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Case Study: Analyzing the outcome of energetic retrofit from a tenant's point of view – who bears the costs?

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Abstract

In order to reduce CO_2-Emissions, the German Government recently called out "efficiency first" as the new principle of the energy transition. Energetic retrofits of the housing stock play a major role, and next to energetic targets, the aim is also to perform the energy transition in a socially fair manner. Nonetheless, we find that studies evaluating the actual outcomes of these retrofits, from an energetic as well a social point of view, are rather rare. This working paper reports the results of a case study carried out in south-western Germany in 10 buildings of a social housing company. We compare calculated consumptions according to the "energy performance ratings" (prior/after retrofit) with actual consumption data after retrofit (N =172 flats). Furthermore, we tackle the issue of the household's expenses comparing increased rent costs due to the retrofit with household's energy expenses prior and after retrofit. While previous studies usually assume that households profit from energy reductions, we find that despite a reduction in energy consumption of 70 percent, more than half of the households face increased costs due to higher rents. This seems to disproportionately affect households which already have a rather low energy consumption. We point out, that different ways of financing the retrofit might contribute to a fairer distribution of the costs and benefits of energetic retrofitting.

1 Introduction

In order to reduce greenhouse gas emissions in the residential sector, the German government targets to increase the rate of energy efficient renovations from 1% to 2% among other measures in the efficiency first initiative (Presse- und Informationsamt der Bundesregierung, 2011). But energy policy also bears economic and social effects, which should be taken into account. Thus, in the case of retrofitting measures, it is stipulated, that they have to be economically viable and affordable housing should be ensured. While efficiency measures are often named as method of choice to prevent energy poverty (Boardman 1991; Brunner et al. 2012), they are also accompanied by problems such as "energetic gentrification", where energetic retrofits can lead to an upgrade of neighborhoods and to increased rents, and thus a displacement of residents. In Germany it is often claimed that retrofits should be designed "warmmietenneutral", which means that the increased rent is offset or even outweighed by the energy savings. Hence the increased rent due to the retrofit shall be financed by a decrease in energy costs.

Nevertheless, empirical assessment of renovation measures is, to our knowledge, rare. Usually, based on the expected reductions in energy consumption, evaluations of costs for inhabitants assume that inhabitants automatically profit from a reduction in heating energy costs after retrofit (c.f. Chapter 2). This paper aims to contribute to this field by presenting results from our case study in a retrofit area in a city in southern Germany. It provided a very unique occasion to gather not only data on planned energy reductions, but furthermore actual consumption data of buildings and households over a period of 6 years. This data made it possible to compare actual consumption and costs of households prior and after retrofit.

In the following we will first give an introduction into the factors influencing the energy performances of buildings as well as rent increases due to retrofits. We then describe our data and methods and present our results concerning the costs of retrofits for residents, which will be discussed afterwards.

2 Framework

2.1 Calculation of primary energy demand

Basis for assessment from ecological as well as economic viewpoints are the calculations on the expected savings of an energetic retrofit. An energy performance rating (EPR) of buildings in general is mandatory since the EU-Directive 2002/91/EC on energy performance of buildings, and it is implemented in German Law since the EnEV 2007. The EPR is calculated by including factors such as the heating system, building size, heat loss through outer surface area etc., while the user's behaviour is held constant and based on assumptions rather than actual observations (Santin 2011; Wei et al. 2014). The measure represents the "expected" energy consumption a building is supposed to have according to standardized calculations (Sunikka-Blank & Galvin, 2012). Actual consumption data is seldom used for these calculations, though in some cases this would be legally possible. This can lead to a situation where the EPR differs from the actual heating energy consumption, for example when energy savings are lower than predicted[1]. This is usually described as the "rebound effect", referring to user's consuming more due to lower prices after retrofit (Sorrell & Dimitropoulos, 2008). However, as elaborated by Sunikka-Blank and Galvin (2012), the method of calculation, which does not take the actual consumption before retrofitting into account, might be another reason. Possible savings are not as high as expected, because the calculated energy consumption of buildings prior retrofitting is too high. Users in non-renovated buildings often consume on average 30% less than anticipated, which is referred to as the "prebound effect" (ibid.).

