPS of 100 kWh/[m² · a], the yearly energy bill amounts to approx. 900 Euro if the gas price is 6 ct/kWh.
377 With electricity heating at a price of 20ct/kWh, the household would pay as much as 3000 Euro per year.

378 6.3. Remaining lifetime of buildings

379 Thus far, the results make it difficult to see clearly whether the valuation of energy efficiency follows
380 reasonable patterns. This section adds one further dimension by focussing on the investment motive behind
381 energy efficiency improvements. Clearly, if retro-fitting becomes necessary for some reason other than an
382 improvement in energy efficiency, the latter can be done incidentally. This splits fixed costs of the investment
383 and therefore increases its profitability. Hence, investors should care for T , the remaining lifetime of the
384 building.

In order to be able to use variation in T while reducing data errors (i.e. unobserved rehabilitation) as

much as possible, we focus on the sub-sample of oil- and gas-heated houses with building ages lower than 7, between 8 and 15, and between 16 and 23 years. EPS coefficients are then estimated for each of these three periods separately:

$$P_i = X_i\beta + \phi_t + \psi_z + \delta(D_i^{\leq 7} \times EPS_i) + \gamma(D_i^{8-15} \times EPS_i) + \kappa(D_i^{16-23} \times EPS_i) + \eta_i. \quad (9)$$

385 $D^{\leq 7}$, D^{8-15} , and D^{16-23} are dummies for the three age groups that are also included in X . δ , γ , and κ capture
 386 separately the value of energy efficiency in the three age groups. Results can be found in Table 9.

387 **[Table 9 about here]**

388 In column (1), a clear pattern emerges: The value of energy efficiency is largest for the youngest group.
 389 As buildings get older, the value associated to EPS decreases, from 2.12 Euro per 1 $kWh/[m^2 \cdot a]$ reduction
 390 in EPS, to 1.98 in the middle group, to 1.47 in the youngest group. This pattern fits well the idea that the
 391 remaining lifetime of the energy efficiency investment is important for its valuation.

392 In Appendix C, it is shown that these three coefficients can be made comparable by imposing the same
 393 distribution of building ages within each age group. Under this condition, it is possible to obtain estimates for
 394 T and $d = (1 + e)/(1 + r)$ directly from the data.⁸ It must be noted that data requirements are enormous—and
 395 much higher than what is available for this paper—because coefficient standard errors are inflated strongly in
 396 the calculation of T and d . Estimates for these two parameters are presented for expositional purposes, but
 397 should be interpreted cautiously.

⁸More precisely, the smallest age group of buildings between 16 and 23 years old was chosen as the reference group. Before the model was estimated, the reference group's age distribution was imposed on the other two groups by dropping observations from years that are over-represented. In the estimation, this was repeated 200 times. In each repetition, 50 draws were made from a normal distribution centered around the coefficient estimate, with a standard deviation equal to the estimated standard error. The reported coefficient estimates and standard errors in column (2) of Table 9 are the empirical means and standard errors of these 200×50 draws.

398 The estimate for T , 30.7 years, is remarkably close to the average lifetime of relevant building parts used
399 in Germany (10–15 years for boilers, 35 – 55 years for insulation, roofs and walls, see Hoier and Erhorn
400 2013). The estimated value for d , 0.829, implies an interest rate r of 20.6% if real gas prices are expected
401 to be constant ($e = 0$). This is a high value, given that interest rates for construction loans were around 2%
402 in 2015.⁹ Nevertheless, high internal discount rates are a common result: In a recent survey, Newell and
403 Siikamäki (2015) report an average individual discount rate of 19% (see also Jaffe and Stavins, 1994, p. 122
404 and Fn. 17). High discount rates could be explained by financing constraints of house buyers who “borrow”
405 additional funds by accepting higher future energy costs in exchange for a lower price of the house.

406 6.4. Discussion of results

407 Taken as a whole, the results suggest that, in parts, energy efficiency is taken into account in an econom-
408 ically meaningful way by sellers of residential houses in Germany. However, potential cost savings are not
409 always and everywhere calculated correctly. According to Giuliatti et al. (2005), switching costs reduce con-
410 siderably the propensity to switch electricity supplier. Hence, if costs related to switching the gas supplier
411 are perceived to be high, ignoring gas price differences can be interpreted as “rational inattention” (Sallee,
412 2014). Variation in local gas prices or climate did not influence the value of EPS (Section 6.1). Additionally,
413 there were no significant differences in the value of EPS across heating fuel type, even though the price of
414 electricity was at least three times the price of gas in the past 24 years. Given the large potential savings in
415 this case, this latter result cannot be explained by rational inattention alone. In line with this finding, recent
416 survey results suggest that there is considerable heterogeneity of behaviour w.r.t. energy efficiency across
417 households (Ramos et al., 2016).

418 One important finding of this paper is that building age alters the value of EPS considerably. Earlier
419 papers have estimated one single coefficient for samples that typically include buildings of all vintages and

⁹Interest rates for construction loans with a duration of 1 to 5 years to private households (new customers) were below 2% throughout the year 2015, see the interest rate statistic of Deutsche Bundesbank from February 3, 2016.

420 heating fuel types – although some have looked at sub-samples of different house types (Fuerst et al., 2015;
421 Hyland et al., 2013). Consider the coefficient of $\text{eps} \times \text{avg. gas price}$ in column (1) of Table 5, indicating
422 that a one Euro increase in expected yearly heating costs per square metre decreases listing prices by approx.
423 23 Euro/ m^2 . At sample means, a change from an A-rated building ($30 \leq \text{EPS} < 50$) to an E-rated building
424 ($160 \leq \text{EPS} < 200$) increases expected heating costs by approximately 9.09 Euro/ $[m^2 \cdot a]$. The decrease in
425 prices amounts to 208.98 Euro, or 10.2% of the sample mean. As noted above, this is very close to the values
426 reported in other studies, e.g. Hyland et al. (2013, 9.3%) and Brounen and Kok (2011, 10.2%).¹⁰ Note that
427 both studies use a selection model because EPS is not reported in all observations. The suspected upward
428 bias of EPS in OLS estimation does not seem to be large.

429 Once the sample is restricted to buildings younger than eight years, the estimated coefficient doubles in
430 size, cf. Table 9. From the perspective of an investor or construction company, the results from Table 9 are
431 much more important than knowing how EPS is capitalised *on average*, i.e. in the existing stock. If a house
432 owner wants to improve energy efficiency of the building substantially, it is very likely that the building
433 is rehabilitated rather than renovated. The results presented here suggest that the premium will be much
434 higher in that case. They are much closer to the policy-relevant question of how to foster energy efficiency
435 investments in an effective manner.

