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The Effects of Building Energy Codes in Rental Housing: The German Experience

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Abstract

This paper investigates the effect of building energy codes on housings' real energy consumption. We argue that building codes should have a twofold effect: lower levels of energy consumption after its implementation and decreasing energy requirements over time, because tighter building codes induce technical progress in the construction sector. We find evidence for both aspects. Based on a large and unique sample of energy certificates from Germany, this study is the first that deals with the empirical effects of energy efficiency standards in apartment/rental housing. Moreover, it is the first, which includes different stages of regulation.

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1. Introduction

Since the Kyoto protocol and at latest since the epic disaster of Fukushima in 2011, a growing number of countries restructure their energy production and aim to reduce commercial and private energy consumption. In this context, a frequently applied policy instrument is the introduction of building energy codes, since energy for space heating and cooling accounts for a large share of total energy consumption (OECD 2003; Iwaro and Mwasha 2010).

The desired effect of building energy codes is a decrease in energy requirements of buildings – this might be achieved by changing the production technology of housing services towards higher energy efficiency (a level effect, e.g. by doubling thermal insulation) and moreover, by innovation over time in the house building industry towards energy saving materials, architecture and construction solutions (a dynamic effect). The latter should be observable as continuously over time decreasing energy consumption in newly constructed homes. This is particularly true in the apartment (rental) housing sector, when returns on investment decline if construction costs rise due to regulation; this puts pressure on the house building industry to innovate and to provide alternative solutions (Jaffe and Palmer 1997; Kok, McGraw, and Quigley 2011; Gann, Wang, and Hawkins 1998).

In a recent paper, Jacobsen and Kotchen (forthcoming) found that the introduction of those codes in Florida (USA) significantly affected energy consumption for space heating and cooling in detached homes. This is not surprising in general; but – as Jacobsen and Kotchen state – still very little is known on the empirical effects of building codes and their amendment. This can be understood as a result of lacking data availability (Dipasquale 1999; Gyourko 2009). But recently scholars discovered alternative information: the assessment of energy consumption bills (Greller et al. 2010; Schröder et al. 2009; Michelsen 2009; Jacobsen and Kotchen forthcoming) as well as large samples of energy certificates (Brounen and Kok 2011; Brounen, Kok, and Quigley 2012; Eichholtz, Kok, and Quigley 2010; Eichholtz, Kok, and Quigley forthcoming; Michelsen and Müller-Michelsen 2010) - both promising approaches for a deeper understanding of housing service supply.

While Jobsen and Kotchen provide evidence for the level-effect of regulation, we take a closer look on both, on the dynamics and the level effect of (changes in) building energy codes by analyzing a unique sample of energy certificates conducted from German apartment houses. For this purpose, Germany provides an excellent example because of its long-term eperience in construction regulation. In particular, we investigate the effects of four changes in regulation since 1978. We expect to find a level effect, if building code's amendment is comparable high. Dynamics should also be affected by tighter regulations.

2. Empirical strategy and data

To evaluate regulation, we estimate a linear regression model (OLS) of the following form:

$$y_i = \alpha + \beta \cdot X_i + \varphi \cdot R_P + \mu \cdot YOC_i + \gamma \cdot R_P \cdot YOC_i + \epsilon_i, \tag{1}$$

where y is the energy coefficient of a house i, calculated as a three year average of annual energy consumption (in kilowatt-hours (kWh)) per square meter of residential space, adjusted by regional climatic parameters. These are provided by the "German Weather Service" (DWD) for 8,400 ZIP-code districts. Based on heating degree days, the procedure adjusts for regional as well as inter-temporal differences in climatic conditions.

Moreover, the analyzed energy certificates include information on the refurbishment status of houses. Only those homes are included, which are reported as not being refurbished to avoid any bias of an ex-post change in housings quality. We analyze an unique sample of $i = 1...41,496$ apartment houses[1], built in the period 1967-2006.[2] In these years four major changes in building energy codes can be observed (see tab.1). The fifth (most recent) regulation in 2009 is not captured by the data. East German houses are dropped, if they were built under GDR-regulation (until 1990).

[1] In Germany, about 80% of multi-family housing refers to the rental segment.

[2] Energy consumption bills and energy certificates are provided by ista Germany GmbH, a worldwide operating energy service provider. For Germany, information on more than 300,000 multi-family houses is available.

X represents an elaborate pool of control variables including dummies for spatial planning regions, the fuel type, the size of a house measured by the number of flats and variables indicating whether the landlord is a professional housing company (measured by the number of flats owned), to account for possible effects of special know-how in portfolio management. ε is the i.i.d. error component.

