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The Costs of Natural Gas Dependency: Price Shocks, Inequality, and Public Policy

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Abstract

Natural gas prices in Germany saw a strong increase at the end of 2021, subsequently worsening with the start of the war in Ukraine in February 2022, raising concerns about the distributional consequences. Our study shows that low-income households are affected the most by the natural gas price increase. Low-income households pay at the median 11.70 percent of their equivalent income on gas bills, compared to 6.21 percent in 2020. Contrarily, high-income households pay at the median 2.41 percent, compared to 1.52 in 2020. Natural gas expenditures are higher for tenants in detached houses and in houses with no double glassing or thermal insulation. Our policy analysis builds on an exploration of new energy expenditure data in 2020 provided by the German Socio-Economic Panel, and shows that a well-targeted subsidy scheme can be more effective for reducing inequality and less costly than a subsidy for all households. Additionally, the introduction of a minimum energy-efficiency standard for buildings can help reduce inequality in the medium-term.

Keywords: Natural gas prices, income distribution, energy efficiency, building retrofit

JEL Codes: D30, Q41, I38

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1 Introduction

Energy prices in Europe are increasing, with tremendous price increases in the first half of 2022. Even in November 2021, average wholesale natural gas prices in Europe had reached levels of 80 Euro per MWh compared to 14 Euro per MWh in November 2020. Following the start of the war in Ukraine, natural gas prices further increased, reaching an unprecedented monthly average of 135 Euro per MWh in March 2022 with no relief in sight.[1] The increase in wholesale prices also affects households, with end consumer prices expected to double from six to about 12 cent per KWh compared to 2021. This has reignited the European debate about energy security and fossil fuel dependence, stressing the need for social policies to provide a minimum level of economic security.

This paper focuses on the distributional effect of the natural gas[2] price shock on heating expenditures in Germany. German households are severely affected by the rise in prices through a rise in the costs for heating, electricity, and other products. One of the most direct impacts of the shock is through an increase in end consumer natural gas prices, since around half of German households use gas for their heating (Bundesverband der Energie- und Wasserwirtschaft, 2019) and the share of renewable energy for heating is still small, at around 16.5 percent in 2021 (Umweltbundesamt, 2022). However, not all households are affected equally by the rise in prices. Households living in larger and less efficient apartments have significantly higher consumption of heating fuels, making them more vulnerable to current increases in consumer prices.

Past studies show that low-income households in Germany spend a significantly higher share of their income on energy and are disproportionately affected by price increases (Grösche and Schröder, 2014, Neuhoff et al., 2013). Often, they cannot reduce their consumption to the same extent as high-income households. Therefore, policy makers will need to introduce energy-related subsidies to prevent social hardships of energy price increases. However, the question of how to best target a subsidy scheme is key for keeping the overall costs of the program low, while maximizing the effect (Giuliano et al., 2020, Alberini and Umapathi, 2021, Barrella et al., 2021). Subsidies for energy-efficient goods and technologies, for example, are preferentially taken up by high-income households and, therefore, often fail to decrease energy poverty (Allcott et al., 2015, Schleich, 2019, Lekavičius et al., 2020).

In Germany, compensation policies were already under discussion at the end of 2021. On

[1]Natural gas prices represent the monthly average of the day ahead price of the European reference price TTF. Natural gas subsequently fell to 89 Euro per MWh in May 2022, thus remaining significantly above the historic average of 19 Euro per MWh during the 2010s.

[2]For the remainder of the paper, we will use the terms natural gas and gas interchangeably.

February 3, 2022, a heating cost subsidy of 135 Euro for recipients of housing benefits ("Wohngeld") was introduced and later increased to 230 and again to 350 Euro, as well as extended to different types of recipients of social benefits. However, doubts remain that the program is well-targeted and sufficient to avoid severe income effects on low-income households. When designing such policy interventions, it is critical to understand the distributional impact of such a program, working to improve the support of vulnerable groups without overcompensating other groups. Moreover, the policy should incorporate incentives to reduce natural gas consumption.