436 It must be noted that this paper faces the same quality bias as other studies (e.g. Brounen and Kok, 2011;
437 Fuerst et al., 2015; Hyland et al., 2013; Kahn and Kok, 2014). Exogenous variation from local climate or gas
438 prices does not seem to be important to house sellers and thus cannot be used to identify the EPS coefficient.
439 However, part of the analysis relies on differences of potentially biased coefficients. Under the assumption
440 that quality bias is equally strong for houses of different fuel types or building ages, the interaction terms in
441 Table 8 and differences of the estimates in Table 9 are identified. The latter were used to calculate estimates

¹⁰Fuerst et al. (2015) report coefficient estimates for A or B rated buildings and find a premium over E-rated buildings of 5.7% for the full sample.

442 for the investment horizon, T , and the factor $d = (1 + e)/(1 + r)$. T and d can be used to calculate the
443 present value of saving one Euro on energy costs per year and square metre in a new building. Setting
444 $T = 31$ and $d = 0.882$, it is 5.83 Euro/ m^2 . Assuming an average gas price of 6.5 ct/kWh, the coefficient
445 estimate for the youngest group implies a NPV of $2.1/0.065 \approx 32.31$ Euro/ m^2 . Because of high uncertainty
446 in the calculation of T and d this is only suggestive of positive quality bias, but it calls for a more rigorous
447 identification of the capitalisation of energy efficiency in future work.¹¹

448 7. Conclusion

449 This paper has investigated several channels that influence how sellers on the housing market value
450 energy efficiency in residential buildings. The results have shown that agents are able to consistently use
451 very precise information such as EPS instead of labels or efficiency bands. Agents also seem to be aware of
452 the investment horizon of energy efficiency investments. Overall, the investment dimension of EPS seems to
453 be understood quite well.

454 The results are less clear about more subtle differences such as local gas prices or climatic conditions.
455 Furthermore, regressions that relied on different fuel types did not produce a consistent pattern with respect to
456 EPS coefficients. Whether this is a sign of irrational or rational inattention cannot be answered conclusively
457 at this point. Anyhow, if there are problems of correct valuation in these dimensions, they could easily be
458 tackled by including estimates of expected heating costs in EPS certificates. These estimates should be based
459 on local fuel prices and climate.

460 Future research should provide other ways of identifying the EPS coefficient. Given the difficulties to
461 assess whether estimated premia reflect energy cost savings, survey evidence along the lines of Newell and
462 Siikamäki (2015) would help greatly to further understanding in this area. A second shortcoming of this
463 study is its use of listing instead of transaction prices. There are sound theories and empirical evidence

¹¹As an example for the sensitivity of T and d consider a change of the coefficient of the youngest group from 2.10 to 2.34 (one standard error). This yields $T = 77.4$ and $d = 0.956$ and a present value of 21.2 Euro/ m^2 .

464 showing that systematically mis-pricing housing characteristics is very costly to house sellers and should
465 thus be avoided. Nevertheless, the use of listing prices is a source of potential bias. It would thus be very
466 interesting to see whether the results are robust to using transaction data such as in Fuerst et al. (2015).

467 The results cast doubt on the interpretation that the correlation between energy efficiency labels and
468 housing prices stems from energy cost considerations. More likely, substantial parts of the correlations stem
469 from a “green marketing”-effect and/or quality bias. The results indicate that it would be desirable to refine
470 existing EPS schemes and establish a tighter connection between EPS and energy cost savings. This is of
471 prime importance if the goal is to reduce energy use (and CO₂ emissions) in residential buildings. If premia
472 are related to “green” marketing alone, simple (binary) labels are not very useful because this will spur
473 investment in marketing and pseudo-efficient rather than truly efficient design (Newell and Siikamäki, 2014;
474 Sallee, 2014). Responsiveness of households to energy taxes is a key ingredient of theoretical analyses that
475 consider the effects of energy taxes on consumer behaviour (see, e.g. Conrad, 2000). Taxation of energy
476 consumption will be much more effective if heating cost savings translate into an increase in the value of
477 energy efficient houses.

478 Besides its implications for climate change, an energy efficient building stock is critical for Europe’s
479 political independence in the future. For these reason, it is worth while to study more thoroughly how
480 markets react to the existing policy instruments.

481 **References**

482 Allcott, H., Greenstone, M., 2012. Is there an energy efficiency gap? *The Journal of Economic Perspectives*
483 26 (1), 3–28.

484 Allcott, H., Mullainathan, S., 2010. Behavioral Science and Energy Policy. *Science* 327 (5970), 1204–1205.

485 Allcott, H., Wozny, N., 2014. Gasoline prices, fuel economy, and the energy paradox. *Review of Economics*
486 and Statistics 96 (5), 779–795.

487 Brounen, D., Kok, N., 2011. On the economics of energy labels in the housing market. *Journal of Environ-*
488 *mental Economics and Management* 62 (2), 166–179.

489 Busse, M. R., Knittel, C. R., Zettelmeyer, F., 2013. Are Consumers Myopic? Evidence from New and Used
490 Car Purchases. *The American Economic Review* 103 (1), 220–256.

491 Chetty, R., Looney, A., Kroft, K., 2009. Salience and Taxation: Theory and Evidence. *American Economic*
492 *Review* 99 (4), 1145–1177.

493 Conrad, K., 2000. Energy tax and competition in energy efficiency: The case of consumer durables. *Envi-*
494 *ronmental and Resource Economics* 15 (2), 159–177.

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

497 Dinan, T. M., Miranowski, J. A., 1989. Estimating the implicit price of energy efficiency improvements in
498 the residential housing market: A hedonic approach. *Journal of Urban Economics* 25 (1), 52–67.

499 Dinkel, M., Kurzrock, B.-M., 2012. Asking prices and sale prices of owner-occupied houses in rural regions
500 of Germany. *Journal of Interdisciplinary Property Research* 2012 (1), 5–23.

501 Eichholtz, P., Kok, N., Quigley, J. M., 2010. Doing Well by Doing Good? Green Office Buildings. *The*
502 *American Economic Review* 100 (5), 2492–2509.

