

How do households react to a real cost shock? Evidence from the energy price crisis in Germany

Puja Singhal ^a,* Kathrin Kaestner ^b, Antonia Schwarz ^a, Michael Pahle ^a

^a Potsdam Institute for Climate Impact Research (PIK), Germany

^b RWI-Leibniz Institute for Economic Research, Germany

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ABSTRACT

The 2022 energy crisis caused gas prices to rise more sharply than those of other fossil fuels. This paper uses this natural experiment to examine how households adjusted their energy consumption and investment decisions in response to real cost shocks. We analyze both household intentions and actual behavior in the aftermath of the crisis. On average, households expected a 70 percent increase in energy costs on their next annual heating bill. While many initially planned to reduce their heat demand in response to higher expected costs, we find that this reduction was short-lived, with room thermostat settings returning to pre-crisis levels. In contrast, energy efficiency investments saw a significant increase, both in planning and implementation. This suggests that investing in home energy upgrades emerged as a major coping strategy for households.

1. Introduction

The recent energy crisis in Europe, sparked by the disruption in gas and oil fuel imports from Russia, offers a unique opportunity to explore how households respond to drastic shifts in energy price levels. Previous studies have questioned the effectiveness of price-based climate policies, as behavioral biases can limit households' awareness of true energy costs, weakening the price mechanism (Sexton, 2015; Prest, 2020). However, when energy prices double or even triple in a short period of time, and information about this is pervasive in the media, the question arises—how does increased awareness of high energy prices impact planned energy usage and investment incentives? This study aims to address this question within the context of the energy crisis that hit many European countries in 2022.

This paper makes use of household survey data from the German Heating and Housing Panel (GHHP)¹ to analyze how households responded to the energy crisis. We focus on two key adjustments. First, we investigate changes in heating consumption in the immediate aftermath of the energy supply crunch during the winter of 2022–2023. In particular, we assess households' efforts to conserve energy by lowering room temperatures, using thermostat settings as the primary measure. Second, we examine households' investment decisions to retrofit or upgrade their homes to understand how cost shocks influenced their long-term incentives for energy-saving strategies.

To leverage the natural variation in heating tariff changes and households' awareness of these changes, we elicit households' expectations of energy cost shocks in the fall of 2022. Using the panel structure of the annual survey, we track households over time to assess whether planned changes in consumption and renovation investments materialize in response to increasing cost expectations in the following years. To isolate the causal effect of higher cost expectations on households' plans to adjust thermostat settings and invest in energy efficiency, we instrument cost expectations with whether a household was heating with gas pre-crisis. Differences in pre-existing heating fuel types allow us to exploit the steep rise in heating costs for gas users compared to other heating fuels. Although our identification strategy relies on a strong exclusion restriction, several features support its credibility in our setting. Our model accounts for persistent differences between fuel types and shows no systematic differences in heating behavior, retrofit intentions, or completed retrofits prior to the energy crisis. In other words, households with gas versus alternative heating systems exhibit parallel pre-shock trends in the main outcomes of interest.

Our findings reveal that as energy cost expectations surge, households with gas heating exhibit a tangible intention to curtail heating consumption and make energy efficiency upgrades to cope long-term with increasing cost expectations. On average, households expecting a 70 percent increase in heating costs on their next bill intended to

* Corresponding author.

E-mail address: singhal@pik-potsdam.de (P. Singhal).

¹ See Frondel et al. (2023) for more information on the panel dataset.

reduce the room thermostat radiator setting by 0.26 units during the day and about 0.18 units during the night. This response translates to a reduction of up to 1°C in mean room temperatures during the day and 0.7°C during the night. While these results indicate that higher cost shocks lead to a greater willingness among households to reduce their home's energy demand, intentions do not necessarily translate to long-lasting concrete actions. This is evident when we repeat the analysis using actual thermostat settings for winter 2022/2023, which we elicited during the subsequent survey in May 2023. We find no measurable impact on either daytime or nighttime thermostat settings which respondents reported to have used during the heating season following the onset of the price crisis. This reveals a significant gap between stated plans and actual behavior when it comes to consumption behavior.

In contrast to short-term behavioral adjustments to energy consumption, planned investment decisions appear to align more consistently with household behavior over time. Our results show that a 10 percent expected increase in heating costs — anticipated on the next heating bill — led to a 3 percentage point rise in the likelihood of households planning energy efficiency upgrades, as reported in the October 2022 survey. Given the inherently lengthy timeline required for home retrofits — which involves substantial planning and staged execution — we track households through 2024 to assess whether these investment plans materialize into completed upgrades. The evidence suggests that the significant increase in retrofit intentions in 2022 was indeed followed by a rise in completed energy efficiency measures in both 2023 and 2024, in response to elevated cost expectations. Notwithstanding, the interpretation of retrofit activity in 2024 requires caution. The increase in completed retrofits during that year is likely influenced not only by earlier cost shocks but also by policy developments—specifically, reforms to the Building Energy Act (GEG²) and adjustments to the Federal Funding for Efficient Buildings (BEG³) introduced in late 2023 and effective from 2024 that encouraged the shift to heat pumps from fossil fuel boilers. This trend remains consistent even when excluding heating system renewals from the analysis. Overall, our analysis indicates that households largely followed through on their investment plans and that the energy price crisis served as a catalyst for advancing the broader climate policy goal of longer-term cost-saving technologies in the residential sector.

Studies and reports most relevant to this paper explore how households reacted to fluctuations in energy prices during the 2022 energy crisis in particular. The winter of 2022–2023 was marked by an exceptional reduction in gas consumption across Europe, including Germany.⁴ Initial research looking at Germany's response to the energy crisis had been limited to analyzing reduction in gas consumption at this aggregate level. Ruhnau et al. (2023) estimate significant reductions in monthly gas demand by small consumers as a response to the energy crisis period, which is confirmed by another work using machine-learning methods (Roth and Schmidt, 2023).⁵ Since these response estimates are derived from aggregate consumption data, they capture the interaction effect of all factors affecting gas consumption by small consumers during time periods of interest. Moreover, the small consumer group includes both households and small commercial users,

² <https://www.bundestag.de/dokumente/textarchiv/2023/kw36-de-gebaudeenergiegesetz-957824>.

³ <https://www.bmwk.de/Redaktion/DE/Pressemitteilungen/2023/12/20231229-neue-foerderung-fuer-heizungsaustausch-und-gebaeude-effizienzmassnahmen-startet.html>.

⁴ European gas consumption declined by approx. 13% in 2022, and a 15% drop in residential plus commercial sectors is documented (IEA, 2023). The Bundesnetzagentur reports that private households and small commercial customers in Germany cut gas consumption by approx. 12% in 2022 relative to the previous four-year average (Bundesnetzagentur, 2023).

⁵ This also aligns with estimates of the gas demand response to price spikes observed due to the tariff reforms in Ukraine (Alberini et al., 2020).

and thus it remains unclear how much households drive the decline in the aggregate.

A growing body of micro-level evidence suggests that much of the observed reduction in gas consumption during the 2022–2023 winter did not arise from households' direct responses to higher energy prices, but instead from crisis-driven behavioral adjustments, public awareness campaigns, and widespread voluntary conservation efforts. For example, Dertwinkel-Kalt et al. (2024) conduct a field experiment among gas customers of a public utility and, despite observing substantial average savings, find that neither targeted economic incentives nor price differentials can account for the reduction. Gerster et al. (2025) further bolster this view: evidence from a large-scale survey experiment among German gas-heating households show that even highly generous incentive programmes may be largely ineffective at inducing additional energy savings, calling into question the effectiveness of direct financial incentives to save energy during the crisis. Similarly, Behr et al. (2025) use building-level data and conclude that the majority of residential gas savings during the crisis were driven by non-monetary factors rather than by price responses, estimating an exceptionally low short-term elasticity of heat demand (−0.07). Our findings speak directly to this emerging evidence. Consistent with these studies, we show that even households facing sharply higher expected heating costs displayed relatively inelastic heat demand. This suggests that the bulk of the crisis-period reduction in gas use was indeed driven by broader behavioral responses rather than by marginal-price incentives alone. In contrast, when examining household investment decisions, we find a markedly different pattern: energy-efficiency retrofits did respond to the financial incentives generated by the extreme price shock of 2022. To our knowledge, our paper is the first to document how the crisis affected investment behavior in the residential sector.

Our paper is related to a large body of literature that examines how households respond to changing energy prices and the energy efficiency gap, more broadly (Allcott and Greenstone, 2012; Gillingham and Palmer, 2014; Gerarden et al., 2017). While most of the research has focused on electricity and gasoline, a growing body of literature examines the determinants of heating demand.⁶ In Germany, heating demand shows price elasticities ranging from −0.44 to −0.69 (Rehdanz, 2007; Schulte and Heindl, 2017; Schmitz and Madlener, 2020; Galvin and Sunikka-Blank, 2012).⁷ Recent studies that address potential endogeneity due to simultaneity in price adjustments estimate significantly smaller price elasticities (Auffhammer and Rubin, 2018; Jamissen et al., 2021). Overall, heating demand remains more inelastic than electricity demand, posing challenges to influence behavior through the pricing mechanism alone. The strand of literature focusing on electricity demand investigates the role of information and beliefs (e.g., Frondel and Kussel, 2019; Werthschulte and Löschel, 2021), the effects of smart metering or related behavioral interventions (e.g., Allcott and Rogers, 2014; Jessoe and Rapson, 2014) and the potential gain from the use of smart thermostats (Blonz et al., 2021; Brandon et al., 2021). Other research establishes the heterogeneity of price responsiveness across different socioeconomic groups (Schmitz and Madlener, 2020; Trotta et al., 2022; Peersman and Wauters, 2024).