Most of the studies that access the (economic and ecologic) effects of energetic renovations usually refer to the EPR calculations, rather than actual energy consumption (Clausnitzer et al. 2011; Diefenbach et al., 2016; Guske et al. 2017; Simons et al. 2010). The costs of renovation vary tremendously and depend on the way of calculation, as well as on the measures taken (Henger & Voigtländer 2012). In apartment buildings, landlords can allocate a proportion of these costs to the rent, which influences the outcome with respect to "Warmmietenneutralität". This will be described in the following.

2.2 Modernisation fee for households

Who bears the costs and who benefits from energetic retrofits is discussed as an agency problem between landlords and tenants. Usually it is stated, that tenants profit from energetic retrofits (Enseling & Hinz, 2008). Next to government incentive programs, the German tenancy law allows landlords to allocate 11% of the modernization costs onto the annual rent in order to facilitate and foster energy-related refurbishments. After landlords allocated the maximum of 11% onto the rent, they are obliged to wait until the local rent level is reached. Once the rent is equal to the local rent level, the landlord has no additional revenues to redeem the retrofit costs. This leads to an ineffective situation, in which a retrofit is profitable if the costs are as high as possible, so that it takes a long time until the local rent level has caught up (longer paypack period/amortisation times) (Gill et al. 2016). In residential regions with a lower demand for living space and a lower rental price level, this can lead to a situation where landlords avoid to carry out costly energetic retrofits (Discher et al. 2010) .

[1] A study of the German energy agency (N = 141) reports, that on average the calculation of post retrofit energy consumption corresponds with the post retrofit EPR. However, no data for the pre-retrofit EPR is available, thus the study does not provide any information on a possible "prebound-effect" (Dena, 2016).

Needless to say this has effects on households' budgets. However, only a few studies estimate possible outcomes from a tenant's point of view, while actual empirical data is rare. Even though in the "energy efficiency strategy for buildings" the Federal Ministry for Economic Affairs and Energy remarks, that the increased cold rents for energy efficient buildings could lead to a displacement effects, it is stated that low-income households would profit from retrofits under the assumption of a rental solution, where the costs are offset or even outweighed by the energy savings. Their own simulations furthermore state, that energy savings exceed the increased rent costs in all cases (BMWi, 2015). An overview over several studies assessing the costs of energetic retrofit and the decrease in energy costs however shows, that the full costs cannot be financed by the energy savings. Moreover: the higher the standard, the more unlikely the refinancing becomes (Henger & Voigtländer 2012). A study of German homeowners who undertook energetic retrofit measures describes an average rent increase of 0,82€/m²/month (Henger & Voigtländer, 2011; KfW/IW Köln, 2010). The German Energy Agency calculated the economic efficiency of energetic retrofits in 2010 and finds out, that the savings in energy costs exceed the rent increase up to the "Effizienzhaus 70", only for the "Effizienzhaus 55" the costs exceeded the savings[2] (Discher et al. 2010). Thus, high costs of overarching retrofitting might not lead to the appropriate decreases in energy consumption compared to specific but reasonable measurements at moderate costs.
In the following, we will present our data on planned reductions, actual consumptions and costs of buildings and households before and after a retrofit, with which we seek to add to existing research.

3 Data and Methods

Empirical data including detailed information on buildings as well as retrofit measurements in combination with actual consumption data are rare (Knissel & Loga, 2006). We had the opportunity to gain access to these data with the support of a housing association in a city in southern Germany. For 10 apartment buildings, which have been subject to energetic refurbishment, we gathered information on the actual energy consumption for the period of 2010 to 2015 (refurbishment measures took place within this period). Additionally, we were provided with the floor and building plans as well as the EPR calculations for prior and post

[2] For the Effizienzhaus 100, the calculated savings in energy costs amount to 0,77€/m²/month, with a rent increase to 0,42€/m²/month, while for a Effizienzhaus 55, the savings amount to 0,99€/m²/month with a rent increase of 1,17€/m²/month (at an energy price of 6,5 cent/kWh) (Discher et al. 2010).

retrofit from restoration plans (cf. Table 1). The buildings have been refurbished renovated to a moderate standard following the EnEV 2009[3] reference building.