503 Eichholtz, P., Kok, N., Quigley, J. M., 2013. The Economics of Green Building. *The Review of Economics*
504 *and Statistics* 95 (1), 50–63.

505 Fuerst, F., McAllister, P., 2011. Green Noise or Green Value? Measuring the Effects of Environmental
506 Certification on Office Values. *Real Estate Economics* 39 (1), 45–69.

507 Fuerst, F., McAllister, P., Nanda, A., Wyatt, P., 2015. Does energy efficiency matter to home-buyers? An
508 investigation of {EPC} ratings and transaction prices in England. *Energy Economics* 48, 145–156.

509 Fuerst, F., McAllister, P., Nanda, A., Wyatt, P., 2016. Energy performance ratings and house prices in wales:
510 An empirical study. *Energy Policy* 92, 20–33.

511 Gabaix, X., Laibson, D., 2006. Shrouded Attributes, Consumer Myopia, and Information Suppression in
512 Competitive Markets. *Quarterly Journal of Economics* 121 (2), 505–540.

513 Gerarden, T. D., Newell, R. G., Stavins, R. N., Stowe, R. C., 2015. An assessment of the energy-efficiency
514 gap and its implications for climate-change policy. NBER Working Paper 20905.

515 Giulietti, M., Price, C. W., Waterson, M., October 2005. Consumer Choice and Competition Policy: A Study
516 of UK Energy Markets. *The Economic Journal* 115, 949–968.

517 Halvorsen, R., Pollakowski, H. O., 1981. The Effects of Fuel Prices on House Prices. *Urban Studies* 18 (2),
518 205–211.

519 Harjunen, O., Liski, M., 2014. Not so Myopic Consumers. Evidence on Capitalization of Energy Technolo-
520 gies in a Housing Market. CESifo Working Paper No. 4989.

521 Hausman, J. A., 1979. Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables.
522 *The Bell Journal of Economics* 10 (1), 33–54.

523 Henger, R., Voigtländer, M., 2014. Transaktions- und Angebotsdaten von Wohnimmobilien – eine Analyse
524 für Hamburg. *IW Trends* 41 (4), 1–16.

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

527 Hoier, A., Erhorn, H., 2013. Entwicklung und energetische Bewertung alternativer Sanierungsfahrpläne. En-
528 ergetische Gebäudesanierung in Deutschland. Studie Teil I. Tech. rep., Fraunhofer-Institut für Bauphysik.

529 Hyland, M., Lyons, R. C., Lyons, S., 2013. The value of domestic building energy efficiency – evidence from
530 Ireland. *Energy Economics* 40, 943–952.

- 531 Jaffe, A. B., Stavins, R. N., 1994. The energy paradox and the diffusion of conservation technology. *Resource*
532 *and Energy Economics* 16 (2), 91–122.
- 533 Kahn, M. E., Kok, N., 2014. The capitalization of green labels in the California housing market. *Regional*
534 *Science and Urban Economics* 47, 25–34, sI: Tribute to John Quigley.
- 535 Kholodilin, K. A., Mense, A., Michelsen, C., April forthcoming. The market value of energy efficiency in
536 buildings and the mode of tenure. *Urban Studies*.
- 537 Knight, J. R., 2002. Listing Price, Time on Market, and Ultimate Selling Price: Causes and Effects of Listing
538 Price Changes. *Real Estate Economics* 30 (2), 213–237.
539 URL <http://dx.doi.org/10.1111/1540-6229.00038>
- 540 Knight, J. R., Sirmans, C., Turnbull, G. K., 1994. List price signaling and buyer behavior in the housing
541 market. *The Journal of Real Estate Finance and Economics* 9 (3), 177–192.
542 URL <http://dx.doi.org/10.1007/BF01099271>
- 543 Malpezzi, S., 2003. Hedonic Pricing Models: A Selective and Applied Review. In: Gibb, K., O’Sullivan, A.
544 (Eds.), *Housing Economics and Public Policy. Essays in Honor of Duncan MacLennan*. Blackwell Science,
545 Oxford, pp. 67–89.
- 546 Merlo, A., Ortalo-Magné, F., 2004. Bargaining over residential real estate: evidence from England. *Journal*
547 *of Urban Economics* 56 (2), 192–216.
548 URL <http://www.sciencedirect.com/science/article/pii/S0094119004000609>
- 549 Newell, R. G., Siikamäki, J., 2014. Nudging Energy Efficiency Behavior: The Role of Information Labels.
550 *Journal of the Association of Environmental and Resource Economists* 1 (4), 555–598.
- 551 Newell, R. G., Siikamäki, J., 2015. Individual time preferences and energy efficiency. *American Economic*
552 *Review: Papers and Proceedings* 105 (5), 196–200.

- 553 Potepan, M. J., 1996. Explaining Intermetropolitan Variation in Housing Prices, Rents and Land Prices. *Real*
554 *Estate Economics* 24 (2), 219–245.
- 555 Ramos, A., Labandeira, X., Löschel, A., 2016. Pro-environmental Households and Energy Efficiency in
556 Spain. *Environmental and Resource Economics* 63 (2), 367–393.
- 557 Rosen, S., 1974. Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *The*
558 *Journal of Political Economy* 82 (1), 34–55.
- 559 Sallee, J. M., 2014. Rational Inattention and Energy Efficiency.
- 560 Sallee, J. M., West, S. E., Fan, W., 2015. Do Consumers Recognize the Value of Fuel Economy? Evidence
561 from Used Car Prices and Gasoline Price Fluctuations. NBER Working paper 21441.
- 562 Semeraro, P., Fregonara, E., 2013. The impact of house characteristics on the bargaining outcome. *Journal*
563 *of European Real Estate Research* 6 (3), 262–278.
- 564 Soriano, F., 2008. Energy efficiency Rating and House Price in the ACT. Modelling the relationship of energy
565 efficiency attributes to house price: the case of detached houses sold in the Australian Capital Territory in
566 2005 and 2006. Tech. rep., Australian Bureau of Statistics, Department of Water, Heritage and the Arts,
567 Canberra.
- 568 Walls, M., Palmer, K. L., Gerarden, T., 2013. Is Energy Efficiency Capitalized into Home Prices? Evidence
569 from Three US Cities. *Resources for the Future Discussin Paper No. 13-18*.

