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Housing Market Fundamentals, Housing Quality and Energy Consumption: Evidence from Germany

Marius Claudy and Claus Michelsen***

ABSTRACT

This study investigates the relationship between regional housing market fundamentals and energy consumption. We argue that dwellings, in particularly rental properties, are not only consumer goods, but also constitute financial market assets. Properties are spatially fixed and traded in regional contexts, where real estate market characteristics like vacancy, income levels, and expectations determine rent and prices, which in turn provide incentives to invest in housing quality. The level of housing quality (e.g. windows, building materials, or heating technology) in turn influences the level of energy consumption. While this view is established in the real estate and urban economics literature, it has only recently found its way into the energy debate. As a result, the relationship between regional housing market fundamentals and energy consumption has received little attention. This study provides a first attempt to address this paucity. Utilizing aggregate data on regional space-heating energy consumption from over 300,000 apartment buildings in 97 German planning regions, the study applies structural equation modeling to estimate the influence of housing market fundamentals on the level housing quality, and subsequently on regional energy consumption. Findings provide first evidence that regional differences in housing market conditions have a significant impact on housing quality and energy consumption. Specifically, the results suggest that carbon abatement programs in buildings should focus on regions with weak housing market fundamentals, as market incentives are unlikely to incentivize investors to invest in housing quality attributes. The authors conclude by highlighting important implications for energy research and avenues for further investigations.

Keywords: heating energy demand, energy efficiency gap, regional housing markets, housing market fundamentals

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1. MOTIVATION

Residential housing plays a vital role in meeting climate change and CO_2-mitigation targets. According to OECD-data, residential energy demand accounts for 25–40% of final energy needs in developed countries. The lion share of residential energy demand stems from space-heating and cooling. For example, in the US this accounts for about half of all residential energy demand, while in Europe two thirds of residential energy demand results from heating and cooling (OECD, 2003). On an aggregate level, factors like income-levels, energy prices and population composition

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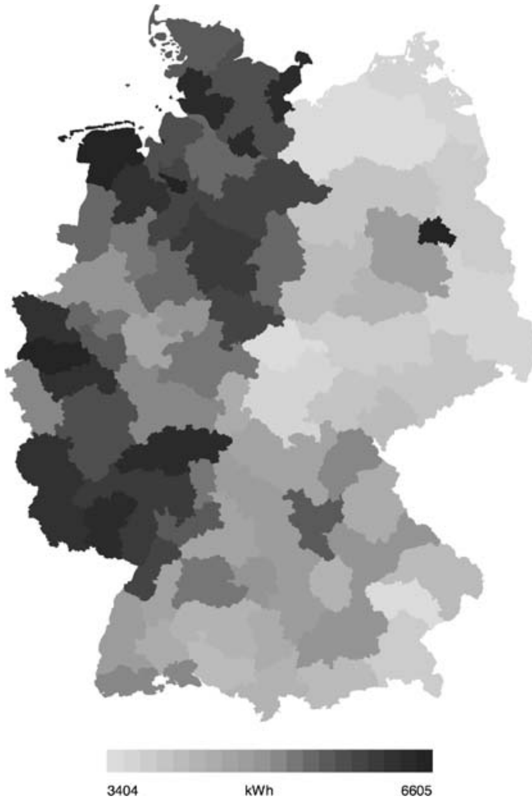
Figure 1: Per Capita Space Heating Energy Consumption (2006)



Source: DIW Berlin.

have been shown to explain spatial differences in energy consumption (for an overview, see: Haas and Schipper, 1998; Nelson, 1975). Yet, observed regional differences in heating energy demand are often substantial (see Figure 1 for the German case), and are unlikely to be explained by varying consumption patterns alone.

Other studies have thus investigated peoples' motives to invest in energy efficiency measures and new heating-technologies. Generally, research suggests that energy prices, investment costs and income levels all influence individuals' likelihood to adopt energy efficient technologies (e.g., Nesbakken, 2001, 1999; Vaage, 2000; Nair et al., 2010; Long, 1993; Cameron, 1985; Brechling and Smith, 1994; Sutherland, 1991; Alberini et al., 2013). Further, socio-economic factors like family size, age, or levels of education have been found to correlate with the adoption of energy efficiency measures (Jeong et al., 2011; Nair et al., 2010). However, as pointed out by several authors, the understanding of the motives and determinants of energy efficiency investments still appears inconsistent and incomplete (Eichholtz et al., 2013; Eichholtz et al., 2010; Schleich and Gruber, 2008; Nair et al., 2010; Mills and Schleich, 2012).

One factor that has been widely neglected in the literature relates to how regional housing market conditions influence people's decision to invest in housing quality, and how this affects energy consumption. For example, in the context of green office space investments Kok et al. (2012, p. 562) concluded that "the diffusion [of green office space] has been more rapid in metropolitan areas with higher incomes, and in those with sound property market fundamentals (for example, lower vacancy rates and higher property values).” Yet, little is understood about how regional market fundamentals influence investment in residential housing quality. Because properties are not only consumer goods, but also capital assets, it is reasonable to assume that individuals optimize their investment decision in regard to expected rental income and anticipated changes in sales prices (Dipasquale and Wheaton, 1992; Leung, 2004). More importantly, these investment decisions are likely to correspond with certain levels in housing quality, which in turn influences energy consumption. In other words, in high-risk markets, or markets with low growth opportunities, the average level of investment should be lower than in regions where investors are faced with low default risks and promising growth opportunities (Capozza and Seguin, 1996; Capozza and Helsley, 1990). For example, in markets with high rents investors are more likely to invest in higher quality housing attributes like building materials, windows or insulation, which result, intentionally or unintentionally, in higher levels of energy-efficiency. While this view is well established in real estate and urban economics, it has only recently found its way into the empirical literature around energy efficiency, which can partially be explained by a lack of adequate data (Eichholtz et al., 2010).

The present study addresses this paucity, and aims to contribute towards a better understanding of the relationship between housing market fundamentals, housing quality investments, and energy consumption. To this aim, we estimate the influence of regional market fundamentals on investors’ decisions to produce a certain level of housing quality. In a second step, regional levels of energy consumption are modeled as a function of housing quality, controlling for key variables like average dwelling size, age and occupier characteristics. By focusing solely on apartment buildings in Germany, we concentrate on dwellings that pre-dominantly constitute capital assets; almost 80% of Germany’s apartment housing stock is for rent. The study utilizes unique aggregated energy billing data from approximately 300,000 apartment houses in Germany. In absence of suitable micro-level data, we can only approximate housing quality by overall development costs. Further, we are limited to cross-sectional data. Nevertheless, our results provide first evidence that regional market fundamentals significantly influence regional levels of energy consumption.

The remainder of this study is structured as follows. In the following section we provide a brief motivation for this research, and discuss the relationship between regional housing market variables, housing quality investments, and energy consumption. Next, we discuss the empirical approach as well as the underlying data on regional space-heating energy consumption and real estate investments. In the final sections we present our empirical findings, and discuss implications for energy research. We conclude by outlining avenues for further research.