Finally, our paper also relates to studies aimed at understanding the role of expectations and uncertainty in household behavior. As Roth and Wohlfart (2020) show in their experimental study, expectations about the macroeconomy affect both personal expectations and consumption plans. Relatedly, uncertainty about the future development of macroeconomic indicators has been shown to affect household spending (Coibion et al., 2024), while recent work on expectations formation

⁶ See Labandeira et al. (2017) for a meta-analysis of the literature.

⁷ Similar elasticities are found in other countries, including Switzerland (Filippini and Kumar, 2021, −0.73), Italy (Favero and Grossi, 2023, −0.35 to −0.83), Denmark (Trotta et al., 2022, −0.530), the United Kingdom (Meier and Rehdanz, 2010; Meier et al., 2013, −0.34 to −0.56), and the USA (Alberini et al., 2011; Salari and Javid, 2016, −0.557 to −0.693).

highlights that the responsiveness of households to information depends on the broader price environment. Using several randomized controlled trials across multiple countries, [Weber et al. \(2025\)](#) find that in high-inflation regimes, agents become more attentive and thus exhibit smaller responses to additional informational treatments, suggesting that context matters for how cost expectations translate into behavior.

Our contribution to the literature is three-fold. First, rather than imposing hypothetical price changes, we rigorously investigate how each household anticipates their next heating bill to change. This approach allows us to precisely measure the real financial impact on households — understood as the actual, non-hypothetical burden they experienced or expected — during the energy crisis and potentially in the years that followed. This is particularly relevant in Germany, where households lack regular updates on incurred costs, unlike monthly bills seen in other countries. Consequently, household cost expectations play a pivotal role in influencing heating demand and determining investment decisions. Thus, we shed light on the extent to which the crisis response was driven by expectations of higher energy bills at the household level. Secondly, our paper is one of the first to explore how households respond to a lingering cost shock over the medium term horizon, examining their decisions regarding investments in energy efficiency over several years. Thirdly, our study assesses both planned and actual household behaviors, thereby shedding light on the potential gap between intention and action in response to the energy price shock.

The next section provides a short account of the public discourse of the energy crisis at the time of the survey. Section 3 describes the survey data, the preferred approach to measure heat consumption, and the effect of the energy crisis on household energy costs. Section 4 then explains the design of the instrumental variable estimation approach, followed by a discussion of the results in Section 5. Section 6 concludes.

2. German energy prices and awareness during the crisis

The analysis in the paper disentangles the effect of real cost shocks, as opposed to changes in marginal prices, on both energy usage and investment incentives at the household level. By “real cost shock”, we refer to respondents’ expectations of higher heating bills, where “real” indicates that the shock was not hypothetically assigned but rather elicited in the context of the actual energy price crisis.

The unique German tariff and billing system for utilities and the energy crisis guided our survey design towards eliciting cost expectations rather than average price levels. This choice of survey instrument is motivated by several factors. First, the extent to which a household is affected by higher energy prices on the market depends on the duration of supplier contracts or the purchase cycle to renew the fuel stock.⁸ Second, there is considerable heterogeneity in how well households are informed about their energy consumption and costs. Previous research has shown that the intermittent nature of billing cycles⁹ likely

⁸ There exists significant variation in both the timing and extent to which higher wholesale gas prices are transmitted to retail customers. While some customers actively seek better rates by switching contracts and suppliers, others are unwilling or constrained from doing so, prompting suppliers to employ differential pricing and contract length across customer segments. Consequently, wholesale price fluctuations do not immediately translate to changes in retail rates but instead trickle down over time. For existing customers, cheaper gas suppliers were largely not available during the 2022 energy crisis period, which meant that households could also not switch to better prices in new contracts as a means of mitigating cost shocks. In fact, it was the new contracts that experienced the initial surge in wholesale prices. Accordingly, differences in prices between new and old contracts widened considerably, resulting in notable price disparities between households.

⁹ Most households in Germany are informed once per year about their heating costs, unless there are unforeseen changes in the contracts like price changes.

contributes to the differences between perceived and realized energy costs—potentially leading to present-bias in consumption or limited salience of information on regular bills ([Werthschulte and Löschel, 2021](#); [Singhal, 2024](#)). However, amidst widespread public discussions on the impending challenge for gas-using households ([Maurer and Hans-Jürgen Weiß, 2023](#)) and the urgent need to curtail heating demand to cut rising energy bills, households were acutely aware of the impending cost escalations.

German residential consumer gas prices witnessed a significant increase leading up to our survey, which was preceded by an even larger price increases in oil, the secondary fuel for space heating (see [Fig. 1](#)).¹⁰ Gas-heating households, in particular, were increasingly aware of rising gas prices. This heightened household awareness can be attributed to three key factors: First, on August 9, 2022, the German government announced the implementation of a gas surcharge of 2.419 ct/kWh on both new and existing gas customers starting from October.¹¹ Second, gas suppliers were required to inform customers via letters about the energy consumption and costs of buildings, compare them with the basic supply tariff from September 1, 2022, and indicate potential savings by reducing the room temperature by 1 degree Celsius ([Bundesministerium für Wirtschaft und Klimaschutz, 2022](#)). This information had to be sent to customers by September 30, 2022, or by December 31, 2022, if significant price changes occurred.¹² Collectively, these factors stress the heightened anticipation among gas users of facing increased costs during the 2022/2023 heating season. Third, the energy crisis and its associated policies sparked extensive public discourse. Notably, the German Ministry of Economics and Climate funded a nation-wide poster campaign promoting energy conservation tips ([von Eichhorn, 2022](#)). Televised coverage of energy policy intensified with the onset of the conflict, as Germany’s dependence on Russia and the search for alternative energy sources came to the forefront. The topic remained prevalent throughout the year and experienced another peak in October 2022 with discussions about soaring prices approaching winter and potential relief measures for citizens and industry ([Maurer and Hans-Jürgen Weiß, 2023](#), see [Figure 7](#)). It is important to emphasize that the data collection for our analysis took place before the announcement of later implemented relief measures such as price caps. Also, other media channels picked up the topic, such as a dedicated podcast by [Südwestrundfunk \(2022\)](#). Furthermore, the omnipresence of the energy crisis was evident in discussions among the general public, including frequent debates on social media platforms about energy prices ([Vrana et al., 2023](#)).

3. Survey data

The paper examines survey data responses from households in the German Heating and Housing Panel (GHHP). The GHHP is a

¹⁰ Average gas prices for household customers increased from around 7 ct/kWh in 2021 to around 20 ct/kWh by the end of 2022 ([BDEW, 2023](#)). According to the 2022 Census, 56% of all residential units in Germany rely on gas for heating, making the potential doubling or tripling of retail prices a major concern. Note that heating oil customers have the option to protect themselves from price increases by purchasing oil supplies when prices are lower.

¹¹ The gas procurement surcharge was supposed to be implemented on October 1, 2022, as per the Gas Price Adjustment Ordinance, which was issued by the Federal Government on August 9, 2022. However, it was abandoned by the end of September in favor of direct support measures for gas-importing companies facing significant costs. The policy change was necessary because the major gas importers were nationalized in the meantime, raising concerns about the constitutionality of collecting the levy.

¹² It is worth noting that the majority (approx. 65%) of households using gas in our sample had received such information letters before our survey period began. This provided affected households with potentially more reliable insights into their forthcoming annual heat energy costs.

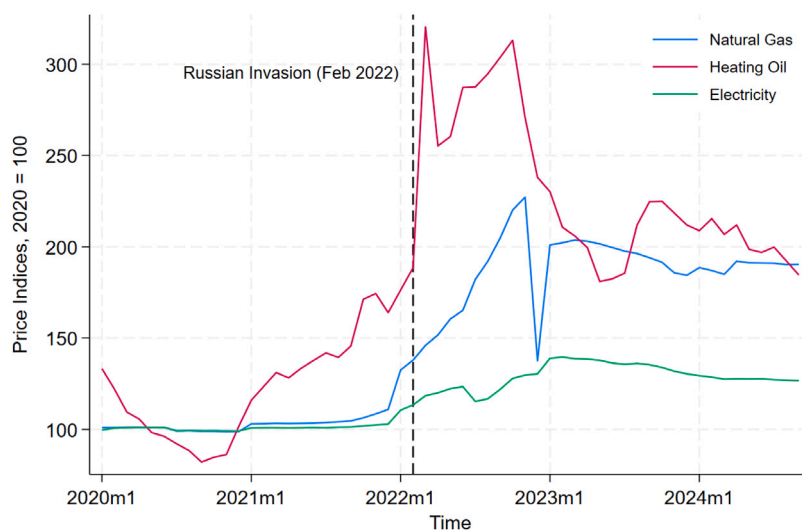


Fig. 1. Household energy price indices.

Notes: The vertical black line demarcates the month in which Russia invaded Ukraine. The index for natural gas excludes operating costs.

Source: Own illustration using data from the Federal Statistical Office, 2024.

unique data basis consisting of annual information about homes, energy retrofits and socio-economic characteristics of approximately 15,000 households in Germany. The panel has been built since 2021 as part of the Ariadne Kopernikus project funded by the German Federal Ministry of Education and Research (see Frondel et al., 2023, for a description of the panel). The survey was first conducted in August 2021.

We designed additional survey modules during the summer of 2022 to test how changes in heating cost expectations, fueled by soaring energy prices, affected energy savings and investments decisions. The survey went to the field from the end of September to the beginning of November 2022, during a period when it was clear to the public that gas prices were set to increase.¹³ The majority of respondents were surveyed during October. Given that the official heating period in Germany lasts from October to April of the following year, our 2022 survey was thus conducted at the very start of the heating season. To monitor household responses over time and assess whether planned actions were carried out, we also incorporate findings from the subsequent two survey waves. The 2023 survey was conducted between 24 May and 22 June, while the 2024 survey took place from 16 October to 6 November.¹⁴

We construct our estimation sample in the following way. We drop those households that (1) do not complete the surveys completely, (2) moved locations since the previous survey, and (3) did not know their heating fuel type or did not have one of the main six fuel types: gas, oil, district heating, electricity, pellets, and LPG and instead reported using “Other” heating fuels. A key variable in our analysis is the expected change in heating costs in 2022. 2888 respondents did not answer the question and had to be dropped from the sample.