Table 1: Heating costs in gas-heated houses

	Quantiles				
	10%	25%	50%	75%	90%
avg. gas price	3.2	5.2	9.7	14.2	18.8
local gas price	-1.2	-0.5	-0.1	0.4	1.4
local climate	-1.3	-0.7	-0.3	0.0	0.3

Table 2: Summary statistics for the gas prices and climate sample

<i>Variable</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Min.</i>	<i>Max.</i>	<i>Description</i>
<i>a) listing price and energy performance score</i>					
listing price per m ²	2043.81	1202.32	200.00	10000.00	listed sales price per m ²
eps	160.12	92.83	0.00	500.00	energy performance score
<i>b) general characteristics</i>					
type semi-detached	0.20	0.40	0	1	semi-detached house
type terraced (middle)	0.10	0.30	0	1	terraced house in the middle of the row
type terraced (end)	0.05	0.23	0	1	terraced house at the end of the row
type villa	0.02	0.15	0	1	house is a villa
type bungalow	0.04	0.20	0	1	house is a bungalow
lot size	736.96	762.52	50.00	10000.00	lot size in m ²
living area	156.72	68.51	50.00	1336.00	living area in m ²
rooms	5.52	1.87	3.00	20.00	Number of rooms
building age	33.15	35.54	0	216	time since (re-)construction
under construction	0.11	0.31	0	1	house is planned or under construction
yc	1973.11	36.90	1800	2018	year of construction
<i>c) quality and design</i>					
qual luxury	0.02	0.15	0	1	very high quality
qual high	0.18	0.39	0	1	high quality
qual low	0.01	0.09	0	1	low quality
cond renovated	0.08	0.28	0	1	renovated house
cond refurbished	0.04	0.19	0	1	refurbished house
second bathroom	0.63	0.48	0	1	two or more bathrooms
basement	0.46	0.50	0	1	house has basement
built in kitchen	0.16	0.37	0	1	equipped w/ built-in kitchen
sauna	0.02	0.14	0	1	house has a sauna
swimming pool	0.03	0.18	0	1	house has a swimming pool
parquet flooring	0.03	0.16	0	1	house has parquet flooring
fireplace	0.23	0.42	0	1	house has a fireplace
rooftop terrace	0.04	0.20	0	1	house has a rooftop terrace
balcony	0.19	0.40	0	1	house has a balcony
terrace	0.53	0.50	0	1	house has a terrace
winter garden	0.08	0.26	0	1	house has a winter garden
loggia	0.02	0.14	0	1	house has a loggia
<i>d) heating</i>					
air condition	0.01	0.09	0	1	house has air conditioning
self cont heating	0.02	0.13	0	1	house has self-contained heating
floor heating	0.22	0.42	0	1	house has floor heating
<i>e) other</i>					
commission	0.03	0.02	0.00	0.10	commission payment required
garage	0.48	0.50	0	1	garage parking available
carport	0.12	0.32	0	1	carport parking available
undergr parking	0.01	0.11	0	1	underground parking available
any parking	0.24	0.43	0	1	any parking available
pop. density	756.37	841.07	0.00	4520.21	population density in 2013
gas price	6.49	0.71	4.58	9.99	local gas price
climate factor	-0.03	0.06	-0.18	0.31	climate factor
Observations	43089				

Table 3: Reporting the energy performance score

<i>Sample</i>	<i>eps reported</i>	<i>eps missing</i>	<i>% eps reported</i>
year of construction, lot size and heating type reported	229072	179795	56.0
year of construction, lot size and heating type reported, building age > 0	185220	93626	66.4
year of construction, lot size, or heating type missing	50670	269687	15.8

Table 4: Baseline regression results

<i>Dependent variable:</i>	<i>log listing price/m²</i> (1)	<i>listing price/m²</i> (2)
<i>a) energy performance score</i>		
eps	-0.00075 (0.00002)***	-1.08 (0.04)***
<i>b) general characteristics</i>		
type semi-detached	-0.05840 (0.00370)***	-114.27 (8.67)***
type terraced (middle)	-0.06156 (0.00589)***	-136.05 (13.13)***
type terraced (end)	-0.05276 (0.00603)***	-116.27 (14.90)***
type villa	0.32807 (0.01312)***	866.08 (55.11)***
type bungalow	0.04183 (0.00546)***	62.86 (14.18)***
lot size	-0.00000 (0.00000)	0.02 (0.01)*
log lot size	0.15013 (0.00504)***	267.20 (11.56)***
log living area	-0.40054 (0.00816)***	-773.54 (24.20)***
rooms	-0.00641 (0.00120)***	7.43 (3.21)*
building age	-0.00034 (0.00014)*	-0.27 (0.26)
building age ²	-0.00001 (0.00000)***	-0.01 (0.00)***
under construction	-0.04547 (0.00596)***	-172.22 (14.20)***
yc 1800-1918	-0.41467 (0.01083)***	-650.35 (25.05)***
yc 1919-1945	-0.31835 (0.01083)***	-580.27 (25.97)***
yc 1946-1960	-0.27684 (0.00927)***	-558.41 (22.50)***
yc 1961-1970	-0.20937 (0.00859)***	-479.03 (21.60)***
yc 1971-1980	-0.18925 (0.00783)***	-464.86 (19.90)***
yc 1981-1990	-0.16040 (0.00800)***	-394.61 (20.40)***
yc 1991-2000	-0.08419 (0.00711)***	-265.37 (18.26)***
yc 2001-2010	-0.02920 (0.00693)***	-86.16 (21.50)***
<i>c) quality and design</i>		
qual luxury	0.15056 (0.00876)***	473.94 (34.51)***
qual high	0.02370 (0.00360)***	49.29 (9.46)***
qual low	-0.10646 (0.00846)***	-160.48 (13.25)***
cond renovated	0.03888 (0.00438)***	45.59 (10.12)***
cond refurbished	0.06712 (0.00764)***	119.82 (17.58)***
cond needs renov	-0.14860 (0.00517)***	-232.83 (7.93)***
second bathroom	0.04934 (0.00286)***	58.77 (6.22)***
basement	0.01976 (0.00301)***	55.22 (7.52)***
built in kitchen	0.05228 (0.00314)***	81.17 (7.24)***
sauna	0.08346 (0.00607)***	145.89 (18.55)***
swimming pool	0.05832 (0.00799)***	119.77 (19.34)***
parquet flooring	0.06671 (0.00771)***	177.03 (22.51)***
fireplace	0.04448 (0.00301)***	85.76 (8.04)***
rooftop terrace	0.02176 (0.00699)**	81.19 (18.74)***
balcony	0.02536 (0.00278)***	37.16 (6.91)***
terrace	0.02729 (0.00230)***	27.61 (5.49)***
winter garden	0.01760 (0.00435)***	-2.79 (10.32)
loggia	0.01356 (0.00736)	14.91 (17.56)
air condition	0.03741 (0.01236)**	118.41 (39.14)**
<i>d) heating</i>		
self cont heating	-0.06539 (0.01089)***	-95.75 (18.69)***
floor heating	0.06499 (0.00319)***	120.41 (8.72)***
heating oil	-0.05872 (0.00394)***	-95.71 (9.31)***
heating fluid gas	-0.15154 (0.01215)***	-290.46 (21.44)***
heating biogas	0.02677 (0.01744)	75.56 (54.10)
heating night storage	-0.15993 (0.01195)***	-282.63 (21.20)***
heating electricity	-0.06621 (0.00606)***	-56.88 (13.06)***
heating solar	0.00228 (0.00627)	-10.78 (14.23)
heating heat pump	0.04013 (0.00702)***	95.51 (18.03)***
heating wood pellets	-0.05970 (0.00897)***	-89.79 (18.02)***
heating geothermal	0.00923 (0.00850)	99.20 (25.86)***
heating district	-0.01589 (0.00990)	-0.81 (24.69)
heating coal	-0.32136 (0.02287)***	-286.51 (27.02)***
multiple heating types	-0.02956 (0.00607)***	-69.35 (13.64)***
<i>e) other</i>		
commission	0.18842 (0.07310)**	299.08 (179.78)
garage	0.00433 (0.00357)	7.18 (8.29)
carport	0.00369 (0.00438)	-11.56 (12.73)
undergr parking	0.05472 (0.01130)***	165.15 (41.33)***
any parking	0.01460 (0.00385)***	20.23 (8.13)*
pop. density	-0.10688 (0.04392)*	-526.91 (138.96)***
pop. density × lot size	0.00001 (0.00001)*	0.04 (0.02)*
pop. density × log lot size	0.02432 (0.00525)***	95.04 (15.00)***
pop. density × log living area	0.03156 (0.00963)**	63.76 (32.42)*
adj. R ²	0.704	0.664
Observations	229072	229072
df	228595	228595