2. DETERMINANTS OF REGIONAL DIFFERENCES IN ENERGY CONSUMPTION

There are several potential sources for differences in space heating energy consumption across regions. The most obvious one is of climatic nature (Sailor and Muñoz, 1997; Jacobsen and Kotchen, 2013; Koirala et al., 2013). The level of energy consumption also depends on the given quality of the regional housing stock, like the average age of dwellings, floor-space or level of refurbishment (Leth-Petersen and Togeby, 2001; Costa and Kahn, 2011; Chong, 2012). Another potential source of regional variation in heat energy consumption stems from socio-economic factors like occupants’ age, income or average household size (Brounen and Kok, 2010; Meier and Rehdanz, 2010; Borenstein, 2013). Other studies have investigated households’ individual motivation to invest in housing quality, which can be improved mainly by higher capital inputs, like better thermal insulation, more efficient heating systems, or thermal glazed windows, which in turn reduces energy consumption (e.g., Brounen and Kok, 2010; Leth-Petersen and Togeby, 2001). Generally, studies arguing from a consumption-based perspective show that the level of housing quality produced by individual households depends, at given budget constraints, on capital costs and expected future energy cost savings (Quigley, 1984). The level of energy consumption is subsequently adjusted according to income and energy price changes.

However, energy efficiency can also be seen as an investment, which will yield future returns that do not necessarily stem from future energy cost savings, but from increased rental income and/or sales prices (Fuerst and McAllister, 2011). The value of energy efficiency is, from a capital-asset perspective, determined in regional housing markets and the underlying fundamentals. The connection between energy efficiency and regional housing market fundamentals becomes apparent when one differentiates between different types of investors. For example, empirical evidence suggests significant differences in housing quality between owner-occupied and rental housing (e.g., Rehdanz, 2007). One key explanation is that landlords' return on energy-efficiency investments is determined by potential increases in rental income and/or future sales prices of the dwelling, and not by energy cost savings (Hyland et al., 2013; Fuerst et al., 2015; Kholodilin and Michelsen, 2014). In other words, the level of energy efficiency is subject to optimization according to anticipated future rental income, sales price and actual investment costs. Scholars have argued that in situations where landlords cannot pass on the cost of energy efficiency investments in form of higher rents or future sale price, one can expect an underinvestment in housing quality—a phenomenon is widely known in the literature as the landlord-tenant dilemma (Schleich and Gruber, 2008). Regional patterns in energy consumption in rental property, as for example observed in Germany, are thus likely to correspond with differences in regional housing market conditions. In the following, we discuss the various influences that are likely to enter investors' decisions in more detail.

2.1 Determinants of Housing Quality Investments

Little is known about how regional market fundamentals influence investors' decisions to choose a certain level of energy efficiency, or more generally housing quality. This is potentially due to some major constraints in the empirical approximation of housing quality. Housing quality can be captured very specifically, i.e. by characterizing the specific attributes of a building and its components. In the energy efficiency context, it would be straight forward to concentrate on the thermal attributes of windows, attic insulation or the efficiency of the heating system. However, empirical studies in this context are often prohibited as aggregate data on the thermal quality of the housing stock is not available in official statistics. Likewise, micro-data on energy efficiency, market conditions, as well as characteristics of buildings and occupants are difficult to obtain.

However, a specific feature of housing is that the quality of its attributes is to a large extend conjoint (for an overview see: Yates and Mackay, 2006; Blakley and Ondrich, 1988). High quality facilities like a fitted kitchen or state-of-the-art bathroom are likely to correspond with a certain level of quality of other housing attributes like windows and insulation. For example, investors are unlikely to fit golden bath taps without also investing in good heating technologies. This implies that there is a complementarity between quality benefitting the household (e.g. better windows against noise) and quality benefitting society (e.g. better windows reducing energy consumption). Importantly, a higher level of housing quality requires larger capital inputs, which suggests that development costs serve as a good proxy for the general quality of buildings.

In order to uncover the potential factors that are driving investors' decisions to invest in certain levels of housing quality, we start with a simple net present value (NPV) calculation. Taking an NPV perspective suggests that rational investors would decide to invest in housing quality if the costs of real estate development (C) is below or equal to sum of the discounted (by the internal factor i) future returns (i.e. sales price (ΔP) and net rental income (r) increases) for the investment period T. In turn, development costs crucially depend on the price of input factors like wages (w), capital and material prices (p), as well as the chosen level of building quality (q).

$$C(p,w,q) \leq NPV = \sum_{t=1}^{T} \frac{r(q,x,tax)}{(1+i)^t} + \frac{\Delta P(r)}{(1+i)^T} \quad (1)$$

Under the standard assumptions, investors choose investments, which maximize the net-present value i.e. projects where the marginal present value for additional housing quality equals or exceeds marginal development costs. However, development costs, revenues from rents and sales, and the internal discount rate are determined by exogenous factors, partially in regional markets.

From an investor's perspective, the level of housing quality is determined by the potential return on investment, which in turn is determined by market fundamentals such as rents, vacancy rates or (potential) future property prices. Rational investors are thus likely to choose a level of housing quality, which yields an acceptable rate of return. As the specific revenues from single housing attributes are commonly unknown, it is reasonable to expect homeowners to compare the aggregate income from investment with the respective aggregate development costs of the construction project. Commonly, the yields of a high, medium or low quality investments are compared.

2.1.1 Determinants of investors' revenues

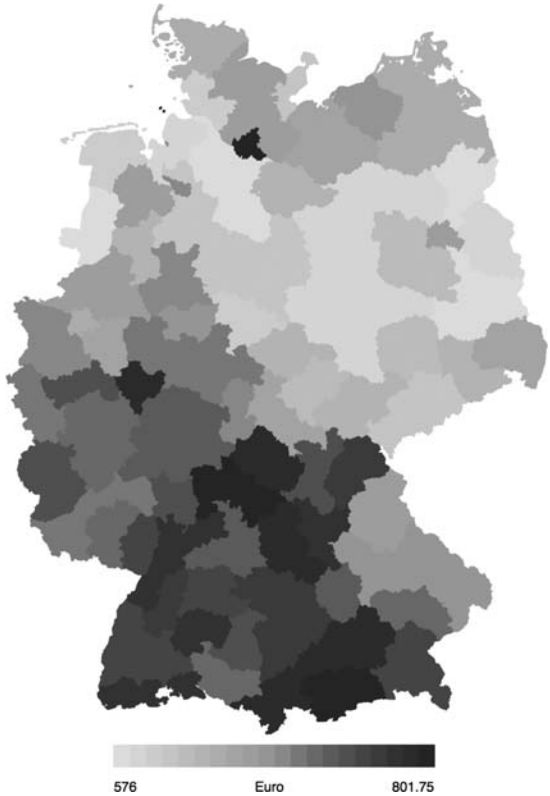
Our aim is to establish the link between the revenue side of the investment rationale and the decisions to invest in housing quality. Revisiting the NPV calculation (equation 1), revenues consists of expected rental income (r) from the investment and the expected change in sales price (ΔP) in the sales period (T). More importantly, rental income moderates the relationship between regional housing market fundamentals (x) and housing quality (q). That is, investors form expectations about future income based on observed market characteristics and chose the level of housing quality accordingly. In the literature, several market fundamentals have been identified that affect investors' expectations about current and future house prices and rents, including: (i) income levels, (ii) vacancy rates, (iii) property taxes, and (iv) market risk.

Clearly, the most important variable is per-capita income, which influences households' ability to pay for residential living space. Numerous studies have demonstrated the impact of disposable income on rents on both individual and regional levels (for an overview, see, Sirmans and Benjamin, 1991). However, people's willingness to pay also depends on their relative market power. Stull (1978) has shown that the higher the vacancy rate in a regional housing market, the lower the likelihood to find tenants at given rents. The risk of vacancy, however, can be partially offset by lower rents, which in turn increase the likelihood of occupation. Thus, income and vacancy constitute an equilibrating rent level in a certain housing market (Zietz, 2003; McDonald, 2000; Read, 1991; Wheaton, 1990; Stull, 1978).