This paper contributes in several ways to the understanding of gas expenditures, inequality and public policies. First, we add to the literature on the distribution of heating expenditures with a specific focus on vulnerable groups using a new survey module from the German Socio-Economic Panel (SOEP). Specifically, we re-evaluate findings in the literature by using detailed representative micro-data on natural gas expenditures of German households. Second, we simulate the distributional consequences of the gas price shock in 2022. Third, we evaluate various policy options in terms of their distributional effect as well as their incentive to reduce natural gas consumption.

In the descriptive analysis of gas expenditure, we find a large variance of heating costs within income groups. We explore different channels to explain the variance and find that the presence of thermal insulation and newer construction decrease the heating costs while larger dwelling-size (especially for single family homes) are associated with higher heating costs. Moreover, home-owners tend to pay less than tenants for their gas bills per square meter. In our policy analysis, we show that targeted schemes, such as a reimbursement of heating costs for low-income households, have lower overall costs while also efficiently reducing the effect of gas price shocks on vulnerable households. However, this might reduce the incentives for building owners to make their buildings more energy efficient. We also show that a minimum standard for buildings would reduce energy expenditures substantially, especially for low-income households.

The rest of the paper proceeds as follows. In section two, we present a summary of the previous literature on the distribution of energy expenditures across income groups and adequate support schemes for alleviating the effect of energy price shocks. In section three, we present the methodology and data used for the analysis. Section four presents summary statistics on the distribution of heating costs in Germany and identifies those groups most vulnerable to extreme price hikes. Section five analyzes three different options for alleviating the effects of such extreme price hikes contrasting lump sum and targeted support schemes. Section six discusses the findings and concludes.

2 Literature Review

Our paper relates to the literature analyzing the distributional effects of heating and energy expenditure. Previous research for the case of Germany has found energy expenditure in Germany to be regressive. In an early contribution, Rehdanz (2007) considers the determinants of heating expenditures using the same dataset as our paper and finds that renters have higher heating costs per square meter than owners. Schulte and Heindl (2017) focus their analysis on the elasticity of energy demand and find that poor households are not able to respond to increases in heating prices in the same way as high-income households. They conduct a simulation of an energy price increase and find that the effects are regressive and that this regressiveness is higher when considering the varying elasticities. Methodologically, the article is most closely related to Grösche and Schröder (2014), who use different inequality measures to analyze the distributional effect of the German feed-in tariff for renewable energy. They find that the German feed-in tariff is regressive. Neuhoff et al. (2013), using a similar approach to analyze the dataset used in our analysis, find, when compared to the average consumer, low-income households pay nearly double the share of their income for electricity. Among other options, the authors simulate how an increase in housing assistance could compensate poor households for this burden. Their results are confirmed by Frondel et al. (2015), who studied the inequality in electricity price burden of German households. Schmitz and Madlener (2020) use the dataset used in our analysis to estimate elasticity of heating consumption to a change in prices for different groups. They find that wealth and home-ownership lead to a lower price responsiveness and find a U-shaped elasticity across consumption deciles indicating that families spending the average amount on gas are the least reactive to heat cost shocks.

International studies find a similar regressive effect of energy expenditures and provide additional information on which groups are especially vulnerable to energy price increases. Mashhoodi (2021) analyze which socio-economic subgroups depend most heavily on natural gas consumption in the Netherlands. They find that natural gas use and dependency is high at both ends of the income distribution. They argue that this is due to poor insulation and low use of electric appliances for low-income households and larger dwellings for high-income households. They further find that elderly people use more natural gas, which is a finding that previous studies echo and which the author relates to a preference for higher temperatures among the elderly. Meier et al. (2013) find that elasticities of British household spending on natural gas and electricity are U-shaped with respect to income, arguing that energy services are a necessity rather than a luxury good for households. In an earlier paper, Meier and Rehdanz (2010) find that income, type of dwelling, household size and age have an important effect on household heating expenditures in Great Britain. For the case of Russia, Orlov (2017) uses a general equilibrium model to analyze the effect of ending natural gas subsidies. He finds that an increase in gas prices would disproportionately harm poor households. He further finds that the most efficient use of the surplus revenues from higher gas prices would be to invest in the energy efficiency of buildings. Hansen (2018) estimate the elasticity of district heating consumers in Denmark and find that the price responsiveness increases with income and decreases with the age of the building. Kostakis et al. (2021) analyze household's natural gas demand in Greece and find that residential demand is inelastic there as well.