Zip code cluster-robust standard errors in parentheses; the regressions in this table include district and time fixed effects.

*** : $p < .001$, ** : $p < .01$, * : $p < .05$.

Table 5: Local gas prices and climate regressions

	<i>Dependent variable: listing price/m²</i>					
	<i>local gas prices</i>				<i>local climate</i>	
	<i>baseline</i>	<i>50 ≤ eps ≤ 300</i>	<i>age matching</i>	<i>age & eps matching</i>	<i>baseline</i>	<i>50 ≤ eps ≤ 300</i>
	(1)	(2)	(3)	(4)	(5)	(6)
eps × avg. gas price	−0.23*** (0.01)	−0.31*** (0.02)	−0.16*** (0.02)	−0.36 (0.23)	−0.23*** (0.01)	−0.29*** (0.02)
eps × dev. from avg. gas price	0.02 (0.08)	−0.06 (0.13)	−0.04 (0.08)	−0.09 (0.18)		
eps × avg. gas price × climate factor					0.17 (0.16)	0.53 (0.27)
pop. density × eps	0.01 (0.09)	0.19 (0.13)	−0.33* (0.15)	1.83 (2.37)	0.03 (0.09)	0.24 (0.14)
dev. from avg. gas price			−1.69 (16.98)	7.93 (28.67)		
local house price diff.			0.98*** (0.05)	0.96*** (0.07)		
adj. R ²	0.805	0.803	0.432	0.420	0.805	0.803
Observations	43089	33994	7235	1789	43089	33994
df	40393	31329	7177	1731	40393	31329
p-value (equal eps coef.)	0.001	0.056	0.178	0.360	0.011	0.002

Zip-code cluster-robust standard errors in parentheses; all regressions include time fixed effects and controls for housing characteristics. Regressions (1), (2), (5), and (6) include zip code fixed effects. Regressions (3) and (4) rely on matches of houses from zip codes with large gas price differences (> 1 ct/kWh), as described in the text. *** : $p < .001$, ** : $p < .01$, * : $p < .05$.

Table 6: Means in the heating types sample

	<i>heating types</i>				
	<i>district</i>	<i>gas</i>		<i>electricity</i>	
	(1)	<i>unweighted</i> (2)	<i>weighted</i> (3)	<i>unweighted</i> (4)	<i>weighted</i> (5)
<i>a) listing price and energy performance score</i>					
listing price per m ²	2507.77	2449.37	2490.33	2377.86	2350.63
eps	111.13	156.46	115.30	81.14	112.33
<i>b) general characteristics</i>					
type semi-detached	0.23	0.21	0.24	0.11	0.25
type terraced (middle)	0.27	0.13	0.26	0.05	0.19
type terraced (end)	0.14	0.07	0.16	0.03	0.13
type villa	0.04	0.03	0.03	0.03	0.01
type bungalow	0.05	0.04	0.06	0.01	0.04
lot size	430.41	683.17	439.86	673.73	509.56
living area	146.95	156.25	147.18	146.28	146.18
rooms	5.17	5.44	5.16	4.94	5.18
building age	17.35	30.14	17.85	18.76	25.94
under construction	0.19	0.10	0.18	0.54	0.14
yc 1800-1918	0.02	0.07	0.02	0.04	0.03
yc 1919-1945	0.03	0.10	0.03	0.05	0.07
yc 1946-1960	0.04	0.12	0.03	0.08	0.07
yc 1961-1970	0.14	0.13	0.14	0.06	0.16
yc 1971-1980	0.09	0.12	0.10	0.09	0.14
yc 1981-1990	0.03	0.05	0.03	0.02	0.05
yc 1991-2000	0.05	0.08	0.05	0.01	0.04
yc 2001-2010	0.13	0.10	0.15	0.03	0.10
<i>c) quality and design</i>					
qual luxury	0.04	0.03	0.03	0.03	0.02
qual high	0.28	0.18	0.23	0.06	0.14
qual low	0.01	0.01	0.01	0.01	0.02
cond renovated	0.04	0.08	0.06	0.03	0.06
cond refurbished	0.02	0.05	0.02	0.01	0.02
second bathroom	0.72	0.64	0.75	0.74	0.66
basement	0.49	0.49	0.49	0.22	0.41
built in kitchen	0.16	0.17	0.12	0.09	0.16
sauna	0.02	0.03	0.02	0.01	0.01
swimming pool	0.02	0.03	0.02	0.01	0.03
parquet flooring	0.02	0.03	0.02	0.01	0.02
fireplace	0.13	0.22	0.15	0.11	0.18
rooftop terrace	0.07	0.05	0.06	0.03	0.06
balcony	0.20	0.20	0.18	0.27	0.26
terrace	0.61	0.55	0.60	0.36	0.56
winter garden	0.04	0.08	0.04	0.03	0.04
loggia	0.02	0.02	0.01	0.01	0.01
<i>d) heating</i>					
air condition	0.01	0.01	0.00	0.01	0.02
self cont heating	0.00	0.02	0.00	0.04	0.00
floor heating	0.27	0.24	0.27	0.51	0.28
<i>e) other</i>					
commission	0.02	0.03	0.03	0.02	0.03
garage	0.42	0.49	0.48	0.24	0.46
carport	0.13	0.12	0.12	0.05	0.11
undergr parking	0.01	0.01	0.01	0.00	0.01
any parking	0.28	0.26	0.25	0.61	0.21
pop. density	0.75	0.48	0.68	0.27	0.55
Observations	1058	5156	938.4	1233	632.9

