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The market value of energy efficiency in buildings and the mode of tenure

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Abstract

Concerns about global warming and growing scarcity of fossile fuels require substantial changes in energy consumption patterns and energy systems, as targeted by many countries around the world. One key element to achieve such transformation is to increase energy efficiency of the housing stock. In this context, it is frequently argued that private investments are too low in the light of the potential energy cost savings. However, heterogenous incentives to invest in energy efficiency, particularly for owner-occupants and landlords, may serve as one explanation. This is particularly important for countries with a large rental sector, like Germany. Nevertheless, previous literature largely focuses on the pay offs owner-occupants receive, leaving out the rental market. This paper addresses this gap by comparing the capitalization of energy efficiency in selling prices (rents) for both types of residences. For this purpose data from the Berlin housing market are analyzed in hedonic regressions. The estimations reveal that energy efficiency is well capitalized in apartment prices and rents. The comparison of implicit prices and the net present value of energy cost savings/rents reveals that investors anticipate future energy and house price movements reasonably. However, in the rental segment, the value of future energy cost savings exceeds tenants' implicit willingness to pay by factor 2.98. This can either be interpreted as a result of market power of tenants, uncertainty in the rental relationship, or the "landlord–tenant dilemma."

Keywords: energy efficiency, house price capitalization, rental/ owner-occupied housing, hedonic analysis, JEL Codes: R21, R31, Q40

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1. Introduction

The energy efficiency of real estate plays a key role in policies directed towards low carbon economies. In industrialized countries, for example, about 40% of total energy consumption is used for space heating and cooling (OECD, 2003). In most studies on residential energy consumption, energy is understood as input for the production of housing services like a warm home. Energy, however, can be substituted by capital inputs, i.e., energy efficiency investments, which have been identified as cost-effective alternatives to energy inputs. Scholars in the fields of climate policy as well as energy economics in this context identified the so called "energy efficiency gap"—the finding that energy efficiency measures are underutilized compared to their potential energy cost savings (see, e.g., Bardhan et al., 2013; Schleich and Gruber, 2008). That so many households do not exhaust the potentials of retrofitting appears puzzling to many authors (see, e.g., Eichholtz et al., 2010, 2013; Mills and Schleich, 2012; Nair et al., 2010).

One possible reason might be the so far not sufficiently considered threefold character of real estate: it serves as production input for firms, as consumption good for households, and as financial asset for investors. In the residential context, research particularly focuses on housing as consumption good—i.e. the choice of the efficient production technology of energy intense services (Quigley, 1984). However, most home owners, even owner-occupants, understand their property also as financial asset. They might expect, additional to cost savings, returns from investment in terms of capital gains when reselling their property. This is particularly true for the case of rental apartments. Landlords are most likely not interested in energy savings per se—they are interested in the value and economic benefits energy efficiency generates in terms of sale price and rental income increases, as well as vacancy risk reductions. As most studies argue, landlords often cannot pass on the investment costs to tenants due to market imperfections, which is called the "landlord-tenant dilemma"(see, e.g., Schleich and Gruber, 2008). As a result, it is argued that landlords—compared to owner-occupants—produce less energy efficient homes, which is confirmed by empirical studies (see, Rehdanz, 2007).

Thus, to comprehensively understand investors rationale, particularly that of landlords, research should also account for the potential effects energy efficiency has on the selling price of a dwelling and the generated rental income streams. However, while changes in price, rental income or the risk of vacancy must be considered as important determinants of investment decisions, the influence of energy efficiency on these measures has been rarely studied. Available insights are focused on US housing markets and limited to the analysis of owner-occupied residences. The findings suggest, that energy savings are efficiently capitalized in house prices. However, as of 2014 there is no study available that would empirically address economic benefits for landlords, i.e. how energy efficiency impacts on rental income or selling prices. For a long time, this could have been explained by a lack of data. However, this has changed and a growing number of researchers are evaluating the economic effects of "green" real estate investments in different contexts (e.g., Brounen et al., 2012; Eichholtz et al., 2010, 2013; Fuerst and McAllister, 2011).

The aim of the present paper is to compare the willingness of owner-occupants, landlords and tenants to pay for energy efficiency and to gain deeper insights about the underlying investment rationale. In a first step, we analyze how energy requirements for space heating capitalize in rental and owner-occupied apartment prices. In a second step, we assess the impact of energy efficiency on rents. Based on this information and actual energy prices, we evaluate in a final step whether homeowners calculations are grounded on reasonable discount rates and expectations. These questions are analyzed using micro-data from Berlin's housing market. Thereby, we benefit from the growing online market for residences and use data obtained from the leading online housing market portals in Germany, *immobilienscout24.de*, *immonet.de*, and *immowelt.de*. In hedonic regressions, we then include the energy performance of buildings as an explanatory variable, along with an extensive set of control variables. Energy performance is measured as the annual energy consumption in kilowatt hours per square meter of residential living space ($kWh/[m^2 \cdot a]$), which allows us to directly compare willingness to pay and energy cost savings at current prices.

The remainder of this paper is structured as follows. In the next section, we provide a brief overview of the relevant empirical literature on energy efficiency capitalization in real estate prices and rents. We proceed in summarizing the underlying arguments, which constitute the "landlord-tenant" or "investor-user dilemma." The third section outlines our empirical strategy, the methods used, and describes the data employed in our study. We then discuss the empirical results and conclude that the implicit prices for energy efficiency of owner-occupied and rental dwellings vary substantially. However, this can be explained by differences in the net present value of the future rental income received by landlords and the potential energy cost savings of owner-occupants. Moreover, we find that investors account for future house and energy price movements as well as rental income increases in a reasonable range.

2. Related literature

2.1. Empirical studies

The number of studies dealing with the effects of energy efficiency investments on the value of real estate is limited. Most of the recent literature focuses on commercial real estate and analyzes the effects of *Energy Star*®and *Leadership in Energy & Environmental Design* (LEED) certification schemes (e.g., Eichholtz et al., 2010, 2013; Fuerst and McAllister, 2011). These studies found significant positive effects of environmental certification on real estate prices, office rents, and vacancy risk.

The first generation of studies on residential real estate point in the same direction, see Table 1. These studies, conducted in the 1980s, were all based on US real estate transaction data. Potential effects of energy performance on residential property are, in most cases, analyzed based on very small samples of detached or semi-detached dwellings, located in one single city or neighborhood. All the studies rely upon hedonic regressions, some specifying the functional form using Box-Cox methodology.

The first study by Halvorsen and Pollakowski (1981) analyzes sales price spreads between homes having oil and gas-fired heating systems installed. The results suggest that abrupt oil price shifts, like those in the 1970s, are associated with an immediate price decrease of houses using this energy source. Johnson and Kaserman (1983) and Dinan and Miranowski (1989) come to the conclusion, that a \$1 decrease on the energy bill is capitalized in sales price increases that vary between \$11.63 and \$20.73 per m^2. Laquatra (1986) estimates the implicit price for thermal integrity to be \$2510 per unit, indicating, similar to Horowitz and Haeri (1990), that energy savings are efficiently capitalized in housing market transactions. However, these early studies mainly suffer from very small sample sizes and thus from a potential loss of generality.