While the 2022 energy price crisis is a unique phenomenon in recent Western-European history, there is historic precedent in the Eastern European and Caucasian countries that indicates that poor households are affected by such price increases the most. Our paper relates to the literature examining the effect of these "extreme price hikes." Ersado (2012) consider a 40 percent increase in Armenian gas prices in 2010 and find that the burden of higher energy prices lies disproportionally with poor households. Analyzing the same price hike, Krauss (2016) find that the reform reduced relative welfare in the poorest quintile twice as much as in the second quintile and that the reform led to approximately three percent of households falling below the poverty line. Alberini et al. (2020) consider the effect of a 700 percent price hike in natural gas and electricity prices in Ukraine between 2013-2016 on consumption patterns and find that households have a low elasticity, even for extreme price increases. They further find that wealthier households show a lower elasticity.

Additionally, there are a number of papers considering the effect of targeting energy subsidy schemes to the most-affected groups. Giuliano et al. (2020) investigate the effect of reducing energy subsidies in Argentina and find that reducing the universal energy subsidy while increasing targeted measures can lead to the same distributional outcome at lower costs for the government. For the case of Ukraine, Alberini and Umapathi (2021) estimate that a better targeting of energy subsidies could cut half the costs for the government at only a small welfare loss. Barrella et al. (2021) analyze the effect of making the Spanish cash transfer for heating assistance conditional on dwelling and household characteristics. They find that the conditional transfer improves outcomes, albeit at a significantly higher cost to the taxpayers.

The correct targeting of corrective measures also plays a role in the design of energy efficiency policies. Allcott et al. (2015) show that subsidies for energy efficient goods might be preferentially be taken up by consumers who are less affected by distortions (i.e., "wealthy environmentalist homeowners"). Similarly, Schleich (2019) shows that, with respect to the uptake of high cost energy efficiency technologies, such as retrofit measures, low-income owners show lower adoption rates than high-income owners. Lekavičius et al.

(2020) find that investment subsidies for renewable energy technologies for residential buildings provide the most benefit to higher income groups and, therefore, fail to reduce energy poverty. Thus, support measures should take affordability concerns into account. Wilson et al. (2019) evaluate energy efficiency potential and adoption in low-income households in the US.

3 Data and Methodology

The subsequent analysis is based on the German-Socio-Economic-Panel (SOEP). The SOEP is a representative, yearly panel survey including various individual and household characteristics (Goebel et al., 2019). The SOEP includes a module with a detailed decomposition of energy costs at the household level and was conducted both in 2015 and 2020. The module includes natural gas expenditures for cooking, heating, and warm water supply. We use this information from the 2015 and 2020 waves to conduct our analysis.

We are interested in the question of how natural gas expenditures vary across households. Thus, our analysis focuses on the sub-sample of all households that use gas for heating in their main housing residence (hereafter, the "Restricted" sample). Table 1 presents summary statistics on gas costs and living conditions in our working sample ("Restricted") and the full SOEP sample. The sample reflects 46.9 percent of the full sample in 2020 and 46.7 percent in 2015. In 2020, 78.9 percent of households in the restricted sample also used gas for warm water (81.8 percent in 2015). The share of households using gas for cooking is relatively small. Households heating with gas had an average gas expenditure of 80.39 Euro per month in 2020. This is a moderate increase from 76.76 Euro in 2015. Interestingly, the standard deviation of monthly gas costs almost tripled across these five years, showing a much higher dispersion in 2020.