Table 1: Information on buildings subject to analysis

Building	Year of construction	Total living space in m²	Number of flats before / after refurbishment
(1)	1966	1.303	14 / 14
(2)	1966	1.303	14 / 14
(3)	1960	627	9 / 9
(4)	1960	901	13 / 13
(5)	1960	901	13 / 13
(6)	1960	901	13 /13
(7)	1931	972	20 / 20
(8)	1931	1.381	32 / 24
(9)	1931	1.716	32 / 32
(10)	1931	577	12 / 12

So far EPR's are calculated and issued for buildings only. As our case study is based on apartment buildings with households living in non-identical flats one has to keep in mind: flats in the top floor of a building have a larger surface area, thus they are expected to consume more heating energy than flats in the middle of a building. Derived by the EPR calculations for buildings, we modified the EPR calculation to estimate the heating demand for single flats.[4] With the help of the floor and building plans and this calculator, the heating demand, i.e. the amount of energy which households are expected to consume in their specific flats under standardised conditions[5], can be calculated. The flat-specific heating demand will be denoted as *EPRflat_prior* and *EPRflat_after* in the following analyses. With permission of the household's we were also able to assess the actual heating energy consumption according to bills of the 172 individual flats in the buildings for the same period before and 164 flats after the retrofit (denoted *CONSflat_prior* and *CONSflat_after*). Drop-outs only occurred for 8 flats

[3] According to EnEV reference building (EnEV 2009, Abschnitt 2, §3, Anlage 1 Tabelle 1) http://www.enev-online.org/enev_2009_volltext/enev_2009_03_anforderungen_an_wohngebaeude.htm. The standards of the kfw refer to the EnEV reference buildings

[4] For further information on the flat-specific heating demand calculator cf. working paper (Weber et al., 2017).

[5] Both the EPR calculations and the flat-specific heating demand calculator assume a standard behavior of households, i.e. that all households heat up their flat to an average temperature of 19 - 20 °C (De Meester et al., 2013; Loga, Diefenbach, Knissel, & Born, 2005).

that have been merged within the retrofitting process (cf. Table 1) and 10 households that moved out. Descriptive statistics of the flats as well as their heating demand and households' heating energy consumption according to bills before and after the refurbishment are depicted in Table 2.

Table 2: Information on flats and households' energy consumption subject to analysis

	Mean	SD	Min	Max
Living space in m²	61	17	27	97
EPRflat_prior in kWh/m²/year	156	61	63	296
CONSflat_prior. in kWh/m²/year	141	42	26	307
EPRflat_after in kWh/m²/year	66	20	35	106
CONSflat_after in kWh/m²/year	45	23	12	121

The average increase of the energy price for district heating in these buildings during the observation period amounts to 62%, from 0.08 €/kWh in 2010 to 0.13 €/kWh in 2015. For the analysis regarding the heating costs of the households before and after the retrofit, costs have been adjusted to the annual energy price. All the buildings belong to a social housing company, which has the advantage that our results refer to a population with lower income and education (cf. Table 3), making it possible to estimate the effects on this vulnerable group. However, the results cannot be generalized to the whole population.

With 47 of these households we were able to conduct semi-standardized interviews. All households living in the retrofitted buildings were approached with the support from the housing association, leading to a response rate of 27% (47 out of 172 flats). The interviews were conducted in 2014 and 2015. They took place in the apartments of the participating households and lasted between 30 and 90 minutes. The standardized part consisted of a questionnaire with 33 questions including various subjects concerning the retrofitting, e.g. general satisfaction with the process as well as acceptance of new heating technologies and structural changes. Information on socio-demographics, i.e. household size, number of children, household income, highest educational achievement and employment relationship was likewise gathered.