The first study that uses a substantially larger amount of transactions was conducted by Nevin and Watson (1998). It is based on data from the

Table 1: Early studies on the effects on energy efficiency on residential real estate prices

Study	**Region**	**Period**	**Data**	**Methodology**	**Key findings**
Halvorsen and Pollakowski (1981)	Seattle, USA	1970-1975	transactions; single-family units; N=269	Box-Cox	Prices of homes using oil-fired heating systems decline in periods of high oil prices.
Johnson and Kaserman (1983)	Knoxville, USA	1978	transactions; single-family detached housing; N=1317	2SLS	A reduction of the annual fuel bill by $1 is capitalized in the selling price by $20.73.
Laquatra (1986)	Minneapolis MSA, USA	1980	transactions; owner-occupied housing; N=81	WLS	An increase of thermal integrity by 1 unit increases house prices by $2510.
Dinan and Miranowski (1989)	Des Moines, USA	1982	transactions; detached single-family housing; N=234	Box-Cox	A decrease of $1 annual heating costs increases the selling price by $11.63.
Horowitz and Haeri (1990)	Tacoma & Pierce Co., USA	1988	transactions; owner-occupied housing; N=67	linear OLS	Energy savings are efficiently capitalized.

Table 2: Recent studies on the effects on energy efficiency on residential real estate prices

Study	Region	Period	Data	Methodology	Key findings
Nevin and Watson (1998)	30 US metropolitan statistical areas	1992-1996	American housing survey; owner-occupied housing; N = 46,000	linear OLS; 45 regressions	Energy efficiency is well capitalized; home buyers can profit from "green" investments even if the time of occupation is uncertain.
Brounen and Kok (2011)	Netherlands	2008-2009	transactions; single-family units; N=177,318	Heckman two-step regression	Energy labels rated from A-C increase up to 10%, E-F decrease selling price up to -5%.
Bloom et al. (2011)	Fort Collins, USA	1999-2005	transactions; single-family units; N=300	linear OLS	The EnergyStar® label is capitalized by $ 8.66 per square foot living space.
Kok and Kahn (2012)	California, USA	2007-2012	transactions; owner-occupied housing; N≈1.6 m; 4,321 labeled	linear OLS	On average "green" labels (EnergyStar®, Green-Point & LEED) provide a 9% market premium.
Deng et al. (2012)	Singapore	2000-2010	transactions; apartments; N=62; 635; 1,377; 1,439	linear OLS;two-stage estimation	significant premium for Green Market Certification. The premium ranges from 10% to 20%.
Högberg (2013)	Stockholm, Sweden	2008	transactions; single-family housing; N=1073	linear OLS	A decrease of energy requirements by 1% is associated with an increase of the sales price by 0.044%.
Walls et al. (2013)	Austin, North Carolina, Portland, USA	2005-2011	transactions; single-family housing; N=60,361; 23,360; 87,366	linear OLS	Houses built in the first ten years of the EnergyStar® program benefit from a market premium, while recently built homes do not. The premium ranges from 5% to 20%.
Hyland et al. (2013)	Ireland	2012	ads; N=397,258 for sale; N=888,211 for rent	Heckman two-step	Implicit price for energy efficiency ranges from 64% to 79% of the NPV of energy cost savings. The rental premium covers 14% to 55% of the savings.

American Housing Survey, covering 30 metropolitan statistical areas. In multiple regressions, the authors analyze the impact of utility expenditures on house prices and conclude that housing markets efficiently value energy cost savings. However, while the study employs a larger sample, it lacks accuracy. The paper relies on total utility expenditure instead of energy costs. Thus, general maintenance costs and the specific effects of energy efficiency cannot be disentangled.

The second generation, studies published since 2011, tried to resolve the paucity of small samples by combining transaction data with "green" certification ratings (see Table 2). Brounen and Kok (2011), Bloom et al. (2011), Kok and Kahn (2012), Deng et al. (2012), Walls et al. (2013) and Hyland et al. (2013) all find positive impacts, especially from LEED and Energy Star®certifications schemes. But these studies also have shortcomings. Since the certificates only require minimum standards of energy efficiency, the exact value of energy savings cannot be identified in this context. Hyland et al. (2013) match their rating schemes with the results of an engineering model, to compare the potential energy costs savings with the implicit prices. They find, that sales prices equal to 64%–79% of the net present value of energy cost savings, while rents cover about 14%–55% of future energy costs.

To summarize, the existing literature indicates that—at reasonable discount rates—energy efficiency is well capitalized in house prices. However, the evidence is concentrated on US housing markets. Notably, only few studies (Brounen and Kok, 2011; Deng et al., 2012; Högberg, 2013; Hyland et al., 2013) provide insights on European or Asian housing markets. Moreover, most studies available analyze single-family detached or semi-detached housing, which is most likely to be owner-occupied. There is no study to date that covers house sales in the rental housing segment, an important market in many countries. This appears even more surprising, given the emphasis of the literature on the discussion of the so called "landlord-tenant dilemma". In this light, a study, which empirically assesses the effects of energy efficiency on rental housing prices and rents, appears long overdue.

2.2. The impact of the rental relationship on house prices

In the literature on energy efficiency investments, the specific problems in the rental relationship are described as the "landlord-tenant dilemma." It is argued that neither landlords nor tenants have sufficient incentives to invest because both groups face substantial market failures and market imperfections. The key problems are identified in asymmetric information, prohibitively high transaction costs, and uncertainty (Schleich and Gruber, 2008). In this context, the following arguments are frequently presented.

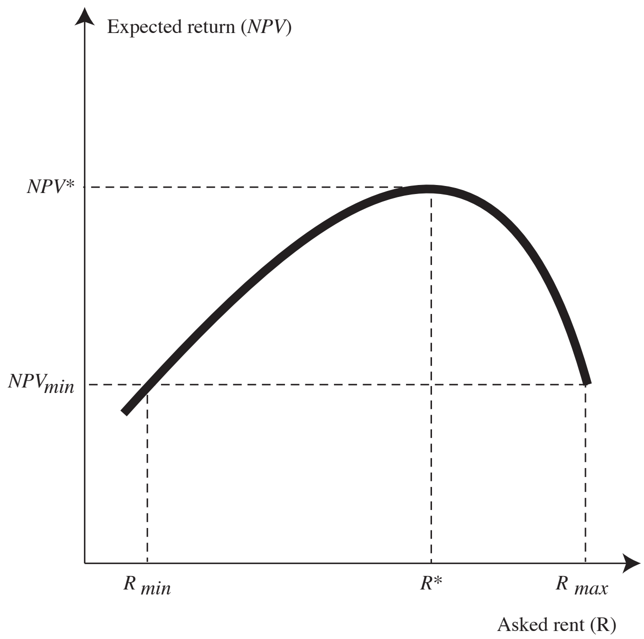
i) Typically, tenants cannot evaluate the real quality of a dwelling due to limited technical understanding or due to missing information on the efforts undertaken by the landlord to produce a certain quality. One potential source of tenants' insecurity has been identified in the so called "rental externality" (Henderson and Ioannides, 1983). Iwata and Yamaga (2008) argue that landlords are likely to expect over-utilization of the dwelling by tenants, which leads to lower optimal housing quality at the time of construction and lower maintenance effort by landlords—thus it results in higher dispersion of housing quality in the rental segment. Consequently, if tenants anticipate such differences, their willingness to pay might not cover the entire value of energy cost savings.

ii) A second potential source for reduced willingness to pay of tenants is that they apply relatively high discount rates on future energy savings and energy price increases (Hassett and Metcalf, 1993). In addition, the length of the rental relationship is frequently uncertain, which strengthens the tendency of undervaluation today.

iii) Moreover, it is claimed that transaction costs incurred when concluding the rental contracts, that allow to fully appropriate the returns of energy saving investments to either the landlord or the tenant (depending on who invests in energy efficiency), are prohibitively high (Schleich and Gruber, 2008).