Property and income taxes also directly affect investors' cost-benefit evaluations. As first shown by Oates (1969), the level of property tax adversely affects real estate values because they reduce landlords' net-rental incomes. In this way, we would expect the level of property tax to have a negative influence on housing quality investments.

Finally, investors' evaluations of future housing market developments and risks both play important roles in real estate investment decisions. An established measure often used in real estate economics, as well as by real estate professionals, is the price to rent ratio, or the so-called multiplier

Figure 2: Development Costs per m² Residential Space Excluding Costs of Land in 2006



Source: German federal statistical office.

(Capozza and Seguin, 1996). The multiplier reflects the level of risk investors are willing to accept in a particular market. A high multiplier means that investors' are willing to accept a long payback period, which can be interpreted as a high level of confidence in a particular real estate market. Thus, a high multiplier should positively relate to housing quality investments (Sirmans and Benjamin, 1991; Zietz, 2003).

2.1.2 Determinants of development cost

Figure 2 clearly shows that there are substantial differences in development costs across regions in Germany. The respective literature has identified four broad factors that determine the development cost of housing in a given market, including: (i) land prices, (ii) capital input prices, (iii) wages, (iv) interest rates, as well as (v) the chosen level of housing quality. However, we argue, based on the existing literature, that it is a fair assumption to make that development cost differences (excluding the land component) are primarily driven by differences in the level of housing quality (q). The studies available, mainly for the U.S., indicate that capital costs, and material prices are unlikely to differ significantly within a country. Moreover, it is found that it can easily be controlled for wage differences by including information on the degree of unionization (Gyourko, 2009). Ceteris paribus, the only remaining source for the distinct regional pattern of construction costs per housing unit are actual differences in housing quality (q). In the German context, this view is supported by studies of the German association of the housing industry (GdW, 2012) and the real estate analyst LBS Research (2006). Both conclude that regional differences in development costs occur mainly because of differences in housing quality and the price of land. In the following, we discuss in more depth why development costs are indeed a suitable proxy for housing quality for regional (intra-country) comparisons.

Land prices can be characterized as the non-tradable component of real estate. Importantly, land prices are likely to vary across regions, mainly because of regulatory or topographic reasons, and also because of the quality of the surrounding amenities (Gyourko, 2009; Mayer and Somerville, 2000; Quigley and Rosenthal, 2005). For example, a lakeside view or the proximity to leisure facilities are factors that are commonly found to increase real estate values. Also, accessibility is well established as a determinant of land price differences (Alonso, 1967). However, in this study we are able to effectively control for differences in land prices, as our data allow us to solely focus on development costs that are directly related to the actual building and technical facilities, excluding the price of land (see further explanations in section 3).

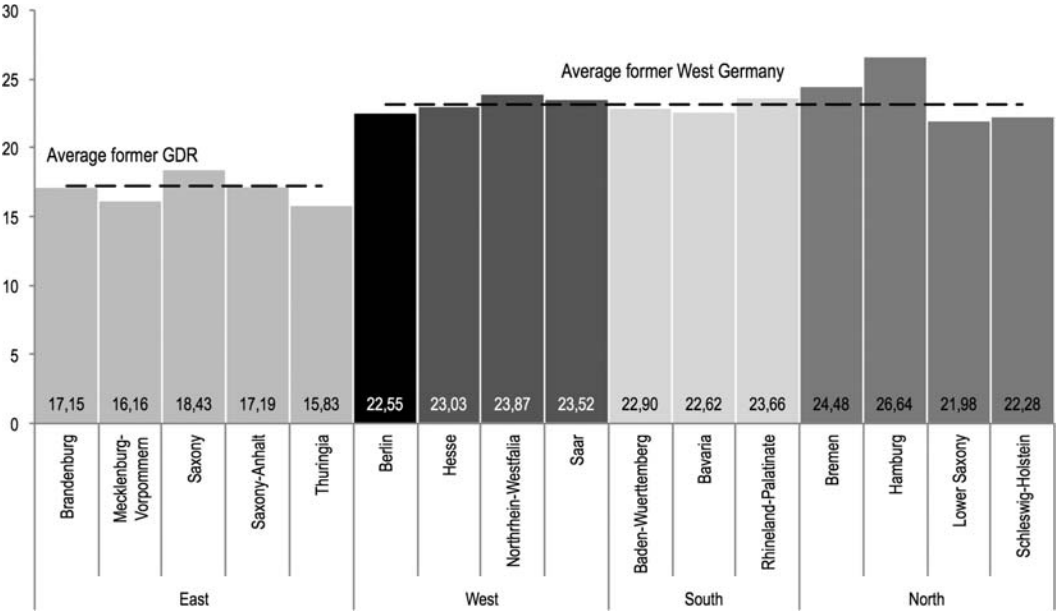
Further, construction is resource intense and variations in material prices might determine the cost of construction across regions. However, important materials like wood, steel, cement or bricks are traded in global or at least national markets. While no data exists for the German market, strong empirical evidence from the comparatively more heterogeneous U.S. market suggests that prices for construction materials do not differ significantly across regions (Saiz, 2010; Gyourko and Saiz, 2006; Ball, 2006; Myers, 2008). Regional differences in material prices are therefore unlikely to occur, mainly because of the extremely competitive nature of the construction industry—in Germany for example, about 90% of the firms can be considered small to medium sized enterprises with less than 20 employees, which makes these companies effectively price takers (Buzzelli and Harris, 2006).

Likewise, differences in the costs for borrowing (i.e. interest rates) would clearly influence investors' construction activities, which can be easily observed in cross-country comparison (Hwang and Quigley, 2010). However, empirical studies do not indicate substantial intra-country variation of interest rates. Reichert (1990, p. 388) concludes that interest rates ". . . impose costs on the housing sector which are distributed fairly evenly across the country." In the German context, now official data on interest rates for housing loans exist on the regional level. Data on consumer credits, provided by a leading online credit broker, shows that interest rates are homogeneous across German federal states, and that the largest gap between any two states was 0.16 percentage points (check24.de, 2013).

In contrast, empirical evidence suggests that wages can disperse significantly across regions. However, Gyourko and Saiz (2006) and Gyourko (2009) find that the level of unionization within the regional construction sector is the main driver of wage differences. In a (spatially) small and relatively homogenous economy like Germany, regional variation is likely to be minuscule due to a high degree of unionization as well as labour and firm mobility. Indeed, Figure 3 shows that wage differences in Germany exist primarily between East and West Germany (and not between federal states), which can be explained by a different unionized tariff in the former GDR. Importantly, potential wage differences can easily controlled for by introducing regional fixed effects.

In summary, our main argument is that, if one can effectively control for wage differences and land prices, than development costs of houses in regional markets are an adequate reflection of the overall level of housing quality. The level of housing quality is in turn influenced by investors' assessment of potential revenues, which can vary by region, depending on differences in key housing market fundamentals like income, vacancy rates or market risk. Finally, one would expect the

Figure 3: Gross Wages in the Construction Sector in Germany by Federal States



Source: German federal statistical office.

level of housing quality to mediate the relationship between regional housing market fundamentals and levels of energy consumption. While the influence of housing market fundamentals has been widely tested in regard to house prices and housing market efficiency, little is known about their influence on housing quality and energy consumption.

3. EMPIRICAL STRATEGY

Based on these conceptual considerations, one can design an adequate strategy to evaluate the impact of market conditions on housing quality investments, and subsequently on energy consumption. We are interested in two key questions: first, to what extend do housing market conditions incentivize landlords to invest in housing quality? Second, how does housing quality translate into regional differences in energy consumption?