To elicit cost expectations, we asked all respondents how they expect the monthly or yearly heating costs to increase on the next billing statement, keeping their consumption units hypothetically fixed to the last billing statement.¹⁵ Table 1 summarizes the cost expectations variable we use to measure the energy price shock on heating bills.

¹³ Close to 90% of respondents surveyed had reported that they were aware of the gas levy that was a tentative policy measure to be introduced by the German Federal government. Interestingly, at the same time, only about 20% of the respondents were aware of the savings awareness campaign (“80 Million together for Energy Savings - take part now”) run by the government: (<https://www.energiewechsel.de/KAENEF/Redaktion/DE/Dossier/energiespartipps-fuer-verbraucher.html>).

¹⁴ We summarize the panel survey timeline in Table A.1.

In particular, the table highlights that gas customers on average were expecting costs to be higher compared to users of other fuel types. However, we also note that households heating with non-gas fuel types were expecting similarly high increases in heating costs on the next billing statement. Moreover, these heightened cost expectations likely pick up long-term perspectives on cost developments as well. This is because more than 90% of those surveyed in 2022 agreed that energy costs will continue to rise until 2030, indicating that the majority of households firmly believed prices will remain on an upward trend. We show the full distribution of the expected change in heating costs in Fig. A.1 in Appendix A.

To assess heat demand, we asked respondents how they regulate their home heating. Households that manually adjust their radiators reported their temperature settings on a scale from 0 to 5, which reflects the typical range of these devices in Germany. Those using room thermostats or digital radiator controls provided their settings in degrees Celsius. We collected temperature settings for each heated room separately for daytime and nighttime. Since most homes in our sample regulate heat manually via radiators, we converted temperature settings in degrees Celsius to the 0–5 scale. The conversion from degree Celsius settings to the scale was structured as follows: $Thermostat = 0$ if (Heater Off or $Temp. < 12^{\circ}C$), $Thermostat = 1$ if ($12^{\circ}C \leq Temp. < 16^{\circ}C$), $Thermostat = 2$ if ($16^{\circ}C \leq Temp. < 20^{\circ}C$), $Thermostat = 3$ if ($20^{\circ}C \leq Temp. < 24^{\circ}C$), $Thermostat = 4$ if ($24^{\circ}C \leq Temp. < 28^{\circ}C$), $Thermostat = 5$ if ($28^{\circ}C \leq Temp.$).

In the 2022 survey, we gathered data on households’ heating behavior during the 2021–2022 winter and their intended thermostat settings for the following 2022–2023 winter. To accurately capture how households adjusted heating temperatures and, consequently, heat energy consumption throughout their entire home (house or apartment) during the winter of 2022–2023, we calculated the change in thermostat settings for each heated room and averaged these values across all rooms. This approach accounts for the interconnected nature of indoor heating, where changes in one room, such as the living room, can influence temperatures in other areas. Using this method, we

¹⁵ We employed a slider mechanism to elicit cost expectations, with its midpoint aligning with the monthly/annual heating cost level queried in a preceding survey question. Respondents adjusted the slider to indicate changes, with corresponding percentage and total alterations in heating costs displayed, mitigating any potential accounting bias from percentage conversions.

Table 1
Cost expectations across fuel types.

	Mean (%)	St. Dev.	Percentiles					Obs.
			10th	25th	50th	75th	90th	
Natural gas	79.63	83.97	0	25	60	108	200	5915
Heating oil	60.28	67.61	0	20	49	100	146	1946
District heating	67.78	73.62	10	23	50	100	155	1538
Electricity	42.38	61.62	0	10	30	60	108	1148
Pellets	65.32	84.15	0	15	42	100	195	477
LPG	58.98	78.38	0	15	40	84	157	225
Total	69.84	78.71	0	21	50	100	166	11 249

Notes: Cost expectations are measured as the year-over-year percentage change in heating costs anticipated on the next heating bill.

determined the average intended change in thermostat settings between the two heating seasons, distinguishing between daytime and nighttime settings. Finally, in the 2023 survey, we asked households to recall their actual thermostat settings during the 2022–2023 heating season to compute the average observed change in thermostat settings.

Lastly, the variables tracking planned renovations until 2030 and renovations completed since the last survey year are indicator variables. They are set to 1 if households report investments in any of the following categories: (1) Roof insulation, (2) Top floor ceiling insulation, (3) External wall insulation including basement wall, (4) Basement ceiling/floor insulation, (5) Window renovation, (6) Optimization of existing heating systems, (7) Installation of new heat generation devices, and (8) Other. Due to the significant overlap between the energy crisis, the GEG reforms, and changes to BEG subsidies, we additionally report retrofit shares when excluding cases involving heating system renewals (7).

Table 2 summarizes the main variables used in our analysis. The majority of households heat with gas and are owner-occupiers of single- or two-family houses.¹⁶ The breakdown of heating fuel types mirrors the national composition, with approximately two-thirds of households using gas or oil. Among these, nearly half rely on gas. These are followed by district heating, used by around 15% of households, and electricity, which accounts for roughly 10%. The remaining households use pellets or LPG for heating.

The mean expected change in heating costs on the next bill is +70%. On the previous heating bill, average cost amounted to 158 Euros monthly. For 77% of the households, the heating bill is inclusive of warm water heating costs. The majority of households in the sample use a manual radiator thermostat to control room heating temperatures (60%) and a smaller proportion of households have either a programmable digital room thermostat mounted on the wall (13%) or digital thermostats installed directly on the radiator (12%). The differences in proportions of the income and living space categorical variables indicate that our estimation sample over-represents the middle- and high-income categories with relatively large homes (57% of homes have more than 100 square meters of living space).

The average room thermostat setting was approximately 2.6 (approx. 22.4°C) during the daytime and 1.8 (approx. 19.2°C) during the nighttime in winter 2021/2022.¹⁷ The average room temperature settings for gas and non-gas customers in the sample are statistically identical for both day and night. During the 2022/2023 winter heating season, households, on average, intended to lower their thermostat settings by 0.34 units (approximately 1.36°C) during the daytime and 0.20

¹⁶ In the GHHP household sample, with two-thirds being owner-occupiers and one-third tenants, owner-occupiers are intentionally over-represented to monitor energy efficiency investment behavior.

¹⁷ Respondents could flexibly state temperature settings in the survey according to their thermostat (either on a scale from 0 to 5 or in degree Celsius). For the small share of respondents who reported in degree Celsius, we converted their thermostat settings to the scale of 0 to 5 for further use.

units (approximately 0.8°C) at night. However, average thermostat settings reported in the follow-up survey in 2023 indicate that daytime thermostat settings are unchanged and nighttime settings even increase when compared with pre-crisis levels (2021/2022 heating season).

Planned retrofits until 2030 indicate a slight increase in the proportion of respondents planning home energy upgrades from 2021 to 2022, after which the proportion of households in the sample planning further retrofits halves by 2024. This pattern also holds when excluding heating system upgrades (see numbers provided in parentheses). Meanwhile, the share of households that completed retrofit projects since the previous survey remained around 20 percent in both 2022 and 2023, and is followed by a sharp increase in 2024. The table further reports the retrofit shares when excluding heating system renewals for comparison in parentheses. The majority of planned and completed retrofits did not involve the renewal or replacement of the heating system.

4. Empirical strategy

4.1. Endogeneity concerns

This study examines how households adjusted their thermostat settings and energy efficiency investments in response to significant changes in household cost beliefs (i.e., expected percent change in costs on the next heating bill). Interpreting the survey responses on cost expectations presents two key challenges. First, households' reported cost expectations may be influenced by their general ability to save. For instance, owner-occupiers and those with programmable thermostats likely have better control over their heating consumption compared to renters or households relying on manual thermostats mounted on room-specific radiators. As a result, they may anticipate less severe cost increases than those who feel they have less control over their energy usage.

Second, although the survey explicitly instructed respondents to estimate how much they expect their heating costs to change on the next bill under the assumption of unchanged consumption from the previous heating season, it remains uncertain whether their reported expectations are truly anchored to stable consumption levels. Considering that some households anticipated a decrease in heating costs (see Fig. A.1) on their next billing statement, it is plausible that certain households have already factored in how they would respond to the cost shock, perhaps by reducing energy consumption or switching off the heating system completely. Thus, as with any survey-based quantitative responses, we expect some degree of measurement error in our survey responses, which would lead the OLS coefficient on cost expectations to be biased towards zero.

Although reported cost beliefs of households comprise some degree of endogenous variation that is correlated with household heating demand, there is also significant “good” exogenous variation that we can exploit to credibly estimate the household-level response to the energy price shock. This is because the survey was conducted during a time in which some households were more likely to face higher prices for heating than others – a natural setting, in which sudden changes in prices were largely unrelated to household characteristics that determine the propensity to consume heat energy. As discussed earlier, gas customers were made aware through various information channels (media, news, supplier, landlord) that they would receive a price increase on their heating consumption moving forward.

We thus adopt an instrumental variable (IV) approach for the identification strategy, exploiting the fact that expected and actual changes in energy prices vary widely across households due to pre-existing differences in the main fuel type.¹⁸ Specifically, the gas supply shortage

¹⁸ Our survey data also show that a high share (66%) of households using gas heating systems had received a letter either from the main supplier or landlord informing households about a change in gas prices and, thus, heating costs up

Table 2
Summary statistics.