Typically, housing market mechanisms and the resulting rent asking strategies by landlords are disregarded in the literature on energy efficiency investments. However, these should also play an important role for differences in the implicit price of rented out versus owner-occupied dwellings. The most important insight in this context is the following one: even if landlords are able to credibly transmit the information about energy savings, this does not imply that tenants are willing to pay the rent (R) that covers total energy cost savings. This is because tenants can move and choose between alternative residences; thus, landlords face a risk of vacancy (ρ). This risk can be diminished by reducing rents (see Stull, 1978). Consequently, rational landlords optimize the net present value from investment NPV at a discount rate

Figure 1: Return maximizing rent asking strategy



Source: Adopted from (Stull, 1978).

d for the investment period T by maximizing asked rents and simultaneously minimizing ρ:

$$NPV = \sum_{t=1}^{T} \frac{(1-\rho) \times R}{(1+d)^t} \tag{1}$$

where $\rho = f(R)$ and $f'(R) \geq 0$.

This relationship is depicted in Figure 1, where R_{max} is the rent that equals total energy cost savings. In our (very common) example, a market where some excess supply hands over market power to tenants, the asked rent (R^*), which maximizes expected return (NPV^*), is below this level.[1]

[1] In housing markets, at least some "natural" vacancy occurs due to household fluctuation and search activities (e.g., Gabriel and Nothaft, 1988, 2001; Rosen and Smith, 1983). Beyond that, higher vacancy rates can be often observed because housing is a durable good and cyclical housing market imbalances tend to be persistent over long periods of time (Glaeser and Gyourko, 2005). Thus, it is likely that landlords frequently cannot

In the present context, the value of energy efficiency in a rental dwelling (all else constant) should be lower compared to the value of energy efficiency in an owner-occupied home, because owner-occupants can fully benefit from energy cost savings (equal to R_{max}).

In summary, all arguments presented indicate that landlords' returns from energy efficiency investments are likely to be lower compared to owner-occupants; consequently the net present value, thus the implicit price of energy efficiency should be below owner-occupied dwellings as well.

3. Empirical strategy

Based on the empirical findings and arguments presented in the literature, the empirical strategy to identify potential differences between the capitalization of energy efficiency in owner-occupied and rental dwellings relies on standard hedonic estimation methods, as first introduced by Rosen (1974). In equation (2), the dependent variable is the price of a dwelling per square meter (P). While controlling for several structural and locational attributes of the dwelling (X), we estimate the influence of the key explanatory variables of interest: the energy performance score (EPS) of a house measured as the annual energy consumption in kilowatt-hours per square meter of residential living space ($kWh/[m^2 \cdot a]$), a dummy indicating whether the dwelling is sold as rental property (RP), and an interaction term of both variables ($EPS \times RP$).

$$P_i = \alpha_0 + \alpha_1 EPS_i + \alpha_2 RP_i + \alpha_3 EPS_i \times RP_i + X_i' \beta + u_i \quad (2)$$

where P_i is the asked price per square meter of the i^{th} dwelling and u_i is an i.i.d. error term. Given that we expect the prices for owner-occupied and rental dwellings to be different, both the coefficients for RP and/or the interaction term $EPS \times RP$ should be statistically significant.

In a second step, we use the monthly rental income per square meter (R) as endogenous variable and assess tenants' willingness to pay for energy cost decreases.

$$R_i = \gamma_0 + \gamma_1 EPS_i + X_i' \delta + v_i \quad (3)$$

realize the maximum rent; this is, in fact, not a result of market imperfection but that of competition.

where R_i is the asked rent per square meter for the i^{th} dwelling; v_i is an i.i.d error term. Based on the estimation results and information on energy prices, we evaluate whether investors' calculations appear reasonable.

3.1. Data and stylized facts

Housing market conditions substantially vary across regions. Accordingly, the value of energy efficiency should also show a distinct regional pattern. Since it is difficult to appropriately control for the specific regional impacts, we concentrate on the Berlin housing market, where already beginning in 2005, the market conditions became more favorable for real estate investors.

Berlin's housing market. Since approximately the end of 2010, after a protracted period of stagnation, the German housing market has been on a strong upward trend. This tendency is especially pronounced in both big and university cities. In particular, in Berlin, between June 2011 and December 2013, the housing prices grew, on average, by 9% per year, whereas the average annual growth rate of rents was almost 5%. As a result, the price-to-rent ratio increased from 21 to 24, which implies that the gross rental yield (including transaction cost) went down from 4.7 to 4.2%. All these are signs of a tight housing market, where the market power of landlords and sellers is constantly increasing.

The reasons for such movements are twofold. On the one hand, demand and supply developed asymmetrically. While both population and the number of households strongly increased since the turn of the century, construction activity has been shrinking throughout this period. Between 2001 and 2011, the number of households in Berlin went up by 9.1%. Construction, however, has been steadily declining since the second half of the 1990s and eventually stagnating in 2005. Between 2001 and 2011, the housing stock increased by only 1.8%. This was preceded by a re-unification boom that was triggered by the overly optimistic expectations about the demand for housing and commercial office space in East Germany and, in particular, in Berlin. These expectations proved to be wrong, which led to a large excess supply and housing vacancies, see Figure 2. The upper panel shows the vacancy rate of the BBU housing enterprises.[2] The BBU vacancy rate is typically lower

[2]BBU stands for "Verband Berlin-Brandenburgischer Wohnungsunternehmen e.V.", the Association of Berlin and Brandenburg's housing enterprises.

than that of the overall Berlin market; however, their dynamics are similar and the BBU indicator is the longest time series available for Berlin.

The lower panel of Figure 2 depicts the difference between the number of flats and the number of households. Starting in 1996 both indicators went up, which reflects an excess supply at the housing market. In 2003, the excess supply turned into a slight excess demand, while the vacancy rate crossed the 3% threshold in 2010.[3] In total, demand and supply movements lead to higher prices and rents.