To answer these questions, we follow a two-step strategy. In absence of suitable micro-data,[1] we use aggregate, regional information on development costs and energy consumption in Germany. In the first step, we regress average development costs per square meter living space (excluding the cost component of land) of newly built homes on housing market fundamentals, while controlling for regional wage differences. As outlines in the previous section, in this way we can establish the link between housing quality and market fundamentals.

1. The initial choice would be to analyse the energy efficiency of newly constructed/recently refurbished apartment houses and to regress these data on housing market fundamentals at the respective time of construction. This however proves challenging. In many countries, including Germany, no individual or aggregate data exists that provide sufficient information about investment projects, related energy efficiency ratings and/or households and market conditions.

In particular, we estimate the influence of housing market fundamentals (X) on development costs (c) in newly constructed homes across different regions (j):

$$c_j = \alpha + \beta_1 X_j + \beta_2 o_j + \beta_3 D + \varepsilon_{j,1} \tag{2}$$

As fundamental determinants of c, we include different variables that capture returns on investment, costs, as well as risk in a specific housing market. In particular, X_i includes all variables identified in the NPV discussion above, including per capita income, local property taxes and vacancy rates in apartment housing, as well as investors' risk evaluations. Unfortunately, wages are not observable on the regional level. However, a high degree of labour and firm mobility should to a large degree smoothen, if not eradicate regional wage differences. In Germany, wage differences exist primarily between East and West Germany (and not between federal states), which can be explained by a different unionized tariff in the former GDR. Importantly, potential wage differences, and other unobservable regional differences, can be captured and controlled for by introducing fixed effects for northern, eastern, western and southern regions.

To account for possible differences in investment behavior between home owners and landlords, we further control for the share of owner occupants (o). The β stand for the respective coefficients, while ε is the i.i.d. error component.

In the second step, we borrow from the conditional demand literature and regress heating energy consumption on regional information. We estimate the following equation:

$$e_j = \alpha + \beta_4 H_j + \beta_5 S_j + \beta_6 c_j + \beta_7 V_j + \varepsilon_{j,2} \tag{3}$$

where again the β are coefficients and ε is the i.i.d. error component. In particular, we explain the level of per capita energy consumption (e) on a regional level (j), as a function of regional development costs (c), which serves as a proxy of housing quality (see discussion above). Further, we include and control for other housing stock attributes (S), household characteristics (H), and other control variables (V). To capture housing stock's attributes, we include size, vintage class, and the share of non-renovated houses. Household characteristics include variables like average household size, income, residential space consumption or the proportion of pensioners, while control variables account for variations in natural gas prices, the ownership ratio and include a dummy for East Germany.

3.1 Data Sources and Restrictions

In order to estimate the above specified relationships, this study takes advantage of a unique regional dataset, which is based on a large number of energy consumption bills for space heating. The data set contains aggregated micro data, which holds three key advantages over data from official statistics. First, in contrast to official data, it allows to spatially disaggregate energy consumption. Secondly, we have information on household energy consumption instead of crude top-down estimations of energy use. Finally, we can distinguish between housing market segments. As mentioned earlier, our analysis focuses on apartments in Germany, which are predominantly rented. In fact, official statistics show that about 80% of apartments are rented (Veser et al., 2007). In this segment, we expect housing market fundamentals to have the strongest influence on investment decisions, and ultimately on housing quality and energy consumption

The data on space-heating energy consumption is gathered from information published by ista Deutschland GmbH, a leading energy billing service provider in Germany and the DIW Berlin,

Table 1: Descriptive Statistics

Variable	Description	Mean	SD	Min	Max
Development costs	costs of construction per m^2 excl. land	668.5	49.18	576	801.8
Energy consumption	annual per capita space heating energy consumption in kWh	4810	702.3	3404	6606
Income	income per household member in 1000 Euros	0.63	0.08	0.47	0.95
Multiplier	construction costs/annual rental income p. m^2	10.33	1.34	7.03	14.34
Property tax	annual tax burden (Euro/m^2)	0.425	0.11	0.24	0.75
Vacancy	share of vacant flats	10.19	5.05	3.36	32.68
Owner occupied	share of owner occupied dwellings	0.17	0.08	0.04	0.35
East	former GDR, Dummy	0.24	0.43	0	1
North	region North, Dummy	0.21	0.41	0	1
West	region West, Dummy	0.19	0.39	0	1
Residential space	per capita residential space consumption	32.80	2.321	27.76	38.59
Energy price	natural log of price per kWh natural gas	2.16	0.06	2.04	2.31
Pensioners	share of population >65 years	19.45	1.495	16.80	23.60
Non-refurbished	share of non-refurbished houses	0.30	0.14	0.03	0.58
Regulated	share of dwellings built 1978-1994	0.14	0.03	0.08	0.19
Post-War	share of dwellings built 1948-1977	0.45	0.10	0.20	0.65
New	share of dwellings built after 1994	0.14	0.05	0.03	0.25
Large	share of dwellings in houses >20 flats	0.06	0.04	0.01	0.19

a German economics think-tank. The underlying dataset covers approximately 300,000 apartment houses with nearly 2.9 million flats, which account for about 15% of the apartment housing stock in Germany.[2] The data is adjusted by regional climatic parameters, which are calculated based on heating degree days and are provided by the official "German Weather Service" (DWD) for 8,400 ZIP-code districts. This way, the data accounts for regional as well as inter-temporal differences in climatic conditions. Based on this information, ista-data report aggregated average energy consumption levels for apartment houses in 97 planning regions in Germany.[3]

Information on the housing stock, general market conditions, as well as socio-economic factors were taken from regional tabulations of official census data (micro-census supplementary survey 2006), which is regularly published by the German federal statistical office. Regional data on costs of construction were also taken from official statistics on building activity provided by the Federal Statistical Office. In order to account for regional energy prices, we employed data provided by Techem AG Techem (2008), another German energy billing service provider.

Although ista provides annual energy data for the period from 2003 to 2013, the analysis could only be performed for 2006. This was due to limitations stemming from micro-census data collected by the Federal Statistics Office. The supplementary census is carried out every four years, and, more importantly, changes in the design of the survey have meant that 2006 was the only suitable dataset for the purpose of this study. Therefore, our study is restricted to a cross-sectional analysis of a regional consumption and investment patterns

3.2 Variable Definitions and Descriptive Statistics

Variable definitions, as well as descriptive statistics, are presented in Table 1. As discussed above, development costs serve as proxy for housing quality and constitute the dependent variable

2. The micro-data has already been used in previous studies. For a detailed description of the micro-data, see Michelsen and Rosenschon (2012); Michelsen et al. (2014); El-Shagi et al. (2014).

3. Planning regions are not administrative units. They are chosen according to economic performance measures as well as economic and labour market integration. Due to these functional ties, one can argue that planning regions constitute to some extend a regional housing market. Planning regions serve as basis for governmental planning. In Germany 97 planning regions exist for the year 2006.

in the first equation. Costs are reported as average nominal residential construction costs (excluding land) per square meter. The dependent variable in equation 2 is the annual heating-energy demand per square meter measured in kilowatt hours. As mentioned above, ista-data is already adjusted for climatic differences, which means that there is no need to include heating-degree days as in most previous studies.