Table 3: Demographics of interviewed households

	Mean	Median	Std. Dev.	Mean Germany[6]
Household size	2.69	2	1.44	2
Age of household head	57.49	59	16.05	43
Monthly net equivalence income in €	1294.75	1250	365.40	1958
Years of education household head	11.80	12	2.27	12.65

The average income and the years of education of the households in our sample are below the German average (cf. Table 3) and reflect the fact that the buildings belong to a public housing association. Furthermore, due to the higher proportion of alone living retirees taking part in the survey, the average age is rather high.

The narrative-generating part of the interview aimed at households' heating behaviour in winter times, i.e. the way households ventilate or regulate their indoor room temperature as well as their knowledge about heating energy bills. In previous analysis of these interviews, we examined practices and values influencing heating energy consumption and identified the room temperature and the efficiency of ventilation as the main behavioural variables. Ideas, such as having a cosy home and/or the need to save energy, influence the room temperature. At the same time the room temperature as well as the ventilation manner depends at the same time on the knowledge of households (Wolff et al. 2017)[7].

4 Results

4.1 Savings in energy heating energy consumption

The 10 buildings have been renovated to a moderate standard, 8 of them meet the requirements of the German "EnEV reference building". For all buildings we calculated the average consumption prior and post retrofit (*CONS_prior* and *CONS_after*), and adjusted it by climate correction factors. Table 4 shows the actual heating energy consumption in kWh as well as the expected consumption according to the EPR for before and after (*EPR_prior* and *EPR_after*) the refurbishment respectively for each building. The sixth column shows the amount of energy reduced with the refurbishment measures in %. From an energetic point of view, the modernizations of these buildings have been successful, the measured average reduction of energy consumption amounts to 69%.

[6] C.f. household size (Destatis, 2016), age (Zensus, 2015), net equivalence income (Destatis, 2017), years of education (Rahlf, 2015).

[7] Previous studies on heating energy consumption also found the strongest influence by room temperature and ventilation (Guerra-Santin et al. 2016; van Raaij & Verhallen, 1983).

Additionally, the pre retrofit EPRs do not deviate strongly from the actual consumption pre retrofit. Therefore the prebound effect, i.e. the difference between the EPR post refurbishment and the actual consumption in the last column, is not as high as in other studies. It ranges between 10 % and −32%. Thus, the EPR calculations do not deviate from the actual consumption to a high degree and rather high reductions in energy consumption have been achieved.

Table 4: Energetic data for retrofitted buildings

Building	Ø CONS _prior in kWh/year	EPR_prior in kWh/year	Ø CONS _after in kWh/year	EPR_after in kWh/year	Reduction of energy consumption	Pre-bound
(1)	210 259	252 429	67 768	79 915	−68 %	−17 %
(2)	264 538	239 514	77 029	74 525	−71 %	10 %
(3)	111 162	148 613	33 458	45 049	−70 %	−25 %
(4)	189 375	190 000	60 165	74 935	−68 %	0 %
(5)	155 454	195 000	50 899	77 649	−67 %	−20 %
(6)	182 614	195 000	44 192	77 649	−76 %	−6 %
(7)	160 331	234 000	52 267	63 600	−67 %	−31 %
(8)	226 530	333 200	63 881	95 900	−72 %	−32 %
(9)	294 992	363 000	104 116	63 600	−65 %	−19 %
(10)	118 655	110 579	35 757	47 957	−70 %	7 %

4.2 Households' costs before and after refurbishment

Due to the moderate standard of renovation, the renovation costs per building have been moderate. Additionally, the social housing company has a rather large stock of buildings, which gives them the opportunity of cross-financing the costs of renovation, and therefore to impose a much smaller rent increase than legally possible 11%. In Table 5 we listed the actual rent increase per m² as well as the legally possible. It becomes clear, that only a proportion of the possible rent increase was realized.