	Mean	St.Dev.	Min	Max
Gas heating	0.54		0	1
Owner-occupied	0.69		0	1
Detached or semi-detached house	0.64		0	1
Living space, in sqm	121.01	56.86	2.00	960.00
<i>Costs</i>				
Expected % change in heating costs	69.84	78.71	-400.00	400.00
Monthly heating costs, in Euro	157.88	90.42	21.25	541.67
Inclusive of warm water	0.77		0	1
<i>Monthly net income categories</i>				
Under 1700	0.06		0	1
1700–3200	0.29		0	1
3200–4700	0.31		0	1
4700 or more	0.28		0	1
<i>Floor area categories</i>				
1–50 sqm	0.04		0	1
51–100 sqm	0.39		0	1
101–150 sqm	0.37		0	1
Over 150 sqm	0.20		0	1
<i>Thermostat type</i>				
Analog room	0.16		0	1
Digital room	0.13		0	1
Manual radiator	0.60		0	1
Digital radiator	0.12		0	1
<i>Winter 2021/2022 room temperature (0–5)</i>				
Daytime setting, gas	2.59	0.68	0	5.00
Nighttime setting, gas	1.80	0.97	0	5.00
Daytime setting, non-gas	2.58	0.69	0	5.00
Nighttime setting, non-gas	1.82	1.03	0	5.00
<i>Winter 2022/2023 room temperature (0–5)</i>				
Planned change in daytime setting	-0.34	0.63	-4.00	4.50
Planned change in nighttime setting	-0.20	0.76	-5.00	5.00
Actual Change in daytime setting	-0.05	0.69	-3.50	4.00
Actual change in nighttime setting	0.17	0.90	-5.00	5.00
<i>Planned retrofits until 2030 by survey year</i>				
2021 (w/o heating system upgrade)	0.37 (0.29)		0	1
2022 (w/o heating system upgrade)	0.44 (0.33)		0	1
2023 (w/o heating system upgrade)	0.40 (0.30)		0	1
2024 (w/o heating system upgrade)	0.23 (0.18)		0	1
<i>Completed retrofits since last year by survey year</i>				
2022 (w/o heating system upgrade)	0.22 (0.17)		0	1
2023 (w/o heating system upgrade)	0.17 (0.13)		0	1
2024 (w/o heating system upgrade)	0.43 (0.36)		0	1

Notes: The table summarizes the main variables of interest in the estimation sample. Settings for room temperature are reported on a scale from 0 to 5, where 0 means the heating device is turned off. Each unit above 0 corresponds to 4 degrees increase above 12 degrees Celsius. The average daytime setting of 2.6 translates to mean room temperature of 22.4 degrees and the average nighttime setting of 1.8 translates to mean room temperature of 19.2 degrees. Planned and completed renovations excluding renewal of heating systems are shown in parentheses for each survey year.

caused by Russia's supply cutoff resulted in record-high prices for households relying on gas as their primary heating fuel. We employ the binary variable of whether the household's heating system uses gas as an IV, which is strongly predictive of heating cost expectations during the survey period, but, as we show, does not have any direct impact on the intended change in temperature settings and investments. This helps us isolate the variation in expected cost beliefs that is related to the natural experiment of a significant change in heating costs at short-notice.

An important identifying assumption hinges on whether a household's heating system runs on gas supply is as good as randomly assigned in relation to heating preferences (proxied by day and night

to the time of our survey. Initially, we considered using the receipt of a letter, informing gas customers about a change in prices, as an instrument, but found a weak positive correlation with expected change in costs on the next heating bill. This may not be a surprise, since cost beliefs had been elevated for all gas customers during 2022, given the media coverage and the resulting high salience of energy price inflation in Germany.

thermostat setpoints) and investment behavior. It should be noted that our identification strategy would estimate a local average treatment effect (LATE) based on the comparison between gas and non-gas households, meaning the estimated effect applies specifically to gas households whose behavior is influenced by this instrument. We check whether gas and non-gas users in our estimation sample had similar heat temperature preferences and investment behavior during the previous heating season, before the energy price crisis in 2022.

In Table 3, we present the estimates from an ordinary least squares regression using the estimation sample where the dependent variables are reported day and night thermostat settings, averaged across all rooms, for the previous winter heating season (2021/2022) and the independent variable is a binary variable indicating whether the respondent has a gas-heated fuel system, along with fixed effects for the predominant thermostat type used by households. The control set includes fixed effects for heated living space brackets, income brackets, whether the heating costs are inclusive of warm water, whether the home is renter- or owner-occupied, and the type of residential building. The estimates suggest that there were no statistical differences in daytime room thermostat settings between gas users and non-gas users

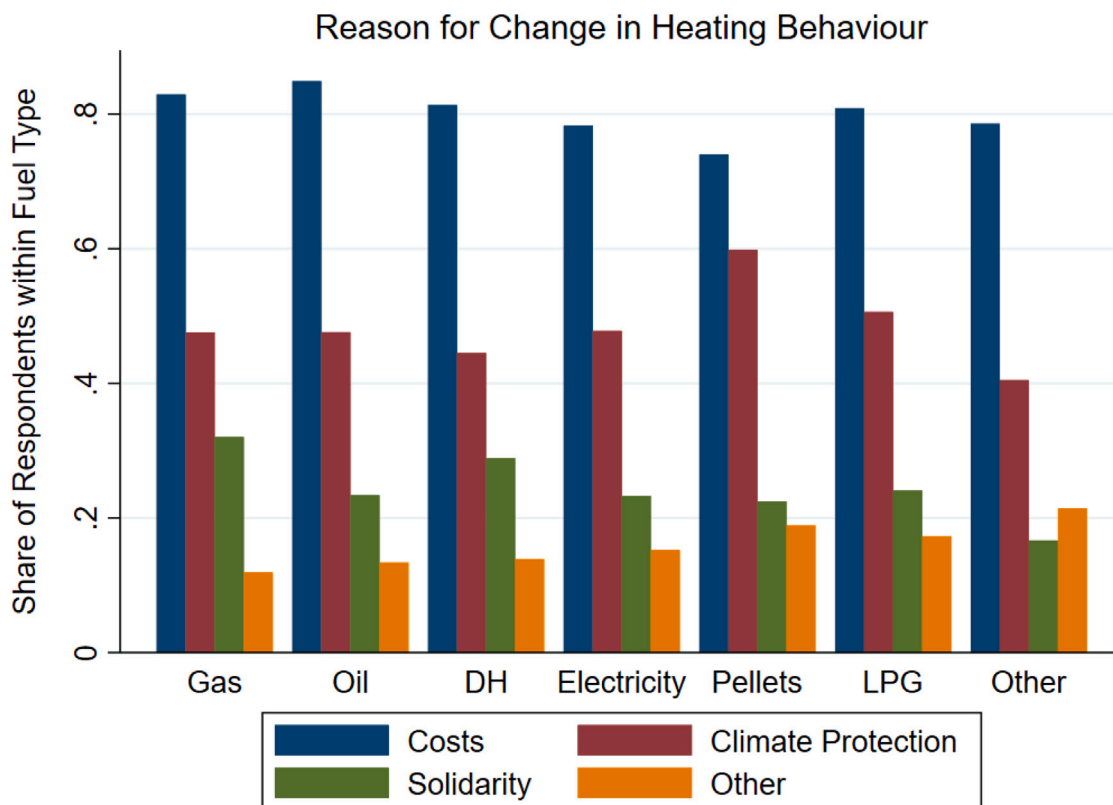


Fig. 2. For what reasons did you change your heating behavior in the last heating period (October 2022 to April 2023)? Pick all that apply. Notes: DH stands for District Heating. Solidarity category includes reasons related to the energy crisis, gas supply shortage, or Ukraine-Russia war.

Table 3
Differences in winter 2021/2022 thermostat settings (0–5).

	Daytime		Nighttime	
	(1)	(2)	(3)	(4)
Gas user	0.007 (0.015)	0.004 (0.015)	-0.027 (0.021)	-0.037* (0.021)
Control set		Yes		Yes
N	7463	7463	8675	8675
Adj. R ²	0.130	0.136	0.075	0.090

Notes: All regressions include fixed effects for the thermostat type of thermostat (predominantly used by the households to control temperature) and tenure status (renter versus owner). Controls include fixed effects for heated living space brackets, income brackets, whether the heating costs are inclusive of warm water, and building type (whether it is a single-family or two-family house). Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

during the previous winter of 2021/2022. However, when we control for a large set of household characteristics, there is some indication that gas users reported to have slightly lower nighttime thermostat settings than their non-gas counterparts (column 4). In the following analysis, we examine *changes* in thermostat settings, which implicitly account for any pre-existing differences in temperature preferences between gas and non-gas households that are time-invariant.

For unbiased estimates of the household response to rising costs, the exclusion restriction further requires that gas customers were not inherently more likely than users of other heating fuel types to save energy for reasons other than rising energy bills. Typically, energy consumers have various motivations for saving energy, and we would a priori expect these motivations to be similar for both gas and non-gas users. Moreover, government-led campaigns aimed at increasing public awareness for energy conservation were not targeting gas users in particular. Fig. 2 summarizes reasons given by the respondents

to save during the heating season of interest (2022/2023). The graph shows that costs were the most important factor for changes in heating behavior among households. Moreover, solidarity to save during the energy crisis was an important reason (top three) for all fuel types and not limited to gas users.