The introduction and measurement of covariates is straightforward. Housing stock characteristics are mainly captured by controlling for vintage classes, housings size and past refurbishment activities. In particular, we expect post-World-War II dwellings (1949–1977) to be less energy efficient compared to other vintage classes (homes built before 1948 and those built between 1978 and 1994). Energy requirements of newly constructed homes dramatically decreased after the introduction of the first 'Heat Insulation Ordinance' (so called WSchV) in 1978 (see, Michelsen and Rosenschon, 2012). The share of old homes (built before 1949) serves as our base group and is thus excluded from the analysis. Further, the fraction of large houses (>20 flats) should capture the widely observed negative effect of housing size on energy consumption. To capture possible effects of past refurbishment, we include the share of entirely non-refurbished homes based on aggregated micro data information from ista data. The data set provides information on the overall refurbishment status of the housing stock. Based on self-reported measures of home owners, the share of homes is calculated where windows, facade, roof, basement ceiling and heating system have not been refurbished or replaced.

Additionally, information on income (disposable income per capita in 1000 Euros), household size (average number of household members), as well as population age (the share of the retired population), is used to account for socio-economic effects in the energy consumption equation. In order to control for differences in energy prices, we use the price (Euro) per kWh for natural Gas, which is the major heating energy source in apartment buildings in Germany.

The risk of vacancy is measured as the share of vacant flats in apartment houses in the respective region. Property taxes are calculated as the average tax burden (generated by the so-called 'Grundsteuer B') per square meter residential space in Euros. The multiplier is calculated as the average construction costs/m^2 divided by the average annual rental income/m^2 in the respective region.

Finally, in both models, there must be controls for unobservable regional differences. This is important because real estate markets in east and west Germany have followed very different investment patterns after reunification (Michelsen and Weiß, 2010) and wages potentially diverge between regions. Additionally, to control for different investment and refurbishment activities, we include the share of owner occupied flats in apartment houses.

3.3 Methods

To appropriately capture the direct and indirect effects of housing market fundamentals on energy consumption, we estimate a small system of two equations in a structural equation framework. Thereby, we can measure the direct, indirect and overall effects of the specific variables of interest. The structural equation framework is specifically suitable to account for interdependencies and simultaneity of influences across equations.

As we argued in the previous section, there are simultaneous direct and indirect effects in our model. For example, income is expected to have both, a direct positive effect on energy consumption and an indirect negative effect over the path of housing quality. Utilizing a simultaneous structural equation framework allows us to disentangle these factors, and capture direct and indirect (potentially oppositional) influences on energy consumption (Greene, 2007). The general framework

Figure 4: Stylized Figure of SEM Estimated

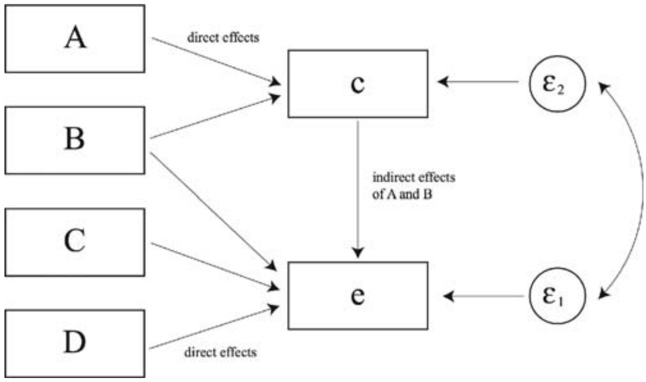


Table 2: Model Diagnostics

Equation 1: development costs	$R^2 = 0.81$	$\chi^2 = 429.7$*
Equation 2: energy consumption	$R^2 = 0.78$	$\chi^2 = 481.1$*
	N = 97	
likelihood ratio test	χ^2	$p > \chi^2$
model vs. saturated	19.38	0.08
baseline vs. saturated	352.06	0.00

* indicates significance at the 1% level of confidence.

we estimate is depicted in Figure 4. In the literature, this specific setup is referred to as path analysis, a special case of structural equation models.

Importantly, the data satisfies all necessary conditions to estimate the two equations of interest simultaneously. Although we have a small cross-section of regions, the number of parameters to be estimated is much smaller than the number of observations. The model is thus over-identified. To estimate the coefficients, we use standard maximum likelihood methods. However, as the sample is small, we use bootstrapped standard errors, which, in the case of small samples, provide more accurate inferences (Fox, 2008). Further, we allow for the correlation of the error terms. We check for commonly observed heteroskedasticity in cross-sectional data. However, we found that this is no major problem for our estimates.[4]

4. EMPIRICAL RESULTS

The structural equation modeling results are presented in Tables 2, 3, 4 and 5. In order to report comparable results, we report both, standardized and observed coefficients. We also report the direct and indirect effects of the specific variables. Overall, the model results indicate a high explanatory power. As reported in Table 2, the first equation explains about 81% of the total variation of housing quality. The second equation explains about 78% of the variation of per capita

4. We also estimated the models as seemingly unrelated regression, standard OLS and as system of equations using Huber-White robust standard errors. The results remain qualitatively unaffected—only the achieved levels of significance differ slightly. We report the bootstrapped results, as these provide the most conservative estimates in terms of significance.

Table 3: Direct Effects of Housing Market Fundamentals on Housing Quality Investment

	Coefficients	Bootstrap SE	z	P>|z|	Std. Coef.
Income	281.6	57.5	4.900	0.000	0.468
Multiplier	10.5	2.290	4.600	0.000	0.288
Property Tax	−28.5	48.27	−0.590	0.555	−0.061
Vacancy	−2.5	0.7	−3.400	0.001	−0.254
Owner occupied	−14.7	48.00	−0.310	0.759	−0.023
East	−22.2	13.0	−1.700	0.088	−0.194
North	−66.7	11.4	−5.860	0.000	−0.552
West	−21.9	7.6	−2.870	0.004	−0.178
Constant	445.0	61.6	7.230	0.000	9.095

space heating energy consumption. The likelihood ratio test indicates that the estimated model performs as good as a saturated model at the 10% level of confidence. The LR-test of the baseline model vs. the saturated model reveals that the baseline model performs poorer at all levels of confidence. Overall, the diagnostics indicate a reasonable good fit of the model. In the following we examine the specified relationships in greater detail.

4.1 The Influence of Market Fundamentals on Housing Quality

In the first equation, we estimate the influence of market fundamentals on housing quality, approximated by development costs. Our results suggest that differences in local housing market conditions have a statistically significant influence on regional differences in housing quality (see Table 3).

In particular, findings show that the level of per capita income, investors' expectations about future housing market development (i.e. multiplier) and vacancy all explain regional differences in housing quality. Moreover, the significance of the dummy variables for regions east, north and south suggest the influence of unobserved regional factors. In contrast, property taxes and the share of owner occupied flats did not turn out to significantly affect housing quality.

The relative importance of these variables can be evaluated in the standardized regression coefficients. The results indicate that income is the most influential variable, followed by market risk (i.e. multiplier) and vacancy rates. According to our estimates, a 100 Euro difference in average per capita income is associated with a 28 Euro difference in the level of housing quality investment per square meter. Likewise, a lower level of risk (i.e. one unit increase in the multiplier) results in 10.5 Euro of additional investments per square meter. In contrast, a one percentage point higher vacancy rate reduces investment in housing quality by 2.5 Euros per square meter in cross-regional comparison.