Table 1: energy building codes in Germany

year	**regulation**	**upper bound of annual energy requirements**$/m^2$
until 1978	no regulation	-
1978	Heat Insulation Ordiance (WSchV)	250 kWh
1984	amendment of WSchV	230 kWh
1995	amendment of WSchV	150 kWh
2002	Energy Saving Ordiance (EnEV)	100 kWh
2009	amendment of EnEV	60 kWh

The variables of interest are R_P and $R_P \cdot YOC_i$: R_P represents a set of dummy variables and captures the level effect of regulation in the period (P, where $P = 1...5$) of construction. $R_P \cdot YOC_i$ is an interaction of housing's year of construction YOC_i and the respective regulation R_P. This captures technical progress in the construction sector. Moreover, to detect significant differences between periods, we test the coefficients of the subsequent regulation periods (R_P for the levels and $R_P \cdot YOC_i$) against each other.

Table 2: descriptive statistics

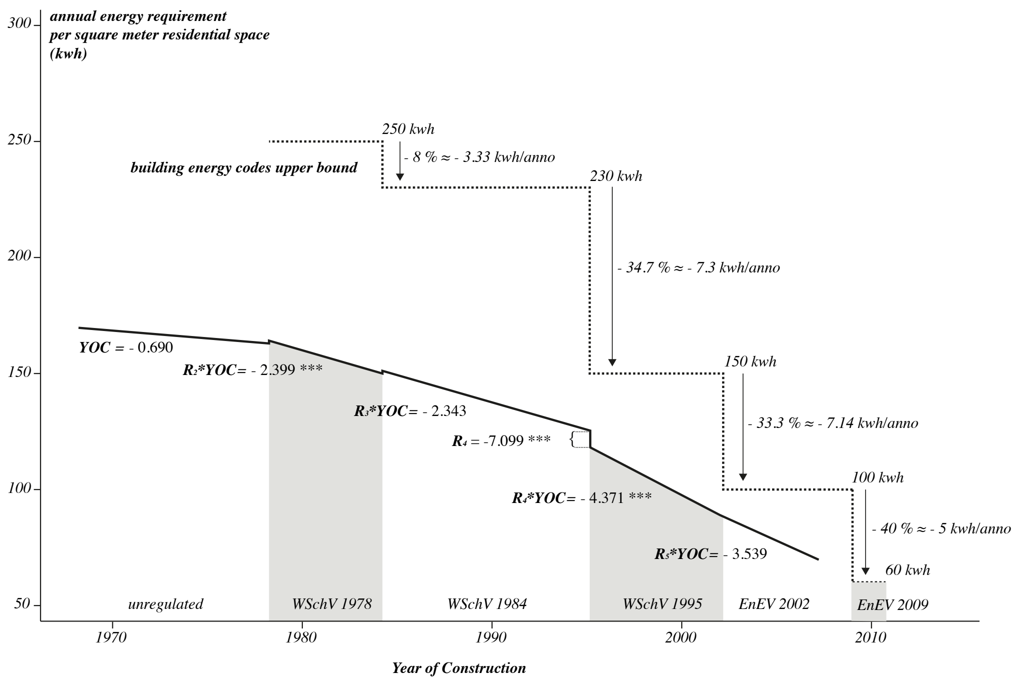
	N	**Mean YOC**	**SD**	**Min.**	**Max.**	**Mean y**
$R_1 \cdot YOC$	3,871	1971.9	2.76	1967	1977	157.19
$R_2 \cdot YOC$	3,254	1981.1	1.63	1978	1983	152.19
$R_3 \cdot YOC$	16,729	1991.1	3.05	1984	1994	132.61
$R_4 \cdot YOC$	15,555	1996.9	1.79	1995	2001	106.78
$R_5 \cdot YOC$	2,087	2003.1	0.97	2002	2006	82.05
Total	41,496	1991.3	8.25	1967	2006	124.21

3. Results

The main results are presented in figure 1 (complete results are reported in the appendix). Overall, our model has significant explanatory power (F (119;41,376) = 161.52) for roughly one third of energy coefficients' total variation ($R^2 = 0.324$).

Four main findings can be drawn from figure one's illustration. First, we find significantly decreasing energy coefficients by the year of construction for all periods (unregulated: annually -0.69 kWh; under regulation: -2.343 to -4.371 kWh), indicating that there is technical progress in the house building industry (regardless if this is triggered by innovation affecting the costs of production or construction techniques).

Figure 1: Estimated energy requirements and building energy codes upper bounds



*** indicates significant deviation from the previous coefficient at the 1% level of confidence.

Second, we identified significant differences of energy requirements among regulation regimes. More precisely, three differing development paths can be detected: significant differences can be observed beyond the change from an unregulated to a regulated setting ($YOC \neq R_2 \cdot YOC$). Energy coefficients decrease 3.5 times faster in the period 1978-1984. However, the amendment of WSchV in 1984 did not affect this path significantly – the test of coefficients against each other did not reveal any differences ($R_3 \cdot YOC = R_2 \cdot YOC$). The third period can be identified after the amendment of WSchV in 1995 – the considerable change by roughly 35% stricter codes is followed by a significant and almost doubled (1.9) decrease in energy coefficients. Again, the subsequent introduction of EnEV 2002 did not affect this development significantly.