Table 5: rent increase due to costs of retrofit according to building

Building	actual rent increase €/m²/year	legally possible rent increase €/m²/year (11 %)
(1) (2)	10.80 €	70.94 €
(3)	10.80 €	93.31 €
(4)	6.00 €	84.20 €
(5)	6.00 €	85.30 €
(6)	6.00 €	83.94 €
(7) (8) (9)	13.20 €	52.01 €

In the following, we will compare the described achieved energy reduction with the rent increase on the household level in order to assess the financial balance. For the analysis we can draw on 109 households without missing values for heating costs, consumption and demand prior and after retrofit. We will refer to the heating costs prior retrofit as *COSTprior* and for the heating costs after retrofit as *COSTafter*. In addition *COSTafter+rent*, stands for the heating costs after retrofit including the rent increase.

COSTprior:	*Heating costs of household per year in € before retrofit*
COSTafter:	*Heating costs of household per year in € after retrofit*
COSTafter+rent:	*Heating costs of household per year in € + rent increase per year in € after retrofit*

Figure 1 compares the *COSTprior* with the *COSTafter*. In line with the large reductions of the heating consumption at the building level, all households profit from the retrofit in terms of heating energy costs. The average reduction in energy consumption amounts up to 96 kWh/m²/year – with the energy price of 13 cents/kWh in the year 2015 this indicates a decrease of energy consumption of 12.48 Euro/m²/year.