We also show in Appendix C, Table C.1, that many households who do not heat with gas also reported high intentions to save energy (on par with gas customers), which involved reducing their thermostat settings strongly. However in 2022, gas households may have had additional priorities to support Ukraine by decreasing energy consumption, thereby reducing the financial resources that fund the ongoing invasion by Russia. Moreover, it was clear that Germany would need to cut back on gas in order to weather the supply shortages after all Russian gas imports came to a halt in September 2022. We argue that the high potential of moral motives to save energy applied to both gas and oil, both largely imported from Russia in 2022. By limiting the estimation sample to gas and oil fuel types, we difference out the bias due to the moral motives of energy users to save during the heating season. In short, comparing two fuel types that were directly affected by the energy supply crunch followed by the Russian invasion serves as a robustness check of the exclusion restriction and thus the main findings (see Appendix D).

Table 4 reports differences in investment behavior between gas and non-gas households across survey years. The specification includes fixed effects for tenure status (renter versus owner) and building type. Using measures of both planned and completed retrofits, we do not observe any significant differences between gas and non-gas households prior to the energy price crisis. These differences, however, emerge following the onset of the crisis and persist for at least three years. In the next subsection, we examine to what extent this pattern can be explained by the initial increase in cost expectations, using our econometric specification.

Table 4
Differences in retrofit investments by survey year.

Panel A: Planned retrofits until 2030				
	(1)	(2)	(3)	(4)
Gas user	0.002 (0.0096)	0.066*** (0.0086)	0.055*** (0.0095)	0.031*** (0.0095)
Survey year	2021	2022	2023	2024
N	8928	11 249	9397	7822
Panel B: Completed retrofits since last survey year				
		(5)	(6)	(7)
Gas user		0.013 (0.0085)	0.025*** (0.0076)	0.047*** (0.0104)
Survey year	n/a	2022	2023	2024
N		9219	9397	7822

Notes: In Panel A, the dependent variable is planned retrofits, an indicator variable, which equals 1 if household reports to have a retrofit planned in at least one of the following categories until 2030: (1) Insulation of the roof, (2) Insulation of the top floor ceiling, (3) Insulation of the external wall including basement wall, (4) Insulation of the basement ceiling/floor, (5) Renovation of the windows, (6) Optimization of the existing heating system, (7) Installation of new devices for heat generation, and (8) Other. In Panel B, the dependent variable is completed retrofits, an indicator variable, which equals 1 if household reports to have completed a retrofit since the previous survey year in at least one of the following categories above. Note that we do not measure completed renovations in 2021, the first wave of the survey. All regressions include fixed effects for tenure status (renter versus owner) and building type (whether it is a single-family or two-family house). Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

4.2. IV estimation

We apply the identification strategy to the full sample of households to analyze the effect of energy cost expectations on heating behavior during the winter of 2022/2023 using the two-stage least squares (2SLS) estimation method:

$$Cost_i = \gamma Z_i + \mathbf{x}'_i \boldsymbol{\pi}_1 + u_{1i} \tag{1}$$

$$Thermostat_i = \beta Cost_i + \mathbf{x}'_i \boldsymbol{\pi}_2 + u_{2i} \tag{2}$$

where Eq. (1) is our first stage regression. $Cost_i$ is a continuous variable measuring a household's expected change in heating costs on the next heating bill and Z_i is the instrumental variable, indicating whether the household uses gas as the main heating fuel source, $Z_i = \mathbb{1}_{(Gas_i=1)}$. $Z_i = 0$ if the household uses oil, district heating, electricity, pellets or LPG. u_{1i} denotes the error term.

Eq. (2) estimates our coefficient of interest β , where $Thermostat_i$ is the dependent variable of interest, capturing both the planned and actual change in room thermostat settings (0–5 radiator units), averaged across all heated rooms in each home i . \mathbf{x}_i is a vector of household characteristics (income, thermostat type, size of the home measured by the heated living space, building type, tenure status, and whether warm water is included in the heating bill) to control for heterogeneity in the structure of homes, heating technology, and other potential differences in household ability to control temperature. u_{2i} denotes the error term of the second-stage regression.

Using the same identification strategy, we further estimate the causal effect on both planned renovations until 2030 and completed investments during year survey year for which we have data. We reduce \mathbf{x}_i to include only tenure status (i.e., whether the respondent is an owner-occupier or a tenant), building type (i.e., whether the respondent resides in a multi-apartment building), and replace Eq. (2) with the following:

$$Renovations_i = \beta Cost_i + \mathbf{x}'_i \boldsymbol{\pi}_2 + u_{2i} \tag{3}$$

where Eq. (3) is the second-stage regression. $Renovations_i$ is a binary dependent variable capturing either planned energy upgrades until 2030 or completed renovations in at least one of the following categories

since the previous survey year: (1) Insulation of the roof, (2) Insulation of the top floor ceiling, (3) Insulation of the external wall including basement wall, (4) Insulation of the basement ceiling/floor, (5) Renovation of the windows, (6) Optimization of the existing heating system, (7) Installation of new devices for heat generation, and (8) Other. It is important to note that we do not observe completed renovations in 2021, the year of the first survey wave. Furthermore, unlike our analysis of temperature-setting behavior, we do not have the same exclusion restriction concerns when considering investment decisions. This is because households with gas heating did not have systematically different incentives to invest in energy-efficient technologies at the onset of the crisis, other than through the cost channel. We confirm this by running falsification tests using the same outcome variables before the energy price crisis. However, reported intentions to retrofit in 2023 and 2024 are likely influenced by concurrent policy interventions—specifically, the GEG reform and changes to BEG funding programs introduced from late 2023 onward. We account for this in the interpretation of our estimates, acknowledging the potential confounding effects of these policy changes on actual retrofit behavior in 2024—a year marked by a notable surge in activity. It is likely that some retrofitting plans, which might otherwise have been implemented later, were accelerated in response to regulatory pressure from the GEG reform and the expansion of available funding support.

5. Results

5.1. Intended and actual thermostat settings

Tables 5 and 6 present the results for the effect on planned average room thermostat settings for daytime and nighttime, respectively. For comparison purposes, the first column (1) presents OLS estimates of Eq. (2) assuming that reported cost expectations do not suffer from endogeneity bias. Note that we scaled the variable capturing expected change in costs by 10 for ease of reading the coefficients. For both day and night temperature thermostat settings, we detect close to a null effect on planned changes in heating behavior. We proceed with correcting for potential endogeneity in the next columns, with and without the full set of controls for household characteristics. The first stage regression captures the strong correlation between the expected change in heating costs and whether heating is fueled by gas. The relevance of the gas indicator as an instrument is confirmed by the high F-statistics estimated in each first stage specification. The coefficient estimate in the first stage indicates that gas users were expecting the change in heating costs to be 20% higher (on the next heating bill) on average, compared to non-gas users.

Turning to the IV estimate of our coefficient of interest, the effect of expected heating cost changes on the intended change in room thermostat settings, we detect a strong reduction in mean room thermostat settings in response to an increase in cost expectations. A 10 percentage point increase in expected costs leads to a household intention to reduce mean room temperature settings by 0.037 units during the day (Table 5) and 0.025 units (Table 6) on the radiator scale during the night. A reduction of one full unit in thermostat or radiator settings corresponds to lower temperatures by about 4 Celsius degrees. To put this into perspective with the expected average changes in costs shown in Table 1, a household expecting a 70% increase in heating costs during the next billing period intended to reduce the average thermostat setting of the room by 0.26 units during the day and about 0.18 units during the night. This represents up to a 1 degree Celsius reduction in mean room temperatures during the day and 0.7 degrees Celsius reduction in mean room temperatures during the night.

While intentions are a strong predictor of actual behavior, planned changes do not always translate into corresponding actions. Table 7 shows that there was no observed effect on either daytime or nighttime thermostat settings, as reported retrospectively for the 2022/23 heating season in the subsequent 2023 survey following the peak of the energy

Table 5
Effect on daytime thermostat settings (0–5).

	(1) - OLS	(2) - 2SLS		(3) - 2SLS	
	Thermostat	First stage Cost Exp./10	IV Thermostat	First stage Cost Exp./10	IV Thermostat
Cost Exp./10	-0.002** (0.001)		-0.037*** (0.007)		-0.038*** (0.008)
Gas user		2.142*** (0.181)		2.142*** (0.182)	
Controls				Yes	Yes
# of Obs.	7463	7463	7463	7463	7463
First stage <i>F</i>		139.66		138.10	

Notes: All regressions include fixed effects for the thermostat type of thermostat (predominantly used by the households to control temperature) and tenure status (renter versus owner). Controls include fixed effects for heated living space brackets, income brackets, whether the heating costs are inclusive of warm water, and building type (whether it is a single-family or two-family house). Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6
Effect on nighttime thermostat settings (0–5).

	(1) - OLS	(2) - 2SLS		(3) - 2SLS	
	Thermostat	First stage Cost Exp./10	IV Thermostat	First stage Cost Exp./10	IV Thermostat
Cost Exp./10	0.000 (0.001)		-0.025*** (0.008)		-0.024*** (0.008)
Gas user		2.018*** (0.168)		2.038*** (0.169)	
Controls				Yes	Yes
# of Obs.	8675	8675	8675	8675	8675
First stage <i>F</i>		144.57		145.64	

Notes: All regressions include fixed effects for the thermostat type of thermostat (predominantly used by the households to control temperature) and tenure status (renter versus owner). Controls include fixed effects for heated living space brackets, income brackets, whether the heating costs are inclusive of warm water, and building type (whether it is a single-family or two-family house). Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7
Effect on actual winter 2022/2023 temperature settings.