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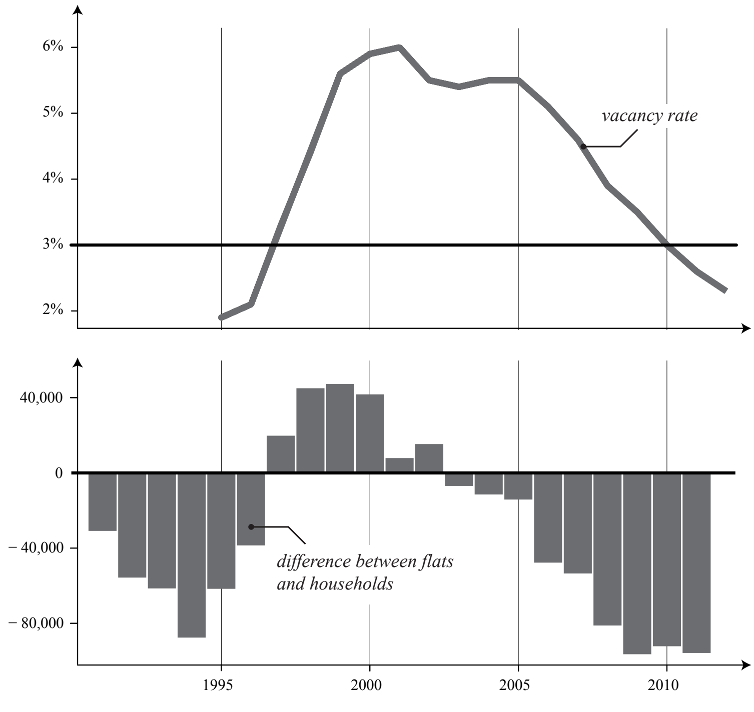
Figure 2: Pressure at the housing market in Berlin, 1991-2012



Source: BBU and German Federal Statistical Office.

[3]As a rule of thumb, the 3% threshold can be interpreted as the "natural" vacancy rate; below this level the market is considered to be tight, which leads to strong price and rent increases.

On the other hand, since the outbreak of the financial market and the euro crisis, Berlin's housing market has been receiving an increasing attention of (international) investors searching for safe assets. Against the background of Germany's strong economy, real estates in the metropolitan areas of Germany are preferred as "safe haven" investments. Moreover, according to analysts, house price levels and movements in Berlin are rated to be moderate in international comparison and opportunities are still perceived to be high.[4] In the light of the favorable market environment, low interest rates, and the search for yield, the increased demand for Berlin real estate fostered the sharp upward trend of the house prices.

Data sources and quality. Empirical real estate research is data demanding. In the past, detailed housing market analysis was not possible due to a lack of information on real-estate transactions (DiPasquale, 1999; Eichholtz et al., 2013; Gyourko, 2009; Olsen, 1987). In this study, as alternative to conventional transaction information, we use data collected from Internet rental and selling advertisements of apartments in Berlin. The data were downloaded on a monthly basis from June 2011 through December 2013 from the three most popular German real-estate websites: immobilienscout24.de, immonet.de, and immowelt.de. The ads placed on the three websites contain extensive information on numerous structural and locational characteristics of the properties for sale/rent.

However, using Internet advertisements in this context suffers from the following four major shortcomings that are addressed in the empirical analysis.

1. Internet data are often plagued by invalid or duplicated observations. Some announcements are likely to be published on different websites simultaneously. The duplicates can cause serious distortions of the estimation results. Therefore, we applied a matching algorithm specifically designed to identify duplicates in the data.[5]

2. In addition, numerous ads of housing for sale are fake. The reason is that many of the objects, especially apartments offered for sale are not

[4] As, for example, pointed out in a recent market report by the German real estate financing specialist DG HYP (2013).

[5] For more details on the identification of duplicates and the probability of the physical existence of a "new" dwelling, see Kholodilin and Mense (2011).

constructed yet and such ads are placed by the construction firms in order to attract new customers. Hence, a substantial share of these dwellings only exists on paper and may never be built. Not accounting for this would lead us to biased results. Therefore, we identified real new apartments by screening the free description of the apartments for sale in the ads. In a nutshell, this is done by identifying both the ads that have explicit information on whether the apartments are built or not (future or current year as construction year, search categories "new" and/or "under construction"), and those, whose text contains certain keywords that indicate that the apartments physically exist. The resulting variable "New" is the probability that the apartment is constructed in reality.

3. Another serious objection against using the asked prices and rents in Internet ads is that they may deviate from the final, or transaction, prices and rents. Although appraised data is reported as a valid substitute for real transaction information (Hyland et al., 2013; Malpezzi, 2003), there are only few studies that evaluate the degree of a deviation from transaction prices. The most prominent study for Germany is that of Faller et al. (2009); The authors investigate the differences between offer and transaction prices for Northrhine-Westphalia. The findings indicate that on average the offers are 8% above the real transaction prices. Significantly smaller gaps are found for urban locations. In our case, we concentrate upon a large city experiencing a housing market expansion, which implies significant market power of sellers and landlords. Thus, discrepancies between asked and real prices/rents should be relatively small.

4. Finally, there may be systematical differences between advertisements including and excluding information on the energy performance of a dwelling. Until 2014, sellers and landlords were not obliged to publish energy performance scores (EPS) in their announcements. Therefore, it is necessary to compare the characteristics of both groups of ads; those containing EPS and those that do not. In case of systematical differences between these two groups, estimation results exclusively based on ads including EPS would not be representative. However, descriptive statistics reveal that differences, if any, are only minor between both groups (see Table 4). Notice also that most of the ads—about 90% of

rental housing and 83% of housing for sale—do not contain EPS. However, the number of observations including EPS is still large enough to permit reasonable econometric estimations.

Despite these potential data imperfections, we opt for using the data from the Internet ads. The main reason is that alternative data, containing information on energy consumption, house prices and rents at the micro level,[6] do not exist.

3.2. Variable description and descriptive statistics

Table 4 presents the descriptive statistics on apartments for rent (column (4)) and for sale (column (5)). In Berlin, the "typical" dwelling for sale is generally larger and better equipped compared to a rental apartment.

Rents and apartment prices. The dependent variables in equations (2) and (3) are the asked selling price and the asked monthly rent, respectively. Both measures are reported in euros per square meter. In the period under consideration, both prices and rents follow an upward trend—to account for these price movements over time, we include dummies for each month. Again, since we analyze prices at an expanding market, we believe that potential bias between realized prices/rents in transactions and the asked prices/rents in the advertisements is rather small. However, in order to additionally control for potential differences, we include a measure for the time on market (in months). A long time on market would indicate that asked prices/rents are set too high—thus, including this measure ensures unbiased results for our variables of interest.