4.2 The Determinants of Energy Consumption

In our second equation, we set out to explain regional differences in space heating energy consumption. However, the main explanatory variable of interest in this case, was the level of housing quality proxied by development costs (c), which served as the dependent variable in equation 2. Indeed, our findings suggest that the level housing quality has a significant influence on regional levels of energy consumption. We find that in regions where investment in housing quality

Table 4: Determinants of Space Heating Energy Consumption

	Coefficients	Bootstrap SE	z	P>|z|	Std. Coef.
Development costs	−7.7	1.7	−4.530	0.000	−0.537
Income	1725.0	798.2	2.2	0.031	0.200
Owner occupied	−2132.0	841.0	−2.530	0.011	−0.229
East	−502.4	358.9	−1.400	0.162	−0.306
Per cap. space	141.8	31.96	4.440	0.000	0.469
Energy price	−1073.0	774.3	−1.390	0.166	−0.095
Pensioners	−63.8	49.1	−1.300	0.194	−0.135
Non-refurbished	1682.0	577.6	2.910	0.004	0.336
Regulated	−4855.0	1710.0	−2.840	0.005	−0.191
Post-war	236.9	1268.0	0.190	0.852	0.033
New	−532.3	1376.0	−0.390	0.699	−0.034
Large	−2509.0	1337.0	−1.880	0.061	−0.128
Constant	8519.0	2435.0	3.500	0.000	12.198

is 10 Euros per square meter above the average, the per capita heating energy consumption is approximately 77 kWh lower.

Income is also found to significantly impact energy consumption. As expected, we find that monthly income of 100 Euro above the average, results in higher energy consumption of 172 kWh per year. Also quite obvious is the impact of higher residential living space demand, which has also a positive impact of 142 kWh per additionally square meter consumed. Interestingly, higher energy prices have no significant impact on energy consumption.

We also controlled for the level of owner occupation, which we expected would have a positive impact on housing quality due to higher incentives to invest in energy efficiency. As expected, our findings indicate that a higher share of owner-occupants has a negative impact on space-heating energy demand. Specifically, findings show that in regions with a one-percentage point higher ownership rate, average space-heating energy consumption is 21.6 kWh per square meter lower.

Considering housing stock characteristics, findings show that a substantial portion of houses built in the period after the introduction of energy building codes in 1978, significantly reduces levels of heating-energy consumption. The same applies for the share of large houses. The results for the share of non-refurbished homes show that resistance to refurbishment significantly affects energy consumption. In regions where the share of entirely non-refurbished homes is 10 percentage points above the average, annual space heating energy consumption is approximately 168 kWh higher. Further, our results indicate no spatial effect of regions of the former German Democratic Republic (GDR). This is somewhat unexpected due to the vast refurbishment activities in the mid-1990s. According to our information, almost 85% of East German homes have been entirely refurbished since the mid-1990s. However, a substantial fraction of this effect is absorbed by the non-refurbishment variable. Also the share of retirees turned out to have no significant impact on energy consumption.

4.3 The Indirect Effects of Housing Market Fundamentals on Energy Consumption

The results suggest that housing quality is, amongst other factors, determined by regional housing market fundamentals (Table 3), and that housing quality, in turn has a significant impact on energy consumption (Table 4). In this way, we provide empirical evidence that regional housing

Table 5: Indirect Effects of Market Fundamentals on Space Heating Energy Consumption

	Coefficients	Bootstrap SE	z	P>|z|	Std. Coef.
Income	−2156.00	630.9	−3.420	0.001	−0.251
Multiplier	−80.69	21.2	−3.820	0.000	−0.154
Property tax	218.00	368.5	0.590	0.554	0.033
Vacancy	19.02	6.02	3.2	0.002	0.137
Owner occupied	112.90	398.1	0.280	0.777	0.012
East	169.60	106.8	1.590	0.112	0.103
North	510.60	108.0	4.730	0.000	0.296
West	167.30	63.7	2.630	0.009	0.095
Overall effects					
Income	−431.1	974.3	−0.440	0.658	−0.0501

market fundamental substantially influence on the level of energy consumption. Table 5 reports the indirect effects of the specific housing market fundamentals on energy consumption.

In particular, findings show that income has the strongest indirect influence on energy consumption. An income of 100 Euro above the average reduces an indirect negative effect on energy consumption of 216 kWh annually. However, although the overall effect of income is −431.1, we fail to reject the null-hypothesis of equality to zero. Thus, from a statistical point of view, the overall effect of income is zero. This is because higher income is positively related to a higher direct heating demand, which offsets the indirect effects from increased housing quality. This phenomenon has been widely discussed as the "rebound" effect (for an overview, see, Greening et al., 2000). A higher multiplier by one corresponds with lower energy consumption of 80 kWh, while one percentage point higher vacancy increases energy consumption by 19 kWh.

5. CONCLUSIONS

The present study investigated the relationship between regional housing market fundamentals and energy consumption. The empirical findings indicate that regional market conditions influence investors' likelihood to invest in housing quality. Further, findings indicate that overall level of housing quality is strongly associated with regional levels of energy consumption. The empirical results thus suggest that regional market conditions indirectly influence levels of energy consumption, holding important implications for energy research and policy.

Housing market fundamentals have, as far the authors are aware, not been investigated as an important determinant of residential housing quality and energy demand. The findings thus provide first evidence for the relationship between regional real-estate market conditions, and levels of energy consumption. Although further analysis is required, our findings could provide an important starting point for more in-depth scenario analysis around regional energy consumption. In particular, the findings could play an important role in formulating assumptions about future levels of energy efficiency and consumption in regional contexts. Taking into consideration the heterogeneity of housing markets and the corresponding investment patterns would allow energy researchers to construct more accurate models of regional energy demand.

Further, the study adds to the discussion around people's motivation to invest in energy efficiency. In particular, the findings contribute to the ongoing debate around the "energy efficiency gap" (Hausman, 1979; Sorrell, 2004). From a climate policy perspective, the underinvestment in energy efficiency constitutes an ongoing problem, and so far researchers have not arrived at a conclusive explanation for the observed under-utilisation of energy saving measures. Our findings offer a different perspective, by arguing that housing quality, including energy efficiency investments, is partially determined by the conditions of regional real-estate markets. In other words, if investors cannot pass on upfront investment costs in form of higher rents or sale prices, they are unlikely to invest in energy efficiency measures. More importantly, however, the study shows that these under investments differ regionally, depending on housing market fundamentals, which determine future levels of rent and house prices. Considering differences in regional housing markets thus provides a way to more accurately understand and predict investment in energy efficiency.

The results also have important implications for energy and climate policies. Most industrialized countries have agreed to ambitious climate protection targets, and there is great political effort to stimulate energy efficiency investments. Yet, most current policies are implemented on a national level, and often take a simple "one size fits all" approach. Our results imply that this approach should be reconsidered. The findings indicate that much can be gained by implementing more regionalized policies, regulations, as well as investment support schemes. If anything, policies should take into consideration regional housing market conditions, and should be adjusted in line with important regional property indicators. For example, a regionalized approach would allow mitigating windfall gains for investors in booming housing markets while creating more accurate investment incentives in regions that are facing more dire economic conditions.

While the study provides a first attempt to address an important and under-researched topic, it also has several limitations, which provide promising avenues for further research. In particular, the empirical design suffers from the limitation of "aggregated" data. While in the absence of more accurate data sources, development costs serve as an adequate proxy for housing quality, micro data on individual investment projects and the surrounding conditions would allow for a more accurate investigation of the causal relationship between regional housing market conditions and energy demand. Further, refurbishment data of buildings would allow for testing the impact of market fundamentals on energy efficiency investments directly. However, as far as the authors are aware, micro data that captures energy efficiency levels, investors' characteristics as well as housing market conditions are difficult to obtain. Overcoming these data limitation issues thus provides the most promising route for further investigations into this under researched area.