Table 7: Heating types – logistic regressions

	<i>Dependent variable: district heating</i>	
	<i>vs. gas heating</i> (1)	<i>vs. electricity heating</i> (2)
<i>a) general characteristics</i>		
type semi-detached	0.398 (0.123)**	1.015 (0.220)***
type terraced (middle)	0.933 (0.156)***	1.852 (0.248)***
type terraced (end)	1.182 (0.162)***	1.984 (0.298)***
type villa	0.657 (0.249)**	0.090 (0.504)
type bungalow	0.850 (0.197)***	2.115 (0.384)***
lot size	-0.462 (0.110)***	-0.942 (0.176)***
living area	0.001 (0.002)*	0.004 (0.002)*
rooms	0.051 (0.043)	0.187 (0.073)*
building age	0.009 (0.003)**	0.002 (0.006)
under construction	-0.146 (0.141)	-1.430 (0.285)***
yc 1800-1918	-3.195 (0.429)***	-1.949 (0.774)*
yc 1919-1945	-2.368 (0.342)***	-1.754 (0.596)**
yc 1946-1960	-2.521 (0.289)***	-2.521 (0.565)***
yc 1961-1970	-0.999 (0.220)***	-0.958 (0.474)*
yc 1971-1980	-1.309 (0.230)***	-1.346 (0.450)**
yc 1981-1990	-1.427 (0.284)***	-1.234 (0.555)*
yc 1991-2000	-1.275 (0.215)***	0.452 (0.519)
yc 2001-2010	-0.280 (0.183)	1.698 (0.444)***
<i>b) quality and design</i>		
second bathroom	0.291 (0.103)**	0.453 (0.192)*
self cont heating	-2.159 (0.760)**	-4.837 (0.904)***
cond refurbished	-0.683 (0.308)*	1.039 (0.693)
type bungalow	0.850 (0.197)***	2.115 (0.384)***
terrace	0.138 (0.089)	0.313 (0.146)*
winter garden	-0.364 (0.203)	0.443 (0.385)
<i>c) other</i>		
any parking	-0.229 (0.105)*	-1.212 (0.178)***
pop. density	0.652 (0.167)***	0.767 (0.248)**
pop. density × yc 1800-1918	0.597 (0.267)*	0.238 (0.431)
pop. density × yc 1919-1945	-0.566 (0.220)*	-0.821 (0.449)
pop. density × yc 1946-1960	-0.441 (0.206)*	-0.341 (0.304)
pop. density × yc 1961-1970	0.030 (0.122)	-0.444 (0.288)
pop. density × yc 1971-1980	-0.273 (0.156)	-0.872 (0.301)**
pop. density × yc 1981-1990	-0.870 (0.458)	-1.012 (0.607)
pop. density × yc 1991-2000	-0.257 (0.199)	-0.059 (0.861)
pop. density × yc 2001-2010	-0.403 (0.142)**	-1.535 (0.345)***
Pseudo-R ² (Nagelkerke)	0.362	0.647
Observations	6214	2291

Heteroskedasticity-robust standard errors in parentheses; all regressions include district fixed effects.

*** : $p < .001$, ** : $p < .01$, * : $p < .05$.

Table 8: Heating types regressions

	<i>Dependent variable: listing price/m²</i>	
	<i>no weighting</i> (1)	<i>prop. score-weighted</i> (2)
eps	-1.41** (0.44)	-1.75** (0.61)
eps × heating gas	-0.27 (0.37)	-0.40 (0.54)
eps × heating electricity	-1.76*** (0.43)	-0.85 (0.53)
heating gas	45.55 (68.58)	52.80 (92.35)
heating electricity	137.10 (78.27)	-68.92 (99.42)
adj. R ²	0.749	0.775
Observations (unweighted)	7447	4675
df (unweighted)	7113	4341

Zip code cluster-robust standard errors in parentheses; all regressions include zip code and time fixed effects, and controls for housing characteristics. *** : $p < .001$, ** : $p < .01$, * : $p < .05$.