Table 3: Tests of coefficients vs. coefficients – dynamics

	marginal effect		**Std. Err.**	**z**	**95% Conf. Interval**	
$R_2 \cdot YOC$ vs. YOC	-1.709	***	0.565	-3.020	-2.816	-0.602
$R_3 \cdot YOC$ vs. $R_2 \cdot YOC$	0.056		0.507	0.11	-0.937	1.050
$R_4 \cdot YOC$ vs. $R_3 \cdot YOC$	-2.028	***	0.185	-10.940	-2.392	-1.665
$R_5 \cdot YOC$ vs. $R_4 \cdot YOC$	0.832		0.683	1.220	-0.507	2.172

*** indicates significance at 1% level of confidence.

Third, in a singular case we found a level effect: R_4 indicates that a descent from $WSchV_{84}$ to $WSchV_{95}$ was accompanied by a shift in production technology of housing towards higher energy efficiency. This cannot be detected for previous and subsequent changes in regulation. It is interesting to note, that building codes amendment was by far the highest in absolute terms (80 kWh).

Table 4: Tests for level effects at regulations introduction/amendment

	difference		**Std. Err.**	**z**	**95% Conf. Interval**	
R_2 vs. 0	1.022		2.748	0.37	-4.365	6.408
R_3 vs. R_2	1.391		1.485	0.94	-1.521	4.302
R_4 vs. R_3	-7.099	***	0.652	-10.880	-8.378	-5.821
R_5 vs. R_4	-0.1		1.728	-0.06	-3.486	3.286

*** indicates significance at 1% level of confidence.

Fourth, for none of the four regulations the politically desired decrease in energy requirements can be observed (ranging from -3.33 kWh up to -7.3 kWh annually). Although the goals were revealed ex-post (by issuing new legal upper bounds), they express politicians' expectations about the development of house building techniques in the previous period. Thus, with all amendments of regulation, the gap between building energy codes' upper bound and the code of praxis in construction became smaller.

4. Conclusions

The present study is (to the best of our knowledge) the first that empirically assess, based on unique data on real energy consumption, the impact of building energy codes on energy requirements in apartment/rental houses. Moreover, we are the first who include the development of regulation over time by considering four different regulative settings. In line with previous research on detached homes (Jacobsen and Kotchen, forthcoming), we find strong evidence for an impact of regulation on housings energy efficiency. Additionally, we find that not only the mere introduction of building energy codes matters. Regulation seems to have, depending on the intensity of intervention, a twofold impact by stimulating innovation (we detected three differing development paths over time) and by inducing a change in the technology of housing service production towards energy efficiency (a level effect). The latter appears to be the case only in response to strong interventions, like the WSchV95. In contrast to the findings of Jacobsen and Kotchen, we cannot provide evidence that investors in rental housing respond to changes in building codes one to one. In fact, the gap between regulations' upper bound and code of praxis in construction became smaller over time. The visual impression from figure 1 lets conclude that an intersection of both lines can be expected for the 2009 amendment of the 'Energy Savings Ordinance' (EnEV). In summary, our results suggest that building energy codes can be seen as an effective instrument to influence housings energy efficiency standards, in its levels and over time, especially if energy requirements are relatively high and technological progress is slow (like it is observed for the early 1970s).

However, there are limitations to this instrument, as they become obvious in recent years. State of the art does obviously not correspond to the code of praxis in construction, which follows simple economic considerations: as long energy or passive house standard investments' revenues are below alternatives, their diffusion in the market is slow. In this context, it would be naive to believe that legal settings are keen instruments to push the uptake of such housing standards. In contrast, they can thwart construction activity. A more promising approach would be to stimulate construction activity in such market segments in order to develop less costly solutions for increasing the profitability of green investments.