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REFERENCES

Alberini, A., S. Banfi, and C. Ramseier (2013). "Energy efficiency investments in the home: Swiss homeowners and expectations about future energy prices." *The Energy Journal* 34(1): 49–86. http://dx.doi.org/10.5547/01956574.34.1.3.

Alonso, W. (1967). "A reformulation of classical location theory and its relation to rent theory." *Papers in Regional Science* 19(1): 22–44. http://dx.doi.org/10.1007/BF01944043.

Ball, M. (2006). *"Markets & institutions in real estate & construction"*. Oxford: Wiley-Blackwell. http://dx.doi.org/10.1002/9780470757581.

Blakley, P. and J. Ondrich (1988). "A limiting joint-choice model for discrete and continuous housing characteristics." *The Review of Economics and Statistics 70*, 266–274. http://dx.doi.org/10.2307/1928311.

Borenstein, S. (2013) "A microeconomic framework for evaluating energy rebound and some implications." *The Energy Journal* 36(1): 1–21.

Brechling, V. and S. Smith (1994). “Household energy efficiency in the UK.” *Fiscal Studies* 15(2): 44–56. http://dx.doi.org/10.1111/j.1475-5890.1994.tb00196.x.

Brounen, D., N. Kok, and J. M. Quigley (2012). “Residential energy use and conservation: Economics and demographics.” *European Economic Review* 56(5): 931–945. http://dx.doi.org/10.1016/j.euroecorev.2012.02.007.

Buzzelli, M. and R. Harris (2006). “Cities as the Industrial Districts of Housebuilding.” *International Journal of Urban and Regional Research* 30(4): 894–917. http://dx.doi.org/10.1111/j.1468-2427.2006.00695.x.

Cameron, T. A. (1985). “A Nested Logit Model of Energy Conservation Activity by Owners of Existing Single Family Dwellings.” *The Review of Economics and Statistics* 67(2): 205–211. http://dx.doi.org/10.2307/1924719.

Capozza, D. and R. W. Helsley (1990). “The stochastic city.” *Journal of Urban Economics* 28(2): 187–203. http://dx.doi.org/10.1016/0094-1190(90)90050-W.

Capozza, D. and P. J. Seguin (1996). “Expectations, efficiency, and euphoria in the housing market.” *Regional Science and Urban Economics* 26(3–4): 369–386. http://dx.doi.org/10.1016/0166-0462(95)02120-5.

check24.de (2013). “Kreditatlas 2013.” *www.check24.de/kredit/publikationen/kreditatlas-2013/bundeslaender*.

Chong, H. (2012). “Building vintage and electricity use: Old homes use less electricity in hot weather.” *European Economic Review* 56(5): 906–930. http://dx.doi.org/10.1016/j.euroecorev.2012.02.009.

Costa, D. L. and M. E. Kahn (2011). “Electricity consumption and durable housing: understanding cohort effects.” *American Economic Review: Papers and Proceedings* 101(3): 88–92. http://dx.doi.org/10.1257/aer.101.3.88.

Dipasquale, D. and W. Wheaton (1992). “The Markets for Real Estate Assets and Space: A Conceptual Framework.” *Real Estate Economics* 20(2): 181–191. http://dx.doi.org/10.1111/1540-6229.00579.

Eichholtz, P., N. Kok, and J. M. Quigley (2010). “Doing Well by Doing Good? Green Office Buildings.” *American Economic Review* 100(5): 2492–2509. http://dx.doi.org/10.1257/aer.100.5.2492.

Eichholtz, P., N. Kok, and J. M. Quigley (2013). “The economics of green building.” *Review of Economics and Statistics* 95(1): 50–63. http://dx.doi.org/10.1162/REST_a_00291.

El-Shagi, M., C. Michelsen, and S. Rosenschon (2014). “Regulation, innovation and technology diffusion: Evidence from building energy efficiency standards in germany.” *DIW Berlin Discussion Paper*. http://dx.doi.org/10.2139/ssrn.2432978.

Figueredo, A. J. and P. S. A. Wolf (2009). “Assortative pairing and life history strategy—a cross-cultural study.” *Human Nature*, 20:317–330. http://dx.doi.org/10.1007/s12110-009-9068-2.

Fox, J. (2008). *“Applied Regression Analysis and Generalized Linear Models”*. New York: Sage Publications.

Fuerst, F. and P. McAllister (2011). “Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Values..” *Real Estate Economics* 39(1): 45–69. http://dx.doi.org/10.1111/j.1540-6229.2010.00286.x.

Fuerst, F., P. McAllister, A. Nanda, and P. Wyatt (2015). “Does energy efficiency matter to home-buyers? an investigation of epc ratings and transaction prices in England.” *Energy Economics*. http://dx.doi.org/10.1016/j.eneco.2014.12.012.

GdW (2012). “Ergebnisse der umfrage wohnungsneubau, ergänzungsumfrage zur gdw jahresstatistik 2010.”

Greene, W. H. (2007). *“Econometric analysis”* (6 ed.). New Jersey: Prentice Hall.

Greening, L. A., D. L. Greene, and C. Difiglio (2000). “Energy efficiency and consumption—the rebound effect—a survey.” *Energy policy* 28(6): 389–401. http://dx.doi.org/10.1016/S0301-4215(00)00021-5.

Gyourko, J. (2009). “Housing Supply.” *Annual Review of Economics* 2009(1): 295–318. http://dx.doi.org/10.1146/annurev.economics.050708.142907.

Gyourko, J. and A. Saiz (2006). “Construction costs and the supply of housing structure.” *Journal of Regional Science* 46(4): 661–680. http://dx.doi.org/10.1111/j.1467-9787.2006.00472.x.

Haas, R. and L. Schipper (1998). “Residential energy demand in oecd-countries and the role of irreversible efficiency improvements..” *Energy Economics* 20(4): 421–442. http://dx.doi.org/10.1016/S0140-9883(98)00003-6.

Hausman, J. A. (1979). “Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables.” *The Bell Journal of Economics* 10(1): 33–54. http://dx.doi.org/10.2307/3003318.

Hwang, M. and J. M. Quigley (2010). “Housing price dynamics in time and space: predictability, liquidity and investor returns.” *The Journal of Real Estate Finance and Economics* 41(1): 3–23. http://dx.doi.org/10.1007/s11146-009-9207-x.

Hyland, M., R. C. Lyons, and S. Lyons (2013). “The value of domestic building energy efficiency—evidence from Ireland.” *Energy Economics 40*, 943–952. http://dx.doi.org/10.1016/j.eneco.2013.07.020.

Jacobsen, G. D. and M. J. Kotchen (2013). “Are Building Codes Effective at Saving Energy? Evidence From Residential Billing Data in Florida.” *Review of Economics and Statistics* 95(1): 34–49. http://dx.doi.org/10.1162/REST_a_00243.

Jeong, J., C. S. Kim, and J. Lee (2011). “Household electricity and gas consumption for heating homes.” *Energy Policy* 39(5): 2679–2687. http://dx.doi.org/10.1016/j.enpol.2011.02.037.

Kholodilin, K. A. and C. Michelsen (2014). “The market value of energy efficiency in buildings and the mode of tenure.” *DIW Berlin Discussion Paper*. http://dx.doi.org/10.2139/ssrn.2472938.

Koirala, B., A. Bohara, and H. Li (2013). "Effects of energy-efficiency building codes in the energy savings and emissions of carbon dioxide." *Environmental Economics and Policy Studies* 15(3). http://dx.doi.org/10.1007/s10018-013-0054-x.