The living conditions of households using natural gas for heating are comparable to the full sample. Average and median household equivalent income in the restricted seems to be slightly above that of the full sample. The remaining housing conditions seem to be slightly better with larger dwellings on average, a higher share of owners, and a similar monthly rent. Our 2020 working sample includes relatively more owners with 54 percent compared to 45.9 percent in the full sample and slightly more individuals seem to live in a city. This is in line with Braun (2010): the likelihood of using gas for heating depends socio-economic factors, like income, and on regional factors and building characteristics. Information on building types is only available in 2015. Finally, the absolute number of observations remained relatively constant with 6,457 (6,416) households in 2020 (2015).

Using the SOEP as our primary dataset, we conduct two analyses. First, we describe the

Variable	Statistic	2015		2020	
		Restricted	Full	Restricted	Full
Information on gas					
Share heating with gas	mean	1	0.467	1	0.469
	sd	0	0.499	0	0.499
Share warm water with gas	mean	0.818	0.389	0.789	0.373
	sd	0.386	0.487	0.408	0.484
Share cooking with gas	mean	0.118	0.0676	0.0658	0.0423
	sd	0.323	0.251	0.248	0.201
Gas costs per month	mean	76.76		80.39	
	sd	45.49		120.7	
	med	67.62		60.65	
Information on households' living conditions					
Household equivalent income	mean	2,988	2,717	3,261	3,006
	sd	2,226	1,966	2,583	2,454
	med	2,540	2,275	2,800	2,500
Square meters of dwelling	mean	101.1	95.37	103.8	98.35
	sd	44.24	44.69	45.49	46.58
	med	95	85	98	90
Construction year (latest)	mean	1969	1970	1971	1972
	sd	26.92	25.17	27.38	26.18
	med	1971	1971	1971	1971
Rooms	mean	3.92	3.72	4.05	3.86
	sd	1.65	1.67	1.67	1.73
	med	4	3	4	3
Monthly rent	mean	649.2	631.8	601.7	600.9
	sd	327.1	297.9	280.1	297.7
	med	584.1	582.0	550	542
Owner	mean	0.547	0.457	0.540	0.459
	sd	0.498	0.498	0.498	0.498
Share living in a city	mean	0.704	0.679	0.715	0.686
	sd	0.457	0.467	0.451	0.464
Share living in detached houses	mean	0.315	0.318	n/a	n/a
	sd	0.465	0.466	n/a	n/a
Share living in terraced houses	mean	0.220	0.150	n/a	n/a
	sd	0.414	0.357	n/a	n/a
Share living in apartment building (3-4)	mean	0.105	0.103	n/a	n/a
	sd	0.307	0.305	n/a	n/a
Share living in apartment building (>4)	mean	0.348	0.411	n/a	n/a
	sd	0.477	0.492	n/a	n/a
	observations	6,416	15,847	6,457	19,475

Table 1: Descriptives on gas usage and living conditions in 2015 and 2020

Notes: Own calculation based on SOEP v37. The table provides statistics about gas and household living conditions in 2015 and 2020 at the household level. The restricted sample includes households that rely on natural gas while the full sample provides the descriptives for the full sample. Cross sectional household weights apply. The household equivalent income is calculated by dividing household income by the square root of household members. All values are in 2020 prices.

distribution of gas costs for several socio-economic characteristics. Second, we provide a policy analysis including a prediction for increasing gas costs in 2022. Furthermore, we discuss the distributional consequences of several policy measures. The descriptive analysis of gas costs includes the absolute and relative burden for the entire household income distribution. Moreover, we condition gas costs on several characteristics, i.e. tenants and homeowners; renovation status; and different types of dwellings. Additionally, we compare the effect size through a regression analysis. In our descriptive regression analysis, we estimate the following linear model:

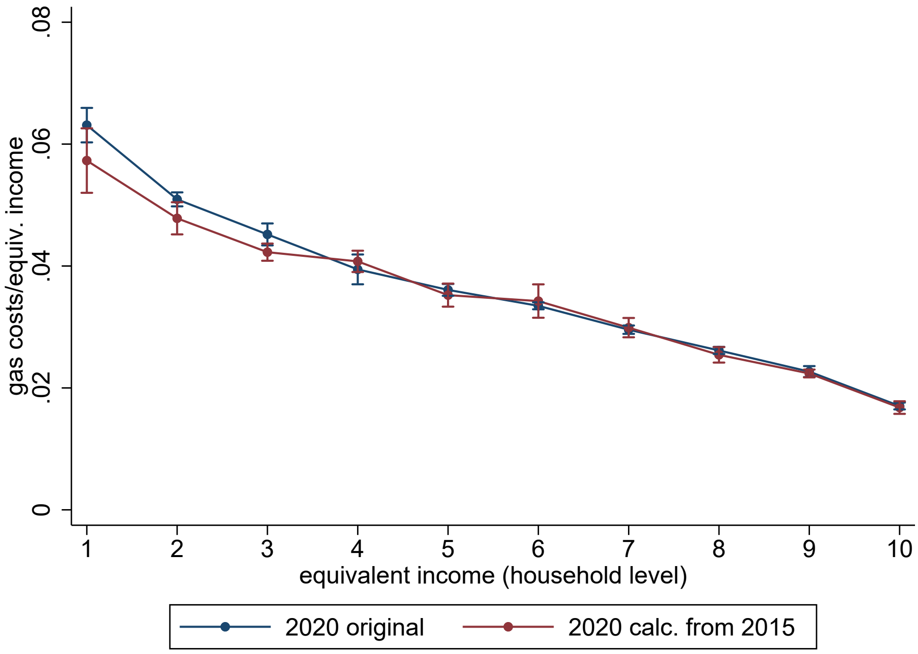
$$ln(c_i^g) = \beta X + \epsilon, \tag{1}$$

where c_i^g describes the monthly natural gas costs for household i, X represents the vector of several household and housing characteristics as well as a constant. ϵ represents the error term. We estimate Equation 1 as ordinary least squares.[3]

Our policy analysis aims to capture the 2022 price shocks in the natural gas market. In Germany, consumer prices rose from around 6.5 to 12.5 cents/kWh at the beginning of 2022. Prices for new contracts even reached 16 cents/kWh in May 2022.[4] We simulate the 2022 gas costs by increasing the household gas prices in 2020 by 90 percent, which is a moderate calculation with regards to developments in the consumer gas market in 2022. Additionally, we assume household income growth per decile at the average rate between 2015 and 2020 according to the information in the SOEP. We then consider the effect that the price increase has by recalculating the share of gas costs on the equivalent income. We next calculate a number of distributional parameters to compare the two outcomes. This approach follows similar simulations by Neuhoff et al. (2013) and Grösche and Schröder (2014). While our simulation approach is straight forward, it includes the strong assumption that gas price elasticities are equal to zero. This assumption potentially distorts the burden of price increases, especially if price elasticities increase with the income distribution (Schulte and Heindl, 2017). As we only observe gas expenditures in two periods, five years apart, the data is not sufficient to measure behavioral responses by households. However, we show that these responses potentially influence the absolute impact of the price shock, but it changes little of the distributional effect. An additional abstraction from the real-life setting is the fact that we do not consider the support systems for heating costs that exist in Germany in 2022. These alleviate the cost increases in the lower percentiles since the heating costs of recipients of social welfare benefits ("Hartz IV") are covered by the state up to a reference value and low-income households that qualify for housing assistance receive an annual lump-sum transfer for heating support.

We test our simulation approach using the fact that we have information for 2015 and 2020 in our dataset. Specifically, we can adjust the gas costs in 2015 according to the *Title Transfer Facility* (TTF) reference price[5] at the end of December 2019. Figure 1 provides the relative burden from gas costs using the original data and using our simulation approach. We see that the approach fits the relative burden along household income deciles quite well, even though it slightly underestimates the real relative burden for the lower deciles. However, the confidence intervals overlap. One advantage of the 2022 extrapolation is that we only estimate over two rather than five years and a smaller time frame potentially reduces biases that arise over time. However, given that the price differences between 2020 and 2022 are considerably larger than between 2015 and 2020,

[3] Additionally, we provide quantile regressions in the Appendix.
[4] End-consumer prices are taken from the commercial comparison site, verivox.de
[5] See Figure 10 in the Appendix for more details.