	(1) - 2SLS Daytime	(2) - 2SLS Daytime	(3) - 2SLS Nighttime	(4) - 2SLS Nighttime
Cost Exp./10	0.000 (0.010)	0.000 (0.010)	0.010 (0.013)	0.010 (0.013)
Controls		Yes		Yes
# of Obs.	5511	5511	6307	6307
First stage <i>F</i>	91.80	91.55	90.23	90.79

Notes: The dependent variable measures either daytime or nighttime room thermostat settings converted to the 0–5 unit scale. All regressions include fixed effects for the thermostat type of thermostat (predominantly used by the households to control temperature) and tenure status (renter versus owner). Controls include fixed effects for heated living space brackets, income brackets, whether the heating costs are inclusive of warm water, and building type (whether it is a single-family or two-family house). Note that we lose about 25 percent of the estimation sample in the following survey wave, thus a lower sample size. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

price crisis. One possible explanation for why intentions to lower temperatures were not realized is that households may have adjusted their thermostat settings multiple times throughout the heating season, making lower settings temporary rather than sustained. Another perspective is that cost expectations declined significantly for many households over the course of winter 2022/23, leading to a weaker behavioral response. However, this explanation seems unlikely, given that prices did not return to pre-crisis levels and remained high throughout 2023 and into 2024 (see Fig. 1). An additional factor could be the timing of the survey. Most respondents were surveyed in October, a month that was unusually warm in 2022 compared to historical norms.¹⁹ As

¹⁹ According to Eurostat temperature data, Germany recorded 140.1 Heating Degree Days in October 2022, which is 1.50 standard deviations below the historical average for the period from 1979 to 2022.

a result, households may have been overly optimistic about how much they could reduce their thermostat settings, only to revise these changes as colder weather sets in later in the season.

5.2. Planned investments and retrofit activity over time

We next analyze how higher cost expectations influence household decisions to invest in retrofits. Table 8 includes all retrofit investment types, while Table 9 focuses specifically on renovations to the building envelope and optimizations of existing heating systems, excluding complete heating system renewals. In both tables, Panel A shows how increased expectations of heating costs affect the likelihood of planning retrofits through 2030 in each survey year. Panel B, in turn, shows the effect on the likelihood of completing retrofit projects, based on responses from each survey year.

Increasing cost expectations provide financial incentives for investments in energy-saving technologies, alternative energy sources, and efficiency improvements in existing technology, all aimed at long-term savings on energy bills. We find that these investment incentives were absent in the year preceding the crisis. In Panel A of Table 8, the estimate in the first column indicates that households with higher cost expectations in 2022 did not have a higher likelihood to make investment plans until 2030 before the energy price crisis (when surveyed in August 2021). In Panel B, we find that households with higher cost expectations were also not more likely to have completed retrofit investments since August 2021 until surveyed in October of 2022. Together, these null estimates suggest that, prior to the energy price crisis (ex-ante), investment incentives were absent for those hit with cost shocks during the energy price crisis.

Starting with the 2022 survey year, households with higher expectations of heating cost increases became more likely to plan retrofit projects in response to rising energy prices. In Panel A, the second column shows that a 10 percent expected increase in heating costs

Table 8
Effect on retrofit investments by survey year.

Panel A: Planned retrofits until 2030				
	(1) - 2SLS	(2) - 2SLS	(3) - 2SLS	(4) - 2SLS
Cost Exp./10	0.001 (0.0046)	0.031*** (0.0046)	0.024*** (0.0046)	0.013*** (0.0040)
Survey year	2021	2022	2023	2024
# of Obs.	8928	11 249	9397	7822
First stage <i>F</i>	155.95	202.56	196.67	200.62
Panel B: Completed retrofits since last survey year				
	(5) - 2SLS	(6) - 2SLS	(7) - 2SLS	
Cost Exp./10		0.006 (0.0040)	0.011*** (0.0035)	0.019*** (0.0044)
Survey year	n/a	2022	2023	2024
# of Obs.		9219	9397	7822
First stage <i>F</i>		172.95	196.67	200.62

Notes: In Panel A, the dependent variable is planned retrofits, an indicator variable, which equals 1 if household reports to have a retrofit planned in at least one of the following categories until 2030: (1) Insulation of the roof, (2) Insulation of the top floor ceiling, (3) Insulation of the external wall including basement wall, (4) Insulation of the basement ceiling/floor, (5) Renovation of the windows, (6) Optimization of the existing heating system, (7) Installation of new devices for heat generation, and (8) Other. In Panel B, the dependent variable is completed retrofits, an indicator variable, which equals 1 if household reports to have completed a retrofit since the previous survey year in at least one of the following categories above. Note that we do not measure completed renovations in 2021, the first wave of the survey. All regressions include fixed effects for tenure status (renter versus owner) and building type (whether it is a single-family or two-family house). Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

increased the likelihood of households planning renovations until 2030 by 3.1 percentage points. The third and fourth columns indicate that these elevated investment plans persisted into 2023 and 2024, though the estimated effects decline over time. This decline is consistent with households having already taken action following the initial 2022 cost shock—such as completing retrofits, switching to more affordable energy contracts, or adopting alternative heating sources. While cost expectations clearly play a central role in investment decisions, these estimates are likely also influenced by policy developments, including the GEG reform and the expansion of subsidies under the BEG program, particularly for heating system upgrades.

We re-estimate the models excluding major upgrades/renewals of the heating system (see Table 9, Panel A) and find that observed effects in 2023 and 2024 are largely driven by plans to upgrade heating systems. Given that transitioning to more efficient technologies—such as heat pumps—is an expected response to rising fossil fuel prices, it is difficult to fully disentangle the influence of the 2022 cost shock from that of policy incentives on planned retrofits in 2023 and 2024. Nevertheless, the findings do suggest that by 2024 there was a substantial shift in household investment plans toward upgrading heating systems.

Did the households follow through with their investment plans? Unlike the intention and behavior gap in consumption changes, we find that households did on average follow through with their investment plans. The probability that households completed retrofits increases by 1 percentage point in 2023. How much of this is driven by fear of the GEG reforms? Given the complex and time-intensive nature of energy retrofits, including energy consultations (“Energieberatung”), contacting multiple tradespeople (“Handwerker”), waiting periods, application processing through KfW (credit institution providing subsidies) and eventual project execution, we do not expect households to have reacted by May or June 2023 (when the survey took place) to the news of the GEG reform in early 2023. Indeed, we find strong effects for 2023 even when not considering heating system replacements in Panel B of Table 9. The estimated effects can be fully attributed to the initial cost shock resulting from rising energy prices in 2022.

Table 9
Effect on retrofits excluding heating system upgrades.

Panel A: Planned retrofits until 2030				
	(1) - 2SLS	(2) - 2SLS	(3) - 2SLS	(4) - 2SLS
Cost Exp./10	0.002 (0.0044)	0.014*** (0.0042)	0.005 (0.0041)	0.006* (0.0035)
Survey year	2021	2022	2023	2024
# of Obs.	8928	11 249	9397	7822
First stage <i>F</i>	155.95	202.56	196.67	200.62
Panel B: Completed retrofits since last survey year				
	(5) - 2SLS	(6) - 2SLS	(7) - 2SLS	
Cost Exp./10		0.001 (0.0036)	0.006** (0.0031)	0.009** (0.0042)
Survey year	n/a	2022	2023	2024
# of Obs.		9219	9397	7822
First stage <i>F</i>		172.95	196.67	200.62

Notes: In Panel A, the dependent variable is planned retrofits, an indicator variable, which equals 1 if household reports to have a retrofit planned in at least one of the following categories until 2030: (1) Insulation of the roof, (2) Insulation of the top floor ceiling, (3) Insulation of the external wall including basement wall, (4) Insulation of the basement ceiling/floor, (5) Renovation of the windows, (6) Optimization of the existing heating system, and (7) Other. In Panel B, the dependent variable is completed retrofits, an indicator variable, which equals 1 if household reports to have completed a retrofit since the previous survey year in at least one of the following categories above. Note that we do not measure completed renovations in 2021, the first wave of the survey. All regressions include fixed effects for tenure status (renter versus owner) and building type (whether it is a single-family or two-family house). Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

We estimate an increased likelihood (2 percentage points) of completed investments in 2024. This increase in magnitude from 2023 to 2024 is likely due to a significant overlap between the impact of the energy crisis on fossil fuel-dependent households and the incentive effects of reforms to the Building Energy Act (GEG) and the Federal Funding for Efficient Buildings (BEG). In Table 9 (Panel B), we find that heating systems account for the majority of the effect on completed retrofits in 2024. Thus, policy interventions late 2023 and early 2023 likely gave further incentives to households to complete their investments earlier rather than further in the future. Overall, these results point to the energy price crisis as a catalyst for spurring investments in the building/housing sector.

6. Conclusion

We designed a survey to capture households’ expectations regarding heating energy costs during the unprecedented energy supply crisis of 2022 and to assess their coping strategies. This paper explores households’ intentions to reduce energy consumption, their plans to invest in energy efficiency upgrades, and, most importantly, whether they follow through on these commitments. Survey respondents provided detailed information on their room thermostat settings, which serve as a proxy for heating demand preferences, as well as annual reports on planned energy retrofits until 2030 and completed renovations. Recognizing the potential for divergence between stated intentions and actual behavior, we analyze households’ medium-term responses to assess how realized consumption patterns and investment decisions have deviated from initial plans, on average.

Households anticipated a substantial increase in heating costs, averaging a nearly 70 percent increase on their forthcoming energy bills. In direct response to this extreme price shock, they initially intended to lower their mean room thermostat settings. However, we do not find a sustained effect of the cost shock on realized temperature settings during the winter of 2022/2023. Notably, households expecting higher energy expenses were more inclined to perceive energy-saving investments as viable post-crisis measures. They not only planned to retrofit their homes with energy-efficient components but were also

more likely to follow through with these plans, underscoring the role of cost expectations in shaping long-term energy efficiency decisions.