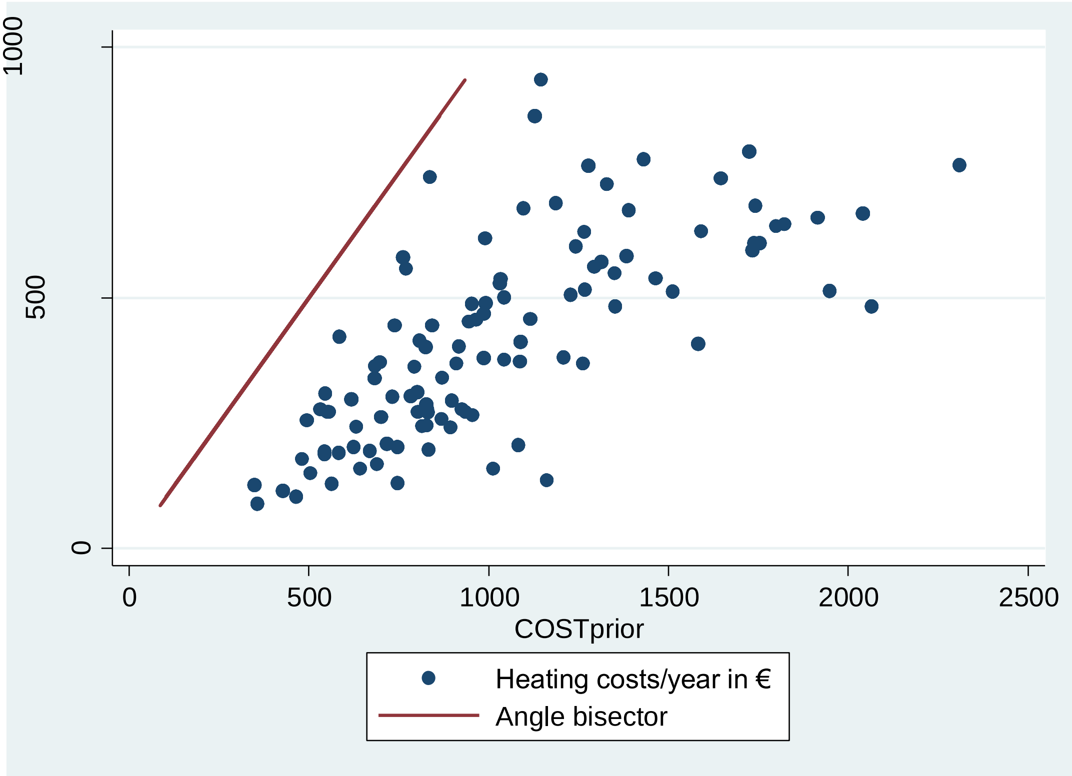

Figure 1: Comparison of annual heating energy costs prior and after the retrofit

But as already mentioned, the households receive a rent increase as a consequence of the modernizations. Therefore, in Figure 2 we compare the amount of the heating costs before the retrofit in €/year (*COSTprior*) with the amount of heating costs added to the rent increase in €/year after the retrofit (*COSTafter+rent*): Whereas all households lie below the angle bisector, i.e. have lower heating costs after the retrofit than before the retrofit in Figure 1, Figure 2 with the rent increase added to the heating energy costs after retrofit shows a different picture: the majority of households lie above the angle bisector. Thus, even though we adjusted the heating costs for the price increases, more than half of the households do not profit from the retrofit from a financial point of view.

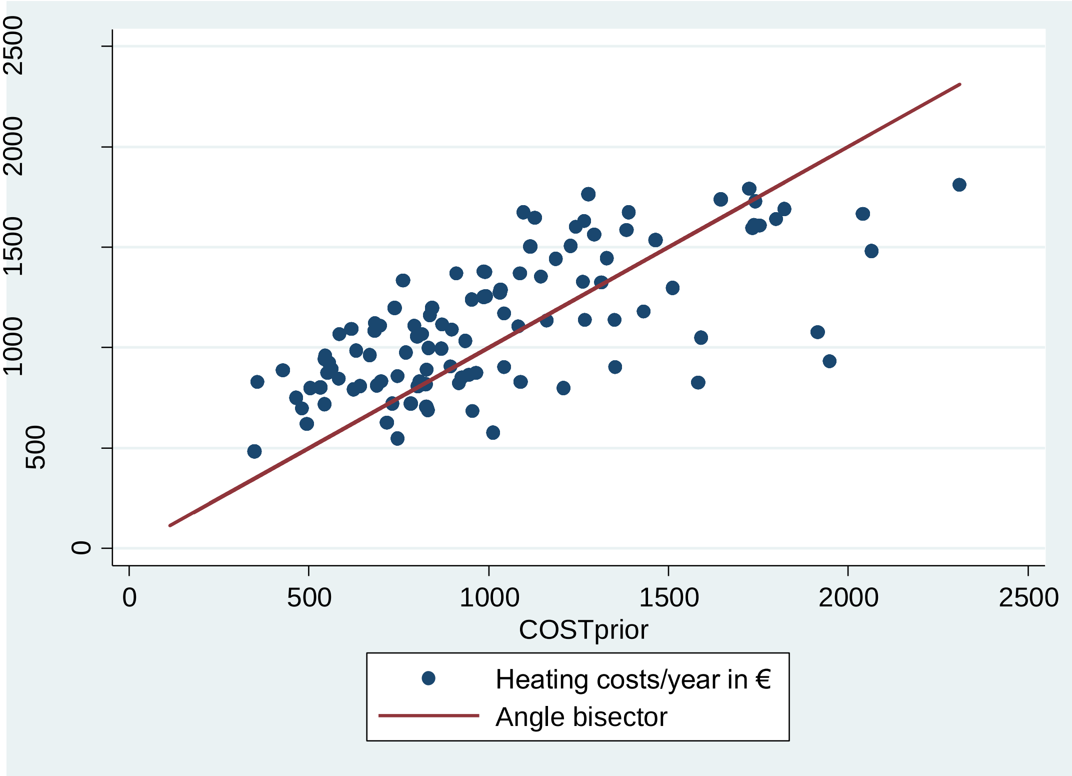

Figure 2: Comparison of annual heating energy costs prior the retrofit with annual heating energy costs including rent increase after the retrofit.

On average, households in our sample spent 15.15 € per square meter and year for heating energy (without hot water) before the retrofit. The average heating costs itself after the retrofit in the sample amount to 5.9 € per square meter and year. The rent increase per square meter and year amounts to 10.8 € on average. An average household living in a flat with 90 m² spent 1363.5 € on heating energy before the retrofit and 531 € after the retrofit. With a rent increase of 972 € he spends 1503 € for heating costs including the increased rent. At first sight, this might not seem like a high increase in costs, but Figure 2 shows, that the increase is especially pronounced for those households, which had low energy costs prior retrofit.