Energy certificates and occupancy status. The first key explanatory variable is the energy performance of buildings—since 2009, it is, if prospective tenants/investors ask for it, mandatory for each landlord/seller of a dwelling to provide information on the heating energy requirements of a building (European Commission, 2002). The German "Energy Performance of Buildings Directive" (Energieeinsparverordnung, EnEV) allows for two alternative ways of obtaining such a measure. The first one is based on real energy billing

[6]The only comparable data set with the data on single dwellings is that of the evaluators' committee (Gutachterausschuss) for Berlin. However, it is much less detailed and does not include information on energy consumption and rents. See *www.gutachterausschuss-berlin.de*.

information. The so called “consumption based” energy certificates are calculated as a three year average of the energy used for space heating, normalized to the climatic conditions of the city of Würzburg in the year 2002. The alternative “performance based” measure is based on an engineer’s assessment of the thermal conductivity of a building. The outcome is the theoretical heating energy requirement of a house. However, both approaches are comparable in terms of their outcomes. They provide measures for the annual heating energy requirement (in kilowatt-hours) per square meter of residential space. However, in case of apartment housing, the consumption based measure is by far more frequently applied, since it is easy to calculate and cheaper in the certification process. Typically, EPS ranges from zero to 300 $kWh/[m^2 \cdot a]$. In our sample, we observe values ranging from 0.5 to 244 for EPS in properties for sale, while in dwellings offered for rent EPS ranges from 0.1 to 681 $kWh/[m^2 \cdot a]$—the reported upper bound for rental dwellings can be considered as outlier (see table 3). Another key insight from table 3 is the substantial difference of the EPS between apartments for rent and free to use dwellings[7]. This is in line with previous studies (Rehdanz, 2007) and can indeed be understood as first evidence for split incentives among the two groups of investors.

Table 3: Descriptive statistics of EPS

	Min.	**Mean**	**Max.**	**Sd.**
(1) Rental apartments for sale	1.0	120.4*	244.0	37.2
(2) Free apartments for sale	0.5	102.5*	244.0	44.8
(3) Apartments for rent	0.1	125.4*	681.0	41.0

Note: * indicates significant differences at 1% level of confidence between (1) vs. (2), (2) vs. (3) and (3) vs. (1) respectively.

The second key variable of interest is the occupancy status of the apartment for sale. Typically, this variable is included in the ads, because it is an important selection criterion for potential buyers. Since tenancy law in Berlin—if the actual tenant wants to stay in the apartment—forbids a trans-

[7]This is confirmed by the Welch two-sample mean equality test. Significant differences can be observed for rental apartments for sale/rent and free to use dwellings. Moreover, although small, the differences between rental apartments for sale and apartments advertised for rent are also significant.

formation from rental to owner occupation within a period of seven years after the sale, it is unlikely that investors aim to buy currently rented out dwellings for the purpose of owner-occupation.[8] Alternatively, a potential buyer can try to compensate the tenant for agreeing to cancel the contract. This, however, is costly and should be negatively capitalized in the property price. In our estimation, a dummy variable indicates whether the apartment refers to the rental segment or can be used directly in owner occupation.[9]

Control variables. In the rich literature using hedonic methods in real estate appraisal, various variables have been proven to be important predictors of the property prices. In our study, we control—as far as possible—for the most frequently tested features (see for a comprehensive summary, e.g., Malpezzi, 2003). The list of variables includes:

> *Size and type of the dwelling:* in almost any study, the size of the dwelling is included as explanatory variable for the (rental) price. In the present paper, size is captured by the number of rooms as well as the total area. Moreover, the studies generally distinguish between the dwelling's type: in particular, we control for potential effects if the apartment is, for example, a loft, a penthouse, or a souterrain flat.
>
> *Comfort:* the general comfort of an apartment can be characterized by different attributes. Using dummy variables, we control whether an elevator, a cellar, or a parking lot is available and if access to a garden is included. Moreover, we control if the dwelling is suited for elderly or disabled people.

[8]The German "Homeownership Law" ("Wohneigentumsgesetz", WEG), German Civil Code ("Bürgerliches Gesetzbuch", BGB), and the Berlin-specific "Tenant Eviction Regulation" ("Kündigungsschutzklauselverordnung") delegate substantial rights to the tenants living in an apartment, which should be sold for purposes of owner occupation. Besides the protection against eviction for seven years, tenants have a preemption right to buy the flat two months after the announcement of the sale.

[9]It must be noted that this variable does not exactly identify rental and owner-occupied flats. While a change from rental to owner occupation is difficult, the conversion to a rental flat can be easily pursued. However, this has a mitigating effect on the spread in the willingness to pay for energy efficiency in owner-occupied and rental dwellings. Our results therefore represent the lower bound of the potential difference.

Table 4: Descriptive statistics and variable definition

Variable	**Variable definition**	**Statistic**	**apartments for rent** EPS/ no EPS	**apartments for sale** EPS/ no EPS
Rent/price	euros per m^2	mean	7.35/7.32	2279.17/2379.65
Total area	m^2	mean	71.40/72.29	84.23/86.15
Number of rooms	number	mean	2.46/2.52	2.72/2.77
Fitted kitchen	available=1	mean	0.53/0.45	0.36/0.40
Cellar	available=1	mean	0.65/0.49	0.83/0.62
Parking lot	available=1	mean	0.16/0.12	0.29/0.25
Suited for elderly	applicable=1	mean	0.10/0.10	0.18/0.13
Elevator	available=1	mean	0.35/0.36	0.46/0.43
Guest WC	available=1	mean	0.14/0.13	0.28/0.23
Suited for disabled	applicable=1	mean	0.10/0.10	0.20/0.16
Access to garden	available=1	mean	0.21/0.15	0.32/0.26
Renovated	applicable=1	mean	0.19/0.15	0.14/0.15
Rented out	applicable=1	mean		0.33/0.24
Architectural monument	applicable=1	mean		0.08/0.07
Newly constructed	applicable=1	mean		0.19/0.24
Distance to city center	km	mean	7.70/7.70	6.11/6.40
Floor:	-1 to 0	share	9.76/6.85	15.70/9.54
	1 to 5	share	75.08/70.88	70.67/63.30
	6 to 10	share	5.87/5.34	2.85/2.36
	11 to 20	share	1.79/1.34	0.09/0.20
	21 to 40	share	0.06/0.05	0.01/0.01
Year of construction:	before 1900	share	12.93/13.16	16.68/14.32
	1901-1940	share	28.78/25.96	24.27/26.02
	1941-1960	share	7.01/7.41	10.57/9.84
	1961-1990	share	31.31/33.56	13.02/14.65
	1991-2000	share	15.88/15.72	12.01/9.71
	after 2000	share	4.02/4.13	23.30/25.41
Type of apartment:	not specified	share	10.66/12.10	6.46/9.80
	studio	share	0.05/0.06	0.09/0.12
	top floor	share	6.89/5.43	7.33/8.44
	ground floor	share	10.34/9.02	14.21/11.12
	regular flat	share	66.40/69.99	61.11/61.50
	loft	share	0.10/0.08	0.17/0.24
	loft/atelier	share	0.66/0.27	0.50 /0.69
	maisonette	share	2.58/1.72	3.44/3.49
	penthouse	share	0.25/0.18	2.24/2.25
	other	share	0.63/0.36	0.40/0.55
	souterrain	share	0.36/0.17	0.34/0.20
	with terrace	share	1.07/0.64	3.67/1.61
Number of observations			11894/102659	31221/152019

Housing attributes: the age of a dwelling is associated to a certain "natural" quality of housing. The housing built in different decades is characterized by specific architectural design, materials, and construction techniques employed as well as aspects of urban planning that affect the quality of life in the apartments. To account for potential differences in the architectural design, we include measures that capture the year of construction as vintage class of a building, whether it is a architectural monument, and the size of the house approximated by the number of floors.