Kok, N., M. McGraw, and J. M. Quigley (2012). "The diffusion over time and space of energy efficiency in building." *The Annals of Regional Science* 48(2): 1–24. http://dx.doi.org/10.1007/s00168-011-0494-9http://dx.doi.org/10.1007/s00168-011-0494-9.

LBS Research (2006). "Baukosten: Eine frage des standorts." *Press Release 2006/5/1*.

Leth-Petersen, S. and M. Togeby (2001). "Demand for space heating in apartment blocks: measuring effects of policy measures aiming at reducing energy consumption." *Energy Economics* 23(4): 387–403. http://dx.doi.org/10.1016/S0140-9883(00)00078-5.

Leung, C. (2004). "Macroeconomics and housing: a review of the literature." *Journal of Housing Economics* 13(4): 249–267. http://dx.doi.org/10.1016/j.jhe.2004.09.002.

Long, J. E. (1993). "An econometric analysis of residential expenditures on energy conservation and renewable energy sources." *Energy Economics* 15(4): 232–238. http://dx.doi.org/10.1016/0140-9883(93)90012-G.

Mayer, C. J. and C. Somerville (2000). "Land use regulation and new construction." *Regional Science and Urban Economics* 30(6): 639–662. http://dx.doi.org/10.1016/S0166-0462(00)00055-7.

McDonald, J. (2000). "Rent, vacancy and equilibrium in real estate markets." *Journal of Real Estate Practice and Education* 3(1): 55–69.

Meier, H. and K. Rehdanz (2010). "Determinants of residential space heating expenditures in Great Britain." *Energy Economics* 32(5): 949–959. http://dx.doi.org/10.1016/j.eneco.2009.11.008.

Michelsen, C. and S. Rosenschon (2012). "The Effects of Building Energy Codes in Rental Housing: The German Experience." *Economics Bulletin* 32(4): 3488–3502.

Michelsen, C., S. Rosenschon, and C. Schulz (2014). "Small might be beautiful, but bigger performs better: Scale economies in 'green' refurbishments of apartment housing." *DIW Berlin Discussion Paper*. http://dx.doi.org/10.2139/ssrn.2503864.

Michelsen, C. and D. Weiß (2010). "What happened to the East German housing market? A historical perspective on the role of public funding." *Post-Communist Economies* 22(3): 387–409. http://dx.doi.org/10.1080/14631377.2010.498686.

Mills, B. and J. Schleich (2012). "Residential energy-efficient technology adoption, energy conservation, knowledge, and attitudes: An analysis of European countries." *Energy Policy 49*, 616–628. http://dx.doi.org/10.1016/j.enpol.2012.07.008.

Myers, D. (2008). *"Construction Economics: A New Approach"*. Taylor & Francis.

Nair, G., L. Gustavsson, and K. Mahapatra (2010). "Factors influencing energy efficiency investments in existing Swedish residential buildings." *Energy Policy* 38(6): 2956–2963. http://dx.doi.org/10.1016/j.enpol.2010.01.033.

Nelson, J. P. (1975). "The Demand for Space Heating Energy." *The Review of Economics and Statistics* 57(4): 508–512. http://dx.doi.org/10.2307/1935912.

Nesbakken, R. (1999). "Price sensitivity of residential energy consumption in Norway." *Energy Economics* 21(6): 493–515. http://dx.doi.org/10.1016/S0140-9883(99)00022-5.

Nesbakken, R. (2001). "Energy consumption for space heating: a discrete–continuous approach." *Scandinavian Journal of Economics* 103(1): 165–184. http://dx.doi.org/10.1111/1467-9442.00236.

Oates, W. E. (1969). "The Effects of Property Taxes and Local Public Spending on Property Values: An Empirical Study of Tax Capitalization and the Tiebout Hypothesis." *The Journal of Political Economy* 77(6): 957–971. http://dx.doi.org/10.1086/259584.

OECD (2003). "Environmentally Sustainable Buildings." Organisation for Economic Co-Operation and Development, Paris.

Quigley, J. M. (1984). "The production of housing services and the derived demand for residential energy." *Rand Journal of Economics* 15(4): 555–567. http://dx.doi.org/10.2307/2555526.

Quigley, J. M. and L. Rosenthal (2005). "The Effects of Land Use Regulation on the Price of Housing: What do we know? What can we learn?" *Cityscape* 8(1): 69–137.

Read, C. (1991). "Maintenance, Housing Quality, and Vacancies under Imperfect Information." *Real Estate Economics* 19(2): 138–153. http://dx.doi.org/10.1111/1540-6229.00546.

Rehdanz, K. (2007). "Determinants of residential space heating expenditures in Germany." *Energy Economics* 29(2): 167–182. http://dx.doi.org/10.1016/j.eneco.2006.04.002.

Reichert, A. K. (1990). "The impact of interest rates, income, and employment upon regional housing prices." *The Journal of Real Estate Finance and Economics* 3(4): 373–391. http://dx.doi.org/10.1007/BF00178859.

Sailor, D. J. and J. R. Muñoz (1997). "Sensitivity of electricity and natural gas consumption to climate in the usa—methodology and results for eight states." *Energy* 22(10): 987–998. http://dx.doi.org/10.1016/S0360-5442(97)00034-0.

Saiz, A. (2010). "The geographic determinants of housing supply." *The Quarterly Journal of Economics* 125(3): 1253–1296. http://dx.doi.org/10.1162/qjec.2010.125.3.1253.

Schleich, J. and E. Gruber (2008). "Beyond case studies: Barriers to energy efficiency in commerce and the services sector." *Energy Economics* 30(2): 449–464. http://dx.doi.org/10.1016/j.eneco.2006.08.004.

Sirmans, G. S. and J. D. Benjamin (1991). "Determinants of market rent." *Journal of Real Estate Research* 6(3): 357–379.

Smith, J. M. and A. B. Jones (2012). *"Chemistry."* 7th edition.

Sorrell, S. (2004). *"The economics of energy efficiency: barriers to cost-effective investment"*. Northampton: Edward Elgar Publishing.

Stull, W. J. (1978). "The landlord's dilemma : Asking rent strategies in a heterogeneous housing market." *Journal of Urban Economics* 5(1): 101–115. http://dx.doi.org/10.1016/0094-1190(78)90039-6.

Sutherland, R. J. (1991). "Market barriers to energy-efficiency investments." *The Energy Journal*, 12(3): 15–34. http://dx.doi.org/10.5547/issn0195-6574-ej-vol12-no3-3.

Techem (2008). *"Energie Kennwerte: Hilfen für den Wohnungswirt"*. Techem AG.

Vaage, K. (2000). "Heating technology and energy use: a discrete/continuous choice approach to Norwegian household energy demand." *Energy Economics* 22(6): 649–666. http://dx.doi.org/10.1016/S0140-9883(00)00053-0.

Veser, J., T. Thrun, and W. Jaedicke (2007). *"Veränderung der Anbieterstruktur im deutschen Wohnungsmarkt und wohnungspolitische Implikationen"*. BBSR Forschungen. Bonn: Bundesamt für Bauwesen und Raumordnung.

Wheaton, W. (1990). "Vacancy, Search, and Prices in a Housing Market Matching Model." *The Journal of Political Economy* 98(6): 1270–1292. http://dx.doi.org/10.1086/261734.

Yates, J. and D. F. Mackay (2006). "Discrete choice modelling of urban housing markets: A critical review and an application." *Urban Studies* 43(3): 559–581. http://dx.doi.org/10.1080/00420980500533695.

Zietz, E. N. (2003). "Multifamily housing: A review of theory and evidence." *Journal of Real Estate Research* 25(2): 185–244.