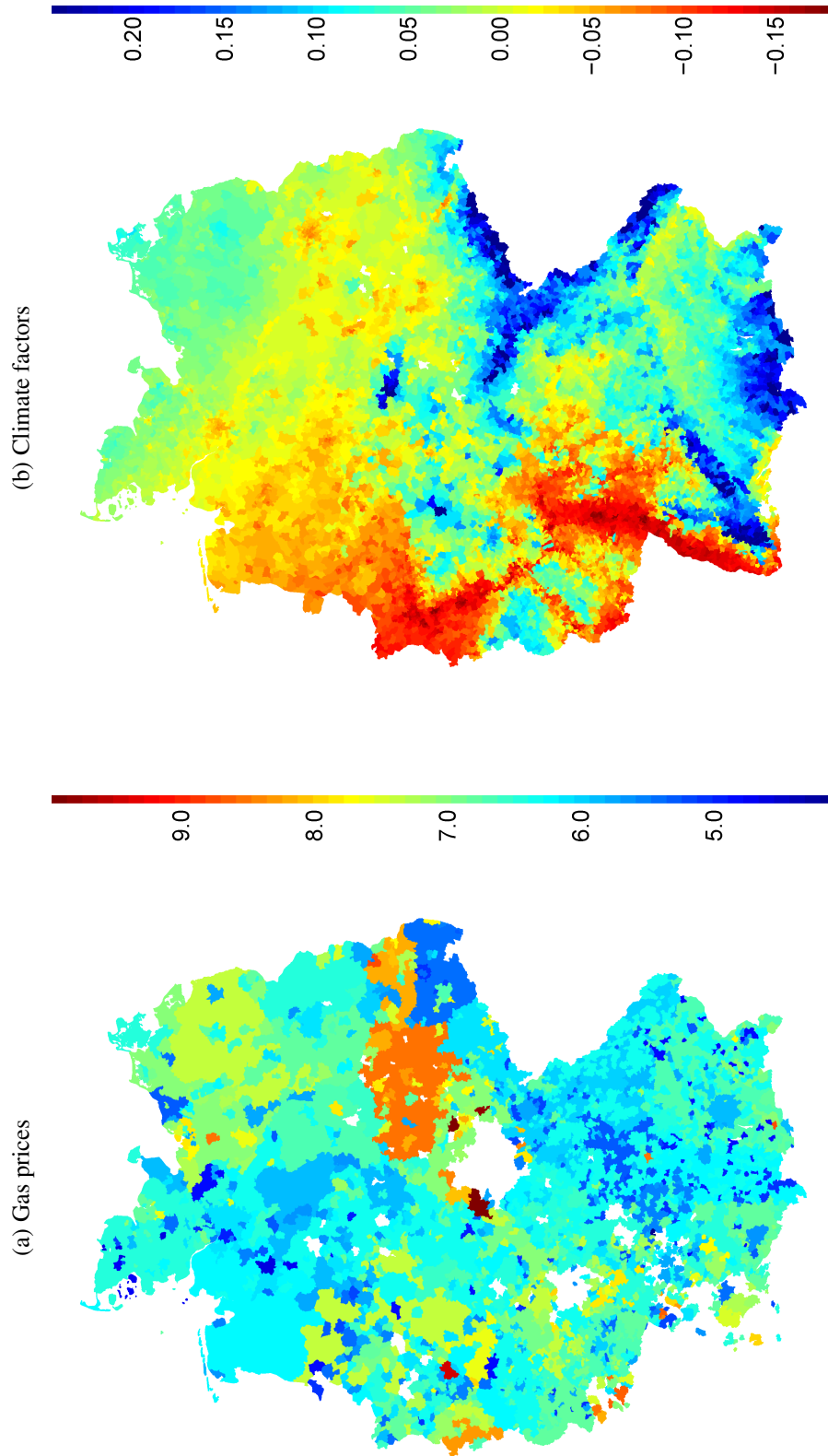
Table 9: Building age regressions

	<i>Dependent variable: listing price/m²</i>	
	<i>no adjustment</i>	<i>age adjustment</i>
	(1)	(2)
eps × pop. density	−0.01 (0.15)	−0.04 (0.17)
eps × building age under 8	−2.12*** (0.20)	−2.10*** (0.24)
eps × building age 8 to 15	−1.98*** (0.22)	−1.99*** (0.25)
eps × building age 16 to 23	−1.47*** (0.32)	−1.49*** (0.33)
adj. R ²	0.790	0.790
Observations	19522	15072
df	17654	13207
$(1 + e)/(1 + r)$		0.829
T		30.675
NPV (new building)		5.828

Zip code cluster-robust standard errors in parentheses; all regressions include zip code and time fixed effects, and controls for housing characteristics. In regression (2), the building age distribution in each age group is adjusted. Coefficients and standard errors are calculated by way of a simulation procedure, see the explanations in the text.

*** : $p < .001$, ** : $p < .01$, * : $p < .05$.

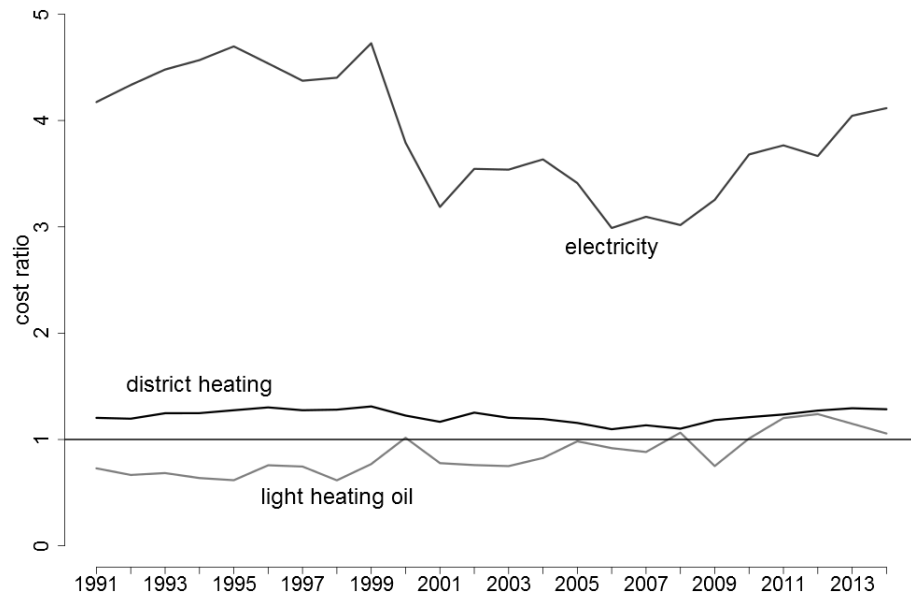
Figure 1: Gas prices and climate factors in German ZIP codes