General housing condition: the general condition is also important for the quality of a dwelling—it should clearly make a difference to potential tenants or buyers, whether an apartment is newly constructed, renovated, or non-refurbished. Consequently, we include dummies indicating the refurbishment status of a home.

Accessibility and amenities: Finally, standard urban economics theory suggests that accessibility is one of the most important predictors for house prices and rents. As standard variable to control for this effect, the distance to the city center is used in many hedonic studies. We include the distance in kilometers to the closest of the two main city centers of Berlin: either "*Zoologischer Garten*" or "*Alexanderplatz*". Moreover, local amenities play an important role for house prices and rents. We use postal code dummies to account for potential differences within Berlin's housing market, e.g. the endowment with, for example, local infrastructure, public parks, or kindergartens.

This set of covariates should capture the most important attributes and thus allow us to estimate the willingness to pay for energy efficiency in a statistically appropriate way.

4. Results

We estimate the impact of energy efficiency upon apartment prices and rents using equations (2) and (3) and the Internet ads data. The estimation results are reported in Tables 6 and 7, correspondingly. Overall, both models have substantial explanatory power, indicated by joint F-tests and the adjusted R^2: In model 1, which predicts selling prices, about two thirds of total variation can be explained. Model 2 accounts for 82% of apartment rent variation, see Table 5.

Table 5: Model diagnostics

Model	F-Statistic	Adj. R^2
(1) House prices	229.0*** (N=12,142; DF=11,898)	0.820
(2) Rents	78.51*** (N=10,154; DF=9,905)	0.664

4.1. Capitalization of energy efficiency in prices and rents

Table 6 presents our estimation results for the effects of energy efficiency and occupancy status on house prices. The key variables in equation (2) are "EPS","RP" and "EPS×RP". All of them are statistically significant at the 1% level of confidence. The coefficient "Rental property" is negative and indicates that a currently rented out dwelling costs 431 euros per m^2 less compared to a dwelling, which is free to use. The coefficient can be interpreted as the discount, which is related to the rental relationship: First, it is costly to get rid of the current tenant. Second, the future rental income is, compared to the utility received in owner occupation, subject to uncertainty. Third, the rental externality creates uncertainty about the intensity of use by the tenant. Thus, it is unclear how much resources are needed for renovation or refurbishment in the future. Altogether, these aspects are likely to reduce the expected net rental income and, consequently, the value, as confirmed by our estimation.

The second variable of interest is the energy performance of the building and its impact on apartment prices. As expected, EPS has a negative sign, which implies that higher energy requirements of a dwelling leads to a higher price discount. For each additional $kWh/[m^2 \cdot a]$ of energy needed, the price is reduced by 1.81 euros. Based on an average actual natural gas price of 8 eurocents (see Techem AG, 2012), a one euro reduction of energy costs is associated with a 22.63 euro increase of the house price. This is in the range previous studies found in their analysis (see, e.g., Johnson and Kaserman, 1983; Nevin and Watson, 1998). Given that the EPS regularly varies between 0 and 300, a square meter price of a dwelling with a maximum energy consumption will be 542.34 euros less compared to a dwelling with zero energy consumption. This accounts for 23.7% of the average price per m^2, which is equal to 2,284 euros.

Table 6: Model 1 – Apartment prices

	Coefficient		**Std. error**
Constant	2574.343	***	46.651
Total area	2.663	***	0.272
Number of rooms	-29.186	***	7.749
Floor: 1-5	204.996	***	16.045
Floor: 6-10	352.583	***	29.631
Floor: 11-20	491.877	***	104.534
Floor: above 20	204.091		251.311
Fitted kitchen	129.695	***	10.420
EPS	-1.8078	***	0.164
EPS × RP	1.096	***	0.230
Rental property (RP)	-431.430	***	29.538
Cellar	74.887	***	11.274
Parking lot	50.090	***	11.956
Suited for elderly	-41.376	**	14.050
Suited for disabled	-37.142	**	14.407
Elevator	144.548	***	11.797
Guest WC	105.424	***	12.561
Vintage class: 1901-1940	-104.966	***	15.005
Vintage class: 1941-1960	-301.628	***	19.860
Vintage class: 1961-1990	-301.797	***	20.627
Vintage class: 1991-2000	64.406	**	22.150
Vintage class: after 2000	536.818	***	21.108
Type of apartment: studio	18.753		151.452
Type of apartment: top floor	192.023	***	21.564
Type of apartment: ground floor	17.63		21.790
Type of apartment: regular flat	19.454		15.907
Type of apartment: loft	-85.002		116.816
Type of apartment: loft/atelier	364.702	***	61.064
Type of apartment: maisonette	73.382	*	29.413
Type of apartment: penthouse	489.320	***	32.512
Type of apartment: other	165.899	*	76.166
Type of apartment: souterrain	-341.889	*	151.747
Type of apartment: with a terrace	91.668	**	28.888
Access to garden	5.038		10.766
Renovated	209.108	***	13.299
Distance to city center	-26.812	***	6.4096
Architecture monument	24.863		16.927
Newly constructed	333.723	***	29.443
Time on market	11.016	***	1.711

Notes:
1) ***, **, * indicate significance at 1%, 5% or 10% level of confidence.
2) The 28 time dummies and 188 postal code dummies are omitted; they are available upon request. The upward trends in both, rents and prices, are well captured by the monthly time dummies and indicate that demand for rental dwellings was growing until September 2013 and stagnating afterwards on a high level. Prices, however, persistently increased throughout the entire period of observation.

Table 7: Model 2 – Apartment rents

	Coefficient		**Std. error**
Intercept	9.335	***	0.154
Total area	-0.007	***	0.001
Number of rooms	-0.041	**	0.015
Floor: 1-5	0.246	***	0.052
Floor: 6-10	0.070		0.073
Floor: 11-20	0.014		0.102
Floor: above 20	0.301		0.419
Fitted kitchen	0.517	***	0.028
EPS	-0.002	***	0.000
Cellar	0.044		0.028
Parking lot	0.270	***	0.034
Suited for elderly	-0.004		0.057
Suited for disabled	-0.294		0.032
Elevator	0.061	***	0.042
Guest WC	0.299		0.039
Vintage class: 1901-1940	-0.055	***	0.056
Vintage class: 1941-1960	-0.364	***	0.048
Vintage class: 1961-1990	-0.558	***	0.052
Vintage class: 1991-2000	0.275	***	0.076
Vintage class: after 2000	1.587	*	0.490
Type of apartment: studio	1.149	***	0.056
Type of apartment: top floor	0.418		0.065
Type of apartment: ground floor	-0.006		0.038
Type of apartment: regular flat	0.009	**	0.374
Type of apartment: loft	0.985	**	0.175
Type of apartment: loft/atelier	0.513		0.084
Type of apartment: maisonette	0.154	***	0.221
Type of apartment: penthouse	1.545	***	0.163
Type of apartment: other	-0.566	***	0.218
Type of apartment: souterrain	-1.217		0.120
with a terrace	0.063	***	0.061
Access to garden	0.179	***	0.034
Renovated	0.340	***	0.031
Distance to city center	-0.028		0.020
Time on market	0.050	***	0.008

Notes:
1) ***, **, * indicate significance at 1%, 5% or 10% level of confidence.
2) The 28 time dummies and 188 postal code dummies are omitted; they are available upon request.