Our findings suggest a promising dynamic in household energy cost management. In the short term, significant cost shocks appear to prompt households to reduce energy consumption as an immediate coping strategy. Simultaneously, households anticipating higher future costs are more inclined to view investments in energy efficiency or heating system upgrades as viable long-term solutions, rather than permanently lowering thermostat settings. This behavior suggests that, for households in our sample, the trade-off between heating costs and indoor comfort may already be near an optimal equilibrium—averaging around 22.5°C during the day and approximately 19°C at night. However, confirming this interpretation would require more detailed, high-frequency household-level data, which is beyond the scope of this article.

One limitation of the paper is that we study cost expectations at the time of the survey. This was necessary due to volatile expectations of surveyed households. For instance, after the survey had taken place, economic measures were put in place to cap the gas price and compensate gas-consuming households for the high costs of heating during the winter of 2022–2023. Our analysis in the paper uses data collected before these policies were announced, and thus largely circumvents the problem of households factoring in lower than expected cost shock in anticipation of social payments from the governments to partially offset the rise in energy bills. However, we capture arguably the upper bound estimates of the willingness of households to lower heating demand and to make long-run investments in response to significant increases in costs. Importantly, these results should be interpreted as capturing expectation-driven responses within a salient policy context, since public signals and anticipated regulation may partly shape the formation of cost expectations themselves. Finally, these findings relate to the marginal behavioral response to cost expectations and thus cannot comment on overall trends in residential gas consumption, which were likely driven by additional channels beyond the price during the winter of 2022/2023.

Price-based climate policy is a cornerstone of an economically efficient strategy for reducing carbon emissions from energy consumption. However, its success in the heating sector largely depends on how responsive households are to price signals, particularly their willingness to take prompt action during energy crises. Our findings indicate that households recognize the benefits of investing in cost-saving technologies as a means of protecting themselves from the long-term financial strain of rising energy prices. In the long run, investments in energy-efficient solutions may prove more effective in reducing consumption than minor behavioral adjustments. Overall, these results reinforce confidence in the price mechanism as a key driver of household investment decisions aimed at decreasing reliance on fossil fuels, whether due to supply constraints or planned phase-outs under climate policy objectives.

Moreover, our results underscore a notable shift by households towards improving the energy efficiency of the building stock following the start of the energy crisis, despite the significant monetary and non-monetary costs that are associated with retrofit investments (Fowlie et al., 2015; Gerarden et al., 2017). While this study focuses on household responses to a sudden, substantial, and salient increase in energy costs, its conclusions may not necessarily extend to the effects of incremental price changes, such as those induced by rising carbon prices. Further research is warranted to explore this distinction.

Finally, the observed household responses also resonate with the broader policy framework established by the European Union's National Energy and Climate Plans (NECPs) for 2030, which foresee a substantial contribution from the residential sector to achieving energy efficiency and emissions reduction targets. The patterns identified here — namely, the responsiveness of households to cost signals and their willingness to invest in long-term efficiency measures — align with the type of behavioral adaptation envisioned in these plans. Situating

our findings within this long-term policy perspective underscores their relevance beyond the immediate crisis context and highlights the potential of price mechanisms to complement regulatory and subsidy-based measures in realizing the EU's energy transition objectives.

CRedit authorship contribution statement

Puja Singhal: Conceptualization, Methodology, Data curation, Software, Investigation, Formal analysis, Visualization, Validation, Writing – original draft, Writing – review & editing. **Kathrin Kaestner:** Methodology, Data curation, Writing – review & editing. **Antonia Schwarz:** Writing – original draft, Writing – review & editing. **Michael Pahle:** Writing – review & editing, Project administration.

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Appendix A. Additional figures and tables

See Fig. A.1 and Table A.1.

Appendix B. Energy cost shocks as financial burden

This section provides evidence that substantial increases in energy costs would be perceived as a financial hardship by respondents in our survey sample. The degree of financial hardship on households due to increases in energy costs was of great concern among policy makers and the general population. A separate survey instrument allowed us to test whether this was indeed the case among households in 2022. See question **Ist20** in Appendix E.

All surveyed head of households were *randomly* assigned a hypothetical increase in their heating costs on the next heating bill from the following set: [10%, 50%, 100%, 200%, 300%]. Subsequently, the respondents were asked to give a qualitative answer on the degree of hardship that such a hypothetical increase in costs would entail for their household finances (Scale: 1 to 5). We created an indicator variable reflecting whether respondents perceived the cost increase as a high financial burden. Fig. B.1 shows the share of respondents who reported high perceived financial burden (vertical axis) in each category of hypothetical cost increase that was shown to the respondents (horizontal axis). The graph shows that higher increases in energy costs cause a greater degree of financial hardship for households in our survey sample. A univariate OLS regression between the two variables produces a highly statistically significant coefficient ($p < 0.001$).

Table A.1

Timeline for panel surveys.

GHHP	Survey year	Field dates
1st wave	2021	04 Aug–02 Sept
2nd wave	2022	29 Sept–03 Nov
3rd wave	2023	24 May–22 June
4th wave	2024	16 Oct–06 Nov

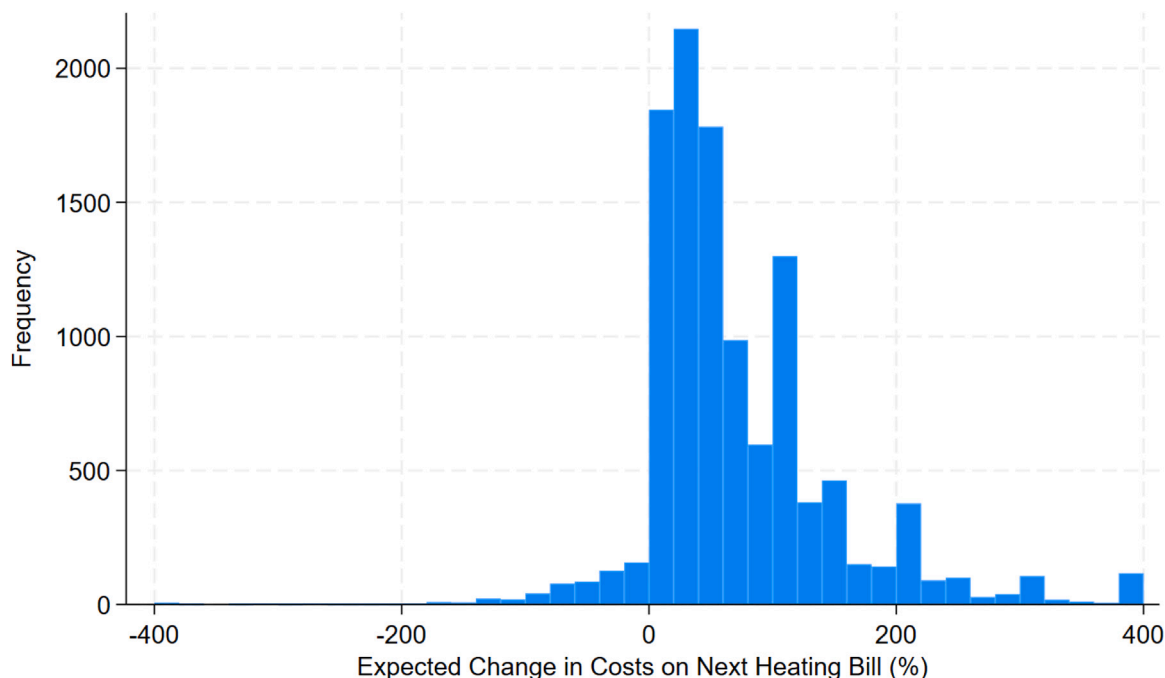


Fig. A.1. Distribution of expected change in heating costs.
Notes: The figure shows the distribution of the expected year-on-year percentage change in heating costs on the next heating bill.

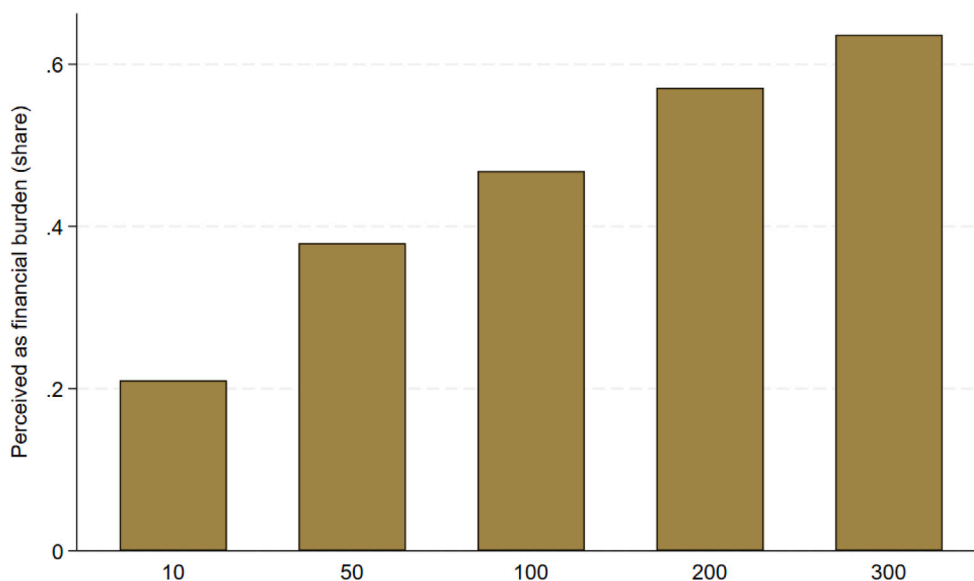


Fig. B.1. High financial burden due to hypothetical increase in energy costs.
Notes: Each surveyed household head was randomly assigned a hypothetical heating cost increase for the next season from the following set: [10%, 50%, 100%, 200%, 300%]. Respondents then rated the perceived financial hardship of this increase on a 1-to-5 scale, with 4 and 5 indicating a high burden. We created an indicator variable reflecting whether respondents perceived the cost increase as a high financial burden. The figure plots the percentage heating cost increase (x-axis) against the share of respondents indicating high financial burden (y-axis).