Source: German Weather Service

Source: online contract offers; own calculation

Figure 2: Costs of different fuel types, relative to natural gas



Source: Federal Ministry for Economic Affairs and Energy; own calculations

Figure 3: Kernel density estimates for the energy performance score

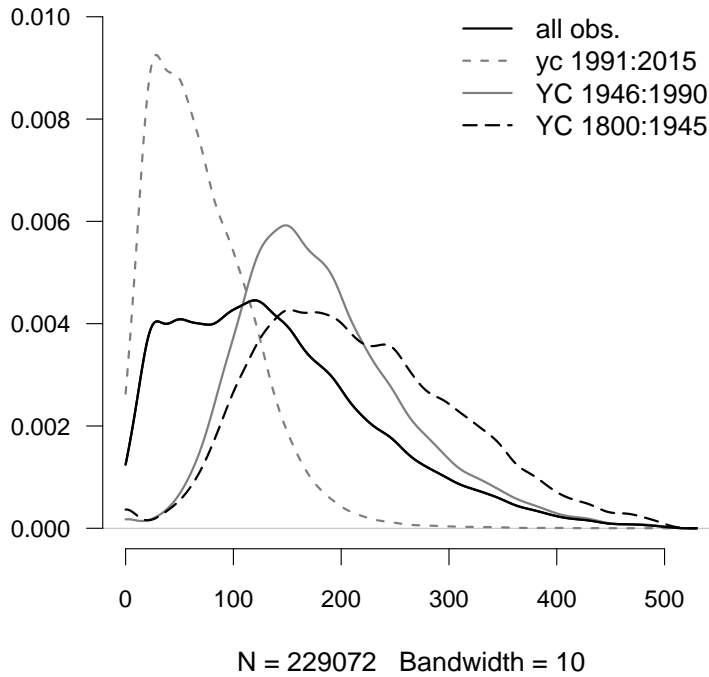
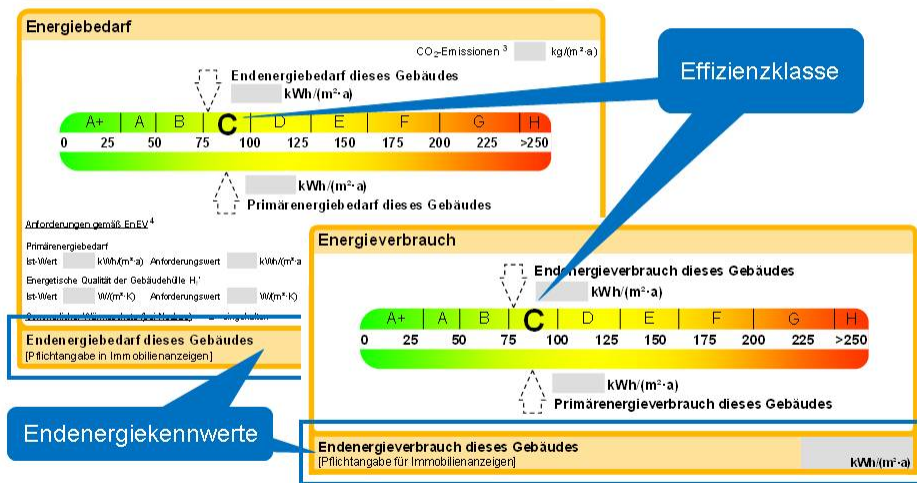


Figure 4: Energy labels for real estate offers in Germany



Source: BBSR/Energieeinsparverordnung⁴

⁴The label in the background (“Endenergiebedarf”) is based on a standardised projection of energy use. It contains a scale (A+ to H) that indicates EPS in steps of 25, and the exact EPS (see the blue label “Endenergiekennwerte”). Additionally, information on energy-related building characteristics is provided below the scale; this information is not available in the data set. The label up front is based on past use. It is structured similarly, but does not contain additional information.

572 **Appendix C Notes on the estimation of T and d from the data**

573 For $k, m, T \in \mathbb{N}_0$, $T > mk$, define

$$\delta^{(m,k)} := \sum_{i=mk}^{(m+1)k-1} p_i \sum_{t=1}^{T-i} d^t, \quad (10)$$

574 where $d > 0$, $p_i \geq 0 \forall i$, and $\sum_{i=mk}^{(m+1)k} p_i = 1$. Think of $\delta^{(m,k)}$ as the absolute value of the slope coefficient in
 575 a regression of house prices per square metre on expected energy costs if the sample consists of houses with
 576 remaining lifetimes $T - mk, T - mk - 1, \dots, T - (m + 1)k + 1$ at shares p_i ($i = mk, \dots, (m + 1)k - 1$).

577 Assume that the sample is balanced in the sense that $p_i = p_{i+k} \forall i$. Then, for $m > 0$,

$$\begin{aligned} \delta^{(m-1,k)} - \delta^{(m,k)} &= \left(\sum_{i=(m-1)k}^{mk-1} p_i \sum_{t=1}^{T-i} d^t - \sum_{i=mk}^{(m+1)k-1} p_i \sum_{t=1}^{T-i} d^t \right) \\ &= \sum_{i=mk}^{(m+1)k-1} p_i \left(\sum_{t=1}^{T+k-i} d^t - \sum_{t=1}^{T-i} d^t \right) \\ &= \sum_{i=mk}^{(m+1)k-1} p_i \left(\sum_{t=T-i+1}^{T-i+k} d^t \right) \\ &= \sum_{i=mk}^{(m+1)k-1} p_i \left(\sum_{t=T-i+1}^{T-i+k} d^{t-k} \right) \\ &= \sum_{i=mk}^{(m+1)k-1} p_i \left(\sum_{t=T-i+1-k}^{T-i} d^t \right) \\ &= \sum_{i=(m+1)k}^{(m+2)k-1} p_i \left(\sum_{t=T-i+1}^{T-i+k} d^t \right) = d^k \left(\delta^{(m,k)} - \delta^{(m+1,k)} \right). \end{aligned} \quad (11)$$

578 If $\delta^{(m,k)} - \delta^{(m+1,k)} > 0$,

$$\frac{\delta^{(m-1,k)} - \delta^{(m,k)}}{\delta^{(m,k)} - \delta^{(m+1,k)}} = d^k \quad (12)$$

579 and, from (11),

$$\delta^{(m-1,k)} - \delta^{(m,k)} = d^T \sum_{i=mk}^{(m+1)k-1} p_i \sum_{t=T-i+1}^{T-i+k} d^{t-T} = d^T \sum_{i=mk}^{(m+1)k-1} p_i \sum_{t=1}^k d^{t-i}$$

580 which can be solved for T easily if d and the left hand side are known.

581 Under the assumptions that (i) participants in the market are aware of the present value concept and
582 (ii) buildings can be categorised by remaining lifetimes—e.g. by building age—, this allows to calculate d ,
583 and then T directly from the data. Even though this does not identify r and e , it at least yields the ratio
584 $d = (1 + e)/(1 + r)$ of expected cost changes $(1 + e)$ to the discounting factor $(1 + r)$, and the expected
585 remaining lifetime of a new building.