Own calculation based on SOEP v37 using the restricted working sample. The y-axis provides the gas expenditures divided by household equivalent income. The x-axis shows the deciles of equivalent household income. Confidence bands indicate the 95th percent around the median value and are based on bootstrapped standard errors with 500 replications. Median value by equivalent income decile are shown in the line graph. The blue line represents the 2020 natural gas costs for each household as found in the data. The red line is the prediction of 2020 gas expenditure using our simulation method with 2015 as the base year.

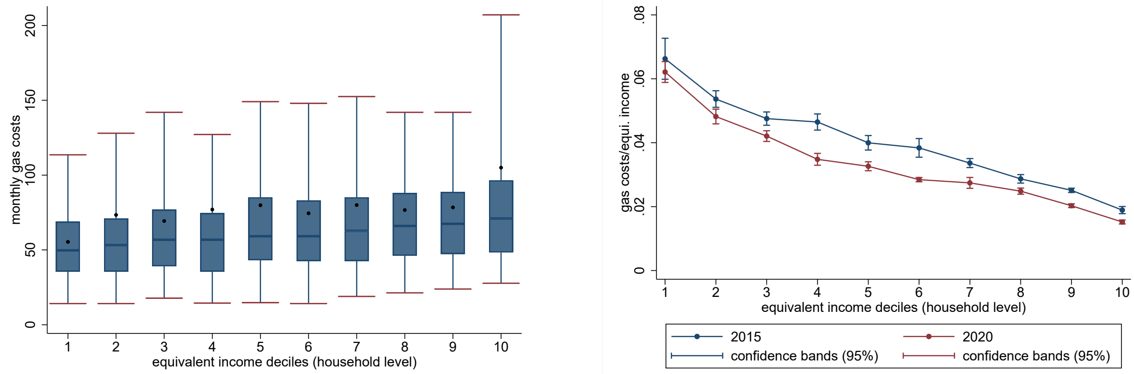
Figure 1: Comparing 2020 versions: calculated and original

the assumption of zero price elasticity might lead to a larger bias with respect to the distributional effect of the price shock. Consequently, we opt for a lower-bound price increase of 90 percent in our main scenario and discuss deviations from these assumptions in the result section.

4 Descriptive Results

4.1 Natural gas expenditures and household income

The first panel of Figure 2 shows natural gas expenditures across income deciles in 2020. Overall, gas expenditure increases with household income. While households with the lowest income had mean gas costs of 55.38 Euro, this increases to 79.88 Euro in middle-income households and 104.98 Euro in the richest households. The figure, however, shows a large variance in the gas costs in all groups. For instance, even in the lowest income group, 25 percent of households have gas costs greater than 68.87 Euro which is above the median value of the last decile. This indicates a small number of highly vulnerable households among the financially weakest members of society.



(a) Absolute gas costs along income deciles

(b) Relative gas costs along income deciles

Own calculation based on SOEP v37 using the restricted working sample. Fig. (a) shows the monthly gas costs across household income deciles. Boxes indicate the 25^{th} to 75^{th} percentile of the distribution. Whiskers indicate the 5^{th} till 95^{th} percentile. Points represent the mean value and horizontal lines represent the median value. Fig (b) shows the relative gas costs of 2015 and 2020. Confidence bands indicate the 95^{th} percent around the median value and are based on bootstrapped standard errors with 500 replications. Median value by equivalent income decile are shown by the line graph.

Figure 2: Gas expenditure and household income

Although higher income households have greater gas costs in absolute terms, this changes when correcting for the household's equivalent income, i.e. household income after correcting for household size. The second panel of Figure 2 displays median gas costs as a share of the equivalent income and illustrates that gas costs have a higher impact on low-income households. In fact, gas costs make up more than 6 percent of household income for the poorest households, which is more than 50 percent higher than the expenditure of the median household (3.3 percent) and more than 300 percent higher than the relative expenditure of the richest decile (1.5 percent). This makes lower-income households more vulnerable to natural gas price increases, especially since they have lower discretionary income to substitute for their additional expense on gas costs. Additionally, previous research shows that poor households are less responsive to heating price increases (Schulte and Heindl, 2017).