4.3 Household's financial burden subject to their individual consumption

In a next step we will further analyze whether and to what extent households have been affected by the rent increase with regard to their individual consumption (Figure 3). In order to assess whether the households have a frugal or a high consumption with respect to their individual flats after the retrofit, a variable for the ratio (*ratio*) of the actual consumption (*CONSflat_after*) and the EPR of the flat (*EPRflat_after*) was constructed (x-axis):

$$ratio\ of\ consumption\ and\ EPRflat = \frac{CONSflat\_after}{EPRflat\_after}$$

A ratio less than 1 indicates a consumption below the EPR of the flat. A ratio above 1 indicates a higher consumption than the EPR. On the y-axis, a ratio of the heating costs prior retrofit (*COSTprior*) and the heating costs after retrofit including the rent increase (*COSTafter+rent*) has been calculated, in order to assess household's expenses. A ratio less than 1 indicates that the household has lower expenses after retrofit, while a ratio higher than 1 indicates higher expenses after retrofit.

$$\boxed{ratio\ of\ expenses = \frac{COSTprior}{COSTafter + rent}}$$

We then divided the scatter graph (every dot represents one household) in four different fields (Figure 4). The most interesting field in terms of social justice is the red field in the upper left corner of the graph – which incorporates 56 of the 109 households. Due to the increased rent these households are worse off financially (ratio of expenses > 1) while at the same time consuming less heating energy than the heating demand according to building physics predicts (ratio CONSflat_after and EPRflat_after < 1). Thus, they economize on heating but spend more overall compared to the time before the retrofit. The yellow field in the upper right stands for households (N = 17) spending more on heating energy and increased cold rent after the retrofit, which at the same time also consume more heating energy than the demand predicts for their flat. In this case households are financially worse off, but they also seem to have a preference for higher indoor temperatures and/or do not ventilate efficiently (cf. Wolff et al. 2017). The 26 households in the blue field (bottom left) consume less than the heating demand would predict, thus these households spend less for heating energy and the increased rent after the retrofit compared to the time before the retrofit.