In contrast, the coefficient of the interaction term “EPS×RP” is positive but smaller in magnitude compared to the estimate for EPS. For a rented out dwelling, the maximum discount for higher energy consumption per m^2 will attain 213 euros $((1.81-1.10)\times 300)$, or 9.4% of the average price. Under the assumption that the currently tenant-occupied dwellings are very likely to be further rented out (due to the legal setting, see previous section), whereas free to use dwellings are most probably to be sold to owner-occupants, this implies that the implicit price for energy efficiency is strongly affected by the rental relationship and the associated uncertainty: the willingness to pay for energy efficiency in owner-occupied dwellings is relatively high (1.81 euros per $kWh/[m^2 \cdot a]$). In rented out apartments it is substantially —almost 2.5 times— smaller (0.71 euros per $kWh/[m^2 \cdot a]$). This is confirmed by an F-test of a linear restriction of a form $\alpha_1 + \alpha_3 = 0$ imposed on equation (2). According to the test results, the null hypothesis of no effect of energy performance upon the price in case of the rented out dwellings can be rejected at the 1% level of confidence.

The question is whether this is a rational response of investors to a low willingness to pay for energy efficiency of tenants or if the rental income implies higher house prices? Therefore, we estimated the capitalization of energy performance in rents by regressing the monthly net rents in euros per m^2 on EPS. The results reported in Table 6 indicate that the coefficient for EPS is negative and statistically significant at 1% level. However, its magnitude is very small. An additional $kWh/[m^2 \cdot a]$ of energy consumption leads to a decrease of rent by roughly 0.2 eurocents per m^2. Assuming again that the EPS ranges between 0 and 300, a square meter rent of a dwelling with a maximum energy consumption will be 0.67 euros less than that of a dwelling with zero energy consumption. This represents only 9% of an average monthly rent, which is equal to 7.3 euros per m^2.

Overall, the coefficients for the control variables are in line with expectations and the results reported in previous studies. For example, the price for a "new" or "renovated" apartment is significantly higher compared to the base, a non-renovated home built before 1900. In contrast, increasing distance to one of Berlin's city centers incurs price discounts. In rented out apartments, attributes like for example, a fitted kitchen, access to a garden, a parking lot and an elevator all increase the rental income.

4.2. The net present value of rental income and energy cost savings

Whether the estimated prices for energy efficiency reflect energy cost savings and rental income reasonably, can be evaluated in net present value (NPV) calculations. Based on our estimation results, we calculate the NPV of the rental income from energy efficiency under three scenarios (see Table 8). In the first case, we assume that the implicit willingness to pay of tenants (R) is constant over the entire twenty year investment period. In a second scenario, we expect that rental income increases analogously to the energy price movement by an average annual rate e. Thirdly, we include potential capital gains from an increasing selling price ($\Delta P = P_T - P_0$). Generally, the NPV of a standard investment project can then be calculated as follows:

$$NPV = R \sum_{t=1}^{T} \left(\frac{1+e}{1+d} \right)^{\frac{t}{12}} + \left(\frac{\Delta P}{1+d} \right)^{\frac{T}{12}} \tag{4}$$

where t is the time index; $T = 240$ is the number of months within a 20-years period; and $d = 0.04$ is the annual discount rate.[10] In the first scenario ($e = 0$ and $\Delta P = 0$), the estimated monthly flow of energy discounts ($R = 0.67$ euros) equals a NPV of 111.62 euros. This is slightly more than a half of the estimated maximum implicit price (213.57 euros) for energy efficiency in a tenant-occupied dwelling.

Given that scarcity of fossil fuels will increase in the future, it appears reasonable to assume that energy costs and consequently rental income from energy efficiency investments should also rise over time (scenario 2). Assuming tenants' willingness to pay to be tied to energy price movements, and taking the past price movements $e = 0.035$,[11] (roughly the average annual increase of the consumer price for natural gas in the period of 2001 to 2011 in Germany) as a reasonable proxy for future heating energy cost development, the NPV of energy cost savings in this scenario equals 152.82 euros. The difference between the NPV and the implicit price would be 60.75 euros,

[10]The internal discount rate is calculated analogously to Discher et al. (2010), who evaluate the economic performance of energy efficiency investments in residential housing. They assume cost for external capital to be 5%, a share of external financing of 80% and a relatively low return on equity of 3%. According to Nevin and Watson (1998), investors have calculated market value of energy efficiency based on a 5% discount rate. However, a more recent survey by Henger and Voigtländer (2011) reports that more than 80% of private homeowners receive a return from energy efficiency investments significantly below the 5% threshold. Since according to the German central bank statistics capital costs for real estate credits continuously declined since 2008, we assume lower capital costs of 4.25%; this is approximately the interest rate charged for 10-year real estate loans at the beginning of the period of observation, in june 2011.

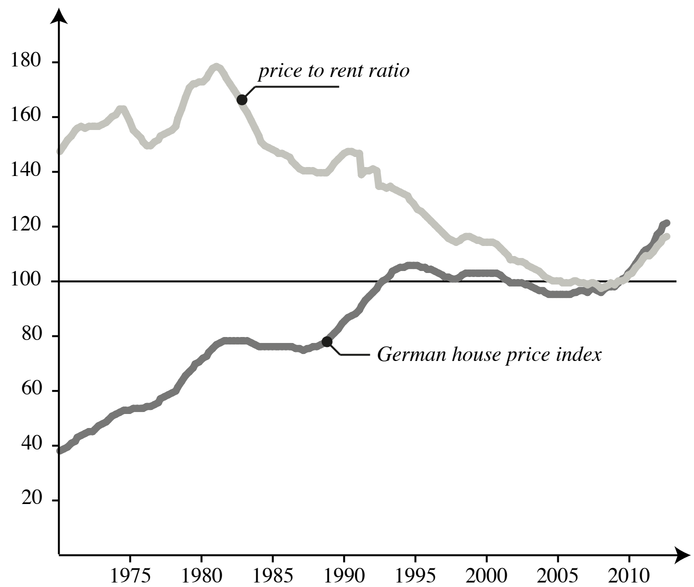
[11]Studies on household's long-run price elasticity report a range from -0.3 for electricity (Filippini, 1999), to -1 for solid fuel, -1.25 for liquid fuel, and -1.7 for natural gas (e.g., Pindyck, 1980). Tenants can either reduce energy consumption or move to a more energy efficient dwelling. An increased demand for energy efficient dwellings would have a positive effect on the implicit rents paid for energy efficiency. Given the range of elasticities reported for heating fuels and the two potential responses to energy cost increases, the assumption of an rent/energy price elasticity of 1 appears to be a plausible approximation.

which is still substantial, see Table 8.