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Appendix: complete results

Variables	Coefficient		Robust Standard Error
Planning Regions (Dummy, Base ROR 1)			
2 ROR	24.975	***	7.718
3 ROR	-3.447		4.439
4 ROR	8.440		6.319
5 ROR	4.913		4.224
6 ROR	10.851	***	4.108
7 ROR	-5.543		4.573
8 ROR	-10.074	**	4.228
9 ROR	10.993	**	4.445
10 ROR	2.137		5.886
11 ROR	5.483		4.203
12 ROR	6.602		4.991
13 ROR	3.377		4.400
14 ROR	0.842		4.047
15 ROR	-0.129		4.183
16 ROR	6.211		4.285
17 ROR	10.870		7.277
18 ROR	-12.175	***	4.428
19 ROR	-11.167	***	4.108
20 ROR	-0.77		4.935
21 ROR	-6.953		4.758
22 ROR	-7.539	*	4.211
23 ROR	-9.797	**	4.445
24 ROR	-7.479		5.464
25 ROR	5.576		4.103
26 ROR	0.767		6.212
27 ROR	13.115	**	5.693

Variables	Coefficient		Robust Standard Error
28 ROR	5.967		4.407
29 ROR	10.546	**	4.185
30 ROR	15.908	***	3.938
31 ROR	-4.493		4.614
32 ROR	6.993		5.206
33 ROR	4.545		4.235
34 ROR	2.622		4.520
35 ROR	-5.033		3.968
36 ROR	-9.353	**	4.093
37 ROR	-10.363		8.259
38 ROR	-5.867		4.398
39 ROR	-6.949		4.244
40 ROR	-5.349		4.009
41 ROR	-1.487		4.087
42 ROR	13.829	***	4.134
43 ROR	4.196		4.189
44 ROR	13.910	***	3.958
45 ROR	1.879		4.136
46 ROR	9.601	**	3.940
47 ROR	5.291		4.801
48 ROR	-4.267		4.133
49 ROR	4.614		4.003
50 ROR	-14.509	***	4.758
51 ROR	16.158	***	3.872
52 ROR	17.173	***	4.098
53 ROR	-2.858		6.415
54 ROR	3.285		4.230
55 ROR	-5.045		4.331
56 ROR	-5.544		4.808

Variables	Coefficient		Robust Standard Error
57 ROR	0.182		4.062
58 ROR	-0.025		3.978
59 ROR	-10.858	**	4.292
60 ROR	-0.571		4.209
61 ROR	-5.239		4.523
62 ROR	2.573		4.164
63 ROR	3.929		6.129
64 ROR	19.345	***	4.365
65 ROR	5.591		4.861
66 ROR	8.887	**	4.139
67 ROR	10.570	**	4.281
68 ROR	11.263	***	3.967
69 ROR	5.244		4.159
70 ROR	7.759	*	4.088
71 ROR	-1.076		4.231
72 ROR	3.724		3.913
73 ROR	-3.586		4.174
74 ROR	-3.314		4.031
75 ROR	3.052		4.064
76 ROR	-5.859		4.746
77 ROR	-5.580		3.986
78 ROR	-0.257		3.997
79 ROR	-4.113		4.334
80 ROR	1.838		4.681
81 ROR	-0.81		4.199
82 ROR	-4.101		4.079
83 ROR	-4.090		4.162
84 ROR	-0.791		4.158
85 ROR	-11.311	**	5.732

Variables	Coefficient		Robust Standard Error
86 ROR	2.974		3.996
87 ROR	-2.403		5.423
88 ROR	7.510	*	4.189
89 ROR	5.960		4.481
90 ROR	-2.551		4.839
91 ROR	-5.765		4.456
92 ROR	-4.436		4.180
93 ROR	-2.014		3.918
94 ROR	3.692		4.273
95 ROR	-17.908	***	4.413
96 ROR	-9.779	**	4.162
97 ROR	-10.965	***	4.070
unknown refurbishment status			
roof	-4.913	*	2.509
facade	2.700		2.691
windows	5.019	***	1.901
basement ceiling	-1.524		2.156
heating system	-2.753	*	1.639
Firm size (Dummy, Base: Landlords owning $<$ 20 flats)			
21 to 200 flats	1.823	***	0.612
201 to 1000 flats	3.256	***	0.52
$>$ 1000 flats	4.356	***	0.581
Fuel type (Dummy, Base: domestic gas)			
fuel oil	-20.861	***	0.547
district heating	-31.409	***	0.666
other	-17.139	***	2.905
Building Size (Dummy, Base: 2 to 6 flats)			
class 7 to 12 flats	-8.420	***	0.439
class 13 to 21 flats	-9.958	***	0.608

Variables	Coefficient		Robust Standard Error
class >21 flats	-13.012	***	0.635
R (Dummy, Base: R67-77)			
R_2	3.379.439	***	1.118.040
R_3	3.268.832	***	577.731
R_4	7.306.434	***	614.145
R_5	5.641.080	***	1.438.199
YOC	-0.69	**	0.272
Interaction of R*YOC			
R_2*YOC	-1.709	***	0.565
R_3*YOC	-1.652	***	0.293
R_4*YOC	-3.681	***	0.311
R_5*YOC	-2.849	***	0.72
Constant	1.534.724	***	535.443

***, **, * indicates significance at 1%, 5%, 10% level of confidence.