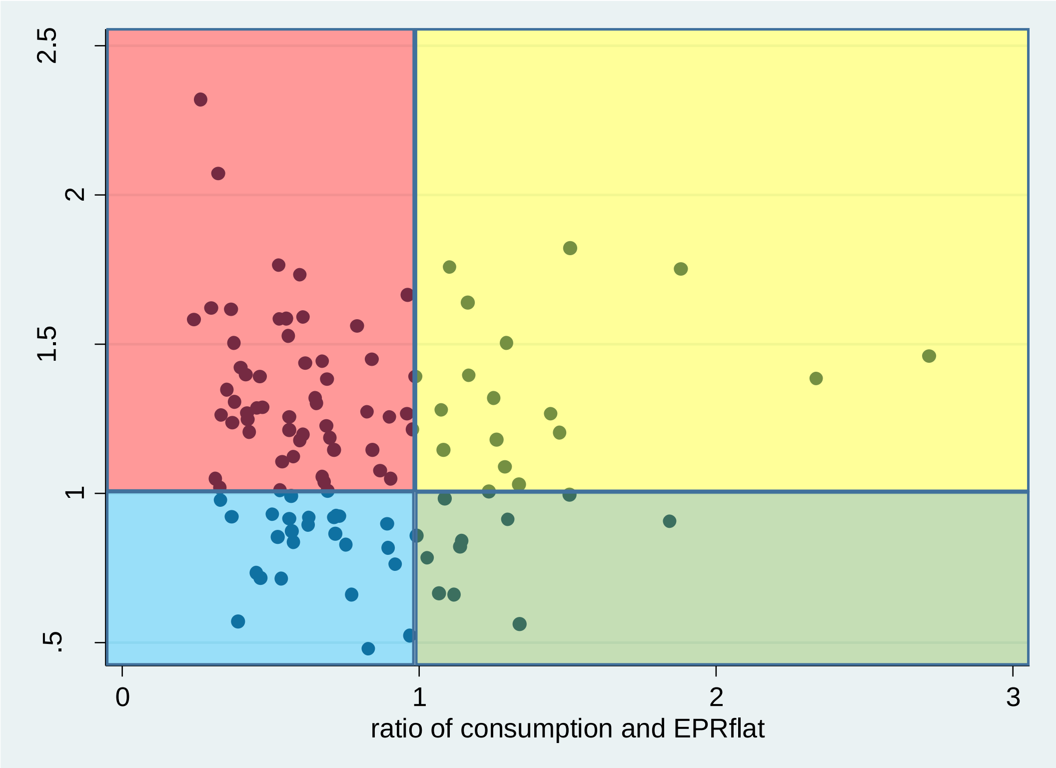

Figure 3: Comparison of the heating consumption relative to the flat-specific heating demand and the heating costs after the retrofit including a rent increase relative to the heating costs prior retrofit

Finally, the green field in the bottom right includes 10 households who profit financially from the retrofit as they spend less on heating energy and the increased cold rent, even though they consume more than expected from the building physics perspective for their flat. But compared to the upper left field the number of households facing increased costs after the retrofit, while at the same time consuming less, by far exceeds the number of households profiting. This represents a serious flaw concerning the retrofit policy, i.e. that households after a retrofit should not pay more compared to before, especially because the households in our sample have a lower socioeconomic status than the German average (cf. Table 3). Due to the limited number of cases including information on the heating behavior (indoor temperature and ventilating behavior) from the interview (less than N = 30), it was not possible to conduct further inductive analysis regarding a deeper insight on why some households profit from a retrofit and others do not.

5 Conclusion and Policy implications

Increasing energy efficiency is an important tool of the energy transition as declared by the German Government. As our results in section 4.1 show, even with moderate standards rather high reductions can be achieved. Hence, claims have been made to rather promote a higher rate than higher standards in energetic retrofit (Henger & Voigtländer 2012). Research also shows, the higher the renovations standards become (e.g. the better insulated a house) the higher the influence of the occupants behavior (De Meester et al. 2013).

However, the crucial point of our analysis is, that despite the very high reductions in energy consumption, for more than half the households the savings in energy consumption cannot offset the rent increase due to the renovation (section 4.2). Also, unlike in our sample, the targets on energy reduction are not always achieved (Henger & Voigtländer 2012). Thus, this result is especially dramatic, because in our case study not even one quarter of the possible 11% has been allocated to the rent. If the full 11% would have been relocated to the tenants, more households would have suffered economically. Furthermore, our results indicate, that this often affects households, which are already having a rather low energy consumption. In consequence, this could lead to households being displaced by the increased costs, an issue which is known as energetic gentrification (Großmann et al., 2014). Nonetheless one has to keep in mind that the results refer to a sample of lower-income households and are thus not easily transferable to the whole population.

Therefore, with the current instrument of the 11 percent rent increase, the aim of a rent neutral renovation is not very likely to be reached, and above all, it is discriminating households which already have a low consumption, while households with a high consumption profit. With future increases in energy prices, savings might be able to offset the rent increase though. The German Government is currently planning a reduction of the rent increase to a maximum of 8%, but as already mentioned, this might foster the current problems, since in areas with an already high rent level, the costs of investments have to be rather high in order to be economically profitable for landlords (Gill et al. 2016). Claims to adjust current incentive policies as well as adding a climate grant to the housing allowances seem to be more reasonable. Financing models, such as contracting models with respect to energy savings, are regarded as promising, however they also come along with high transaction costs and uncertainties (Ziehm, 2016). While energy performance contracting is slowly becoming more common for municipalities and companies, it is still unusual when it comes to residential properties (Ástmarsson et al. 2013; Offermann & Seefeldt, 2013), among other things, because the measurement of energy savings in the residential sector is more demanding (Polzin et al. 2016). Such models would also meet another remedy: with the current 11 percent model, all the renovation costs are imposed on the current tenants, while future tenants profit from a retrofitted apartment.

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