Appendix C. Household intentions to save energy

Table C.1 presents descriptive evidence indicating that on average both gas and non-gas users had the intention to reduce their room temperature. Moreover, we note a strong alignment between reported

changes in average room thermostat settings and the qualitative intention to conserve energy categories reported by respondents (as shown in the first column of the table). Thus, we can infer that respondents possess a solid understanding of how adjustments to thermostat settings contribute to energy conservation. Particularly striking is that

Table C.1
Intention to reduce heating during winter 2022–2023.

Qualitative category	Gas		Non-Gas		All
	Δ in Day setting	Δ in Night setting	Δ in Day setting	Δ in Night setting	
	Reduce very strongly	−0.62 (0.80)	−0.32 (0.93)	−0.62 (0.91)	
Reduce strongly	−0.50 (0.66)	−0.28 (0.84)	−0.52 (0.71)	−0.27 (0.89)	2359
Reduce slightly	−0.35 (0.65)	−0.23 (0.79)	−0.33 (0.61)	−0.19 (0.79)	4050
Reduce very slightly	−0.26 (0.65)	−0.12 (0.76)	−0.26 (0.55)	−0.19 (0.74)	993
Full sample	−0.37 (0.65)	−0.21 (0.77)	−0.30 (0.60)	−0.17 (0.74)	9180

Notes: The table summarizes change in room thermostat or temperature settings (averaged across all rooms), separately for daytime and nighttime, where Day/Night Setting = 0 if (Heater Off or Temp. < 12°C), = 1 if (12°C ≤ Temp. < 16°C), = 2 if (16°C ≤ Temp. < 20°C), = 3 if (20°C ≤ Temp. < 24°C), = 4 if (24°C ≤ Temp. < 28°C), = 5 if (28°C ≤ Temp.) The table reports means, with standard deviations in parentheses. We report these stats by the qualitative intention to change heat energy consumption in the coming winter (2022–2023) compared to last winter (2021–2022), indicated in the first column. “Full sample” also includes those respondents (N = 1365) who reported that they do not intend to change consumption (temperature settings) from last heating season, i.e. change in the thermostat setting is 0.

the average desired reduction in thermostat settings appears generally consistent within qualitative responses across both gas and non-gas users. This indicates that there was a general willingness to save energy during the winter heating season of 2022/2023, which was not only limited to gas users. Nevertheless, the data do suggest that households heating with gas had intentions to reduce the room thermostat set-points slightly more in comparison to non-gas users, both during daytime and nighttime (see last row “Full Sample”).

Appendix D. Gas versus heating oil

This section provides a robustness check for the main specification used in this study. While we cannot directly prove the exclusion restriction, we offer supporting evidence that our results remain consistent when adjusting the sample to include users with similar non-financial incentives to conserve energy. Specifically, we restrict the sample to households that rely on gas and oil for heating—two energy sources primarily supplied by Russia in 2022. As a result, we focus on households that likely had direct political and moral motivations to reduce energy consumption during the winter of 2022–2023.

Fig. D.1 highlights the significant concern among German online search users regarding heating oil following Russia’s invasion of Ukraine and throughout Europe’s energy supply crisis. Given that oil users have more flexibility in timing their purchases, the sustained interest in heating oil is unsurprising. Throughout this period, heating oil remained the dominant search topic, except for one week (August 14–20, 2022), when searches for the gas levy briefly surpassed it. By the fall of 2022, just before the start of the winter heating season, interest in the gas surcharge and heating equipment (thermostats) had risen sharply, making them particularly prominent topics in online searches.

Before presenting the new IV estimates (Local Average Treatment Effects), we show results from OLS regressions to check the balance in temperature preferences between households heating with gas and oil. Table D.1 shows that both reported daytime and nighttime thermostat preferences between gas and oil households were statistically identical during the winter of 2021/2021.

Finally, to support our causal interpretation of the estimates in the main analysis, we re-estimate the regression specification (Eqs. (1) and (2)) comparing households that heat with gas and oil. Tables

Table D.1
Gas & oil - winter 2021/2022 thermostat settings (0–5).

	Daytime		Nighttime	
	(1)	(2)	(3)	(4)
Gas user	0.007 (0.021)	0.008 (0.021)	0.019 (0.021)	0.033 (0.021)
Control set		Yes		Yes
N	5362	5362	6153	6153
Adj. R ²	0.117	0.122	0.047	0.060

Notes: The sample of households is limited to those using gas and heating oil for heating purposes. All regressions include fixed effects for the thermostat type of thermostat (predominantly used by the households to control temperature) and tenure status (renter versus owner). Controls include fixed effects for heated living space brackets, income brackets, whether the heating costs are inclusive of warm water, and building type (whether it is a single-family or two-family house). Standard errors are reported in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

D.2 and D.3 show the results. The gas indicator continues to be a relevant instrumental variable in this setting; this is captured by the high F statistics computed in the first stage of the 2SLS regressions (with and without controls). The coefficient of approximately 2.2 on the gas indicator means that gas users were expecting heating costs to be 22 percent higher on the next heating bill compared to heating oil users. Using only heating oil users as a comparison group for gas users, coefficient estimates in the second stage regressions yield higher reductions in mean room thermostat settings in response to an increase in cost expectations. Specifically, a 10 percent point increase in expected costs leads to households intending to reduce mean daytime thermostat setpoint by 0.043 units and mean nighttime thermostat setpoint by 0.035 units. This translates to a 1.2 degree Celsius reduction during the day and 1 degree Celsius reduction during the night as a household response to heating costs expected to rise by 70% on the next heating bill.

Appendix E. Supplementary data

Supplementary material related to this article can be found online at <https://doi.org/10.1016/j.eneco.2026.109142>.

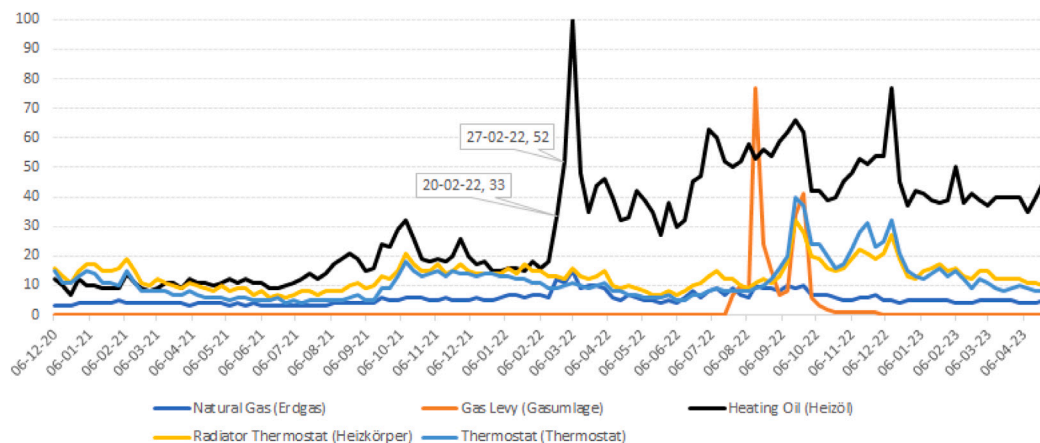


Fig. D.1. Interest over time in Germany.

Notes: The figure shows interests over time in keywords relevant to the empirical analysis. Interests are measured by how many web searches were done for the key term, relative to the total number of searches done on Google in Germany. The data is presented on the 1–100 scale and plotted at the weekly frequency—this means that during the week of February 20–26 2022, heating oil received an interest rating of 33. The plot here shows that heating oil’s relative popularity increased more than that for natural gas and has been particularly elevated since the beginning of the Russian invasion of Ukraine (Feb. 24 2022). Another interesting observation is that the relative interest in the radiator thermostat and room thermostat coincides with the spike in interest for the potential gas surcharge that was announced during the summer of 2022 by the German government.

Table D.2
Gas & Oil - daytime thermostat settings (0–5).

	(1) - OLS	(2) - 2SLS		(3) - 2SLS	
	Thermostat	First stage Cost Exp./10	IV Thermostat	First stage Cost Exp./10	IV Thermostat
Cost Exp./10	-0.002* (0.001)		-0.043*** (0.011)		-0.044*** (0.011)
Gas user		2.167*** (0.261)		2.184*** (0.264)	
Controls				Yes	Yes
# of Obs.	5362	5362	5362	5362	5362
First stage F		69.17		68.37	

Notes: The sample of households is limited to those using gas and heating oil for heating purposes. All regressions include fixed effects for the thermostat type of thermostat (predominantly used by the households to control temperature) and tenure status (renter versus owner). Controls include fixed effects for heated living space brackets, income brackets, whether the heating costs are inclusive of warm water, and building type (whether it is a single-family or two-family house). Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.3
Gas & Oil - nighttime thermostat settings (0–5).

	(1) - OLS	(2) - 2SLS		(3) - 2SLS	
	Thermostat	First stage Cost Exp./10	IV Thermostat	First stage Cost Exp./10	IV Thermostat
Cost Exp./10	0.000 (0.001)		-0.035*** (0.011)		-0.033*** (0.011)
Gas user		2.171*** (0.238)		2.179*** (0.242)	
Controls				Yes	Yes
# of Obs.	6153	6153	6153	6153	6153
First stage F		82.96		81.40	

Notes: The sample of households is limited to those using gas and heating oil for heating purposes. All regressions include fixed effects for the thermostat type of thermostat (predominantly used by the households to control temperature) and tenure status (renter versus owner). Controls include fixed effects for heated living space brackets, income brackets, whether the heating costs are inclusive of warm water, and building type (whether it is a single-family or two-family house). Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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