4.2 Natural gas expenditures: household and building characteristics

Next, we are interested in seeing how different characteristics correlate with gas expenditure per square meter. By further decomposing the effect of different household and building characteristics, we can investigate how common factors from the literature potentially drive the distributional effect of changes in natural gas prices. We focus on expenditure per square meter for the analysis of ownership and retrofit measures, as it can be seen as an indicator for the energy efficiency of the dwelling. [6] We see that property ownership and energy efficiency investments benefit high-income households, while the type of housing leads to higher energy expenditure among high-income households.

4.2.1 Natural gas expenditures and home ownership

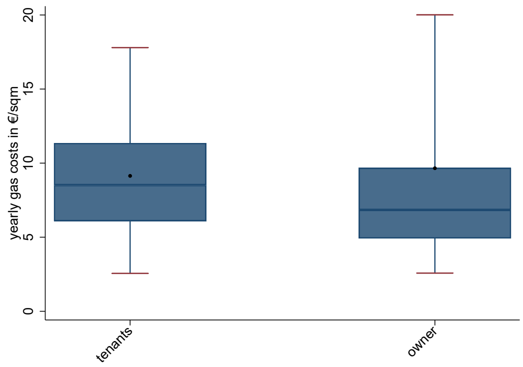
One factor discussed in the literature is the difference in heating expenditures between tenants and home owners due to higher incentives for energy efficiency investments by owners of the property. Incentives for investments by landlords are lower, since the variable costs of heating are paid for by the tenants, while the fixed costs of energy efficiency investments are paid upfront by the owners. For owners-occupied houses, incentives to invest in energy efficiency are higher because they benefit from it directly via reduced energy costs. Empirical analyses of Germany, such as Rehdanz (2007), find that tenants do indeed have higher heating costs per square meter than owners. We can confirm these findings when looking at the median gas costs per square meter of owners and renters in the first panel of Figure 3. The median expenditure of tenants (8.32 Euro per square meter) is 22 percent higher than the median expenditure of owners (6.84 Euro per square meter). This difference hints at the above described "landlord-tenant-dilemma." There is, however, a large dispersion in the gas costs of owners, thus indicating differences in vulnerability of home owners with some owners seemingly living in low-insulated buildings.

The incentives for energy efficiency effects clearly benefit high-income households. The second panel of Figure 3 shows yearly gas costs per sqm on the left y-axis and deciles of the equivalent household income at the x-axis. The right y-axis also provides the share of tenants and homeowners in each decile. The difference between gas costs per square meter for tenants and homeowners is significant for most of the upper half deciles of the income distribution. The figure further shows that there is a clear relation between equivalent income and house ownership with high income households being more likely to live in a dwelling that they own themselves.

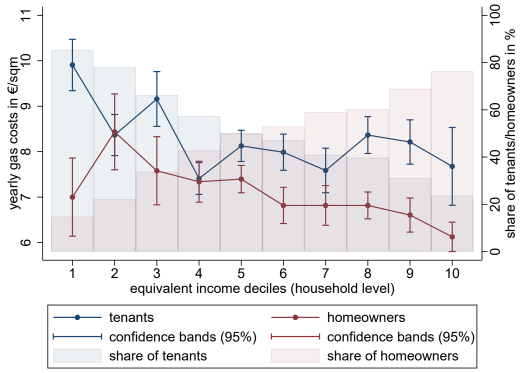
4.2.2 Natural gas expenditures and building type

A possible factor limiting the distributional impact of gas price increases is the building type. The first panel of Figure 4 shows that the distribution of gas costs per square meter decreases with building size. This confirms the results of Meier and Rehdanz (2010), which finds that, for the case of the UK, bungalows and terraced houses have higher heating costs than flats. We learn from the second panel of Figure 4 that households

[6] Similarly, the different classes of energy-performance certificates (EPCs) in the EU, ranging from label A to H, depend on the energy use per square meter.



(a) Gas costs for tenants and owners