Table 8: Net present value of rental income and selling price increases of rental apartments

	Scenario 1 constant rents	**Scenario 2** increasing rents	**Scenario 3** increasing rents and prices
Increase of implicit rent p.a., e	0.00 %	3.5 %	3.5 %
Increase of implicit real estate price p.a., ΔP	0.00 %	0.00 %	2.5 %
Internal discount rate, d	4.00 %	4.00 %	4.00 %
NPV of rental income	111.26	152.82	152.82
NPV of implicit house price increase	0.00	0.00	60.75
Total net present value	**111.26**	**152.82**	**213.57**
Investors' implicit willingness to pay for energy efficiency	**213.57**	**213.57**	**213.57**
Difference	**102.31**	**60.75**	**0.00**

Figure 3: Quarterly German house price index and price-to-rent ratio, 2010=100



Source: OECD.

Third, if rental income goes up over time, it is straightforward to expect, in addition, positive effects on the implicit price for energy efficiency. Provided that all else remains like in the second scenario, a selling price increase at an annual growth rate of roughly 2.5% could close the remaining gap between NPV and the implicit price. This appears—compared to the general house price dynamics of the 10 years of stagnation from 2000 through 2010—quite optimistic. However, in the light of the recent real estate price movements (see Figure 3) a substantial increase of nominal house prices over the next years can be expected. In previous cycles, nominal house prices increased by annual rates of roughly 4.2% (1970–1987) and 1.4% (1988–2005). Against this background and in the light of the persistent upward trend of fossil fuel prices, the expected capital gains also appear to be in a plausible order of magnitude.

A similar picture can be drawn for the value of potential energy cost savings in owner-occupied dwellings, see Table 9. The NPV can be calculated analogously to equation (4), while income is generated by energy cost savings (C) instead of rental income (R):

$$NPV = C \sum_{t=1}^{T} \left(\frac{1+e}{1+d} \right)^{\frac{t}{12}} + \left(\frac{\Delta P}{1+d} \right)^{\frac{T}{12}} \tag{5}$$

Assuming in a first scenario a price of 8 eurocents per kWh heating energy (roughly the current total consumer price for natural gas, see (Techem AG, 2012)), the potential monthly energy cost saving per square meter (C) equals 2 euros. The NPV—all else equal to the rental housing case—of future energy cost savings at constant fuel prices (see equation (5)) equals 332.11 euros, which covers roughly 61% of the estimated implicit price. Again, assuming in a second scenario an annual increase of energy costs (e) by 3.5%, the NPV (456.19 euros) covers about 92% of investor's willingness to pay (542.34 euros). The remaining gap of 86.15 euros can be closed (scenario 3) by an expectation of annually increasing implicit prices for energy efficiency in owner-occupied dwellings by roughly 1.5%, equal to the current inflation rate in Germany.

Table 9: Net present value of energy cost savings and selling price increases of owner-occupied apartments

	Scenario 1 constant prices	**Scenario 2** increasing energy price	**Scenario 3** increasing energy & house price
Increase of energy cost saving p.a., e	0.0 %	3.5 %	3.5 %
Increase of implicit house price p.a., ΔP	0.0 %	0.0 %	1.5 %
Internal discount rate, d	4.0 %	4.0 %	4.0 %
NPV of energy cost savings	332.11	456.19	456.19
NPV of implicit house price increase	0.00	0.00	86.15
Total net present value	**332.11**	**456.19**	**542.34**
Investors' implicit willingness to pay for energy efficiency	**542.34**	**542.34**	**542.34**
Difference	**210.23**	**86.15**	**0.00**

The results on the NPV of energy cost savings are in the range reported in the recently published study of Hyland et al. (2013) on the Irish housing market. In detail, the implicit price for energy efficiency seems to cover actual and future energy cost savings, rental income streams, as well as house price movements. While in owner-occupied housing, the NPVs of today's and future energy cost savings already account for a large share of the implicit house price, investors in the rental segment seem to be be more optimistic about future house price increases; in the third scenario (see Table 8), expected house price increases are higher than the expected rental income increases. Against the background of the current housing boom, this is contradicted by the actual dynamics of the price-to-rent ratio. However, this assumption holds in the long run (see Figure 3). Overall, the expectations of both homeowners and landlords appear to fall in a plausible range, which indicates rational investment behavior.

5. Conclusions

In this study, we investigated investor's willingness to pay for energy efficiency in the Berlin apartment housing market. In line with previous studies, we found that energy efficiency is capitalized in house prices. Moreover, investors seem to account for potential future energy and house price movements. While this is an established finding in the literature around energy efficiency of owner-occupied dwellings, up to date no insights existed on the capitalization of energy efficiency in rental apartment prices and the underlying rational of investors. In this context, the present study adds four key insights to the debate.

i) The implicit price of energy efficiency in a tenant-occupied dwelling is significantly below the level of free to use (most likely owner-occupied) dwellings—roughly by a factor of 2.5.

ii) This however, can be interpreted as a rational response to differences in the revenues. While the NPV of constant energy cost savings in a standard investment project equals to 332.11 euros, the NPV of constant rental income streams equals to 111.26 euros. Although the ratio of the NPV of future rental income to energy cost savings (2.98) is slightly different compared to the ratio of implicit prices, investors' understanding of the market and the relation of potential revenues appears to be quite comprehensive.

iii) The rental relationship substantially reduces the revenues (rents vs. cost savings) of energy efficiency. The NPV thus varies substantially: 213.57 euros for rented out dwellings versus 542.34 euros in owner-occupied apartments, respectively. In summary, our study provides the underlying rationale for the finding in our data, consistent with the previous literature, that landlords tend to invest less in energy efficiency than owner-occupants. However, whether this is a result of market imperfections, as argued by the authors emphasizing the existence of the "landlord–tenant dilemma" or if this is a result of shared market power between landlords and tenants, must be a subject of a future research.

iv) Under the assumption of constant rents, the NPV of the implicit rental income/of the energy cost savings from energy efficiency equal about 52% (rental housing) and 60% (owner-occupied housing) of the implicit price that investors are willing to pay. This indicates that both groups of investors expect increasing rental income or cost savings from energy efficiency and potentially increasing apartment prices over time. Assuming in this context an annual growth in rental income/energy cost savings by 3.5% (the average increase of the consumer price of natural gas between 2001 and 2011), the NPV reflects about 92% of the estimated implicit price of owner-occupied dwellings and roughly 71% in rental apartments. Thus, investors in the rental segment appear to be more optimistic about future house price or rental income increases. In contrast, capital gains from selling the home do not play an important role for owner occupants.

Overall, our results indicate rational behavior by both groups of real estate investors: Energy price movements are anticipated, current and future revenues are well capitalized in apartment prices.

For policy makers, our findings imply a differentiated treatment of rental and owner-occupied housing in future policies towards the "Nearly Zero-Energy Buildings" (NZEB) standard, as, for example, targeted in the European Union by the year 2021. This should be taken into account in support schemes as well as in building energy codes, which, in general, do not consider different building types (i.e., owner-occupied and rental housing).

Future research in this field should also consider the comparison of the effects of EPS on house prices and rents under heterogeneous market conditions. While the findings in our study hold for the growing Berlin market, there are still no studies concerning the implicit price for energy efficiency in markets that are facing population decline and a less favorable market environment. It can be expected that rental revenues and apartment prices would vary substantially, as indicated by the study of Hyland et al. (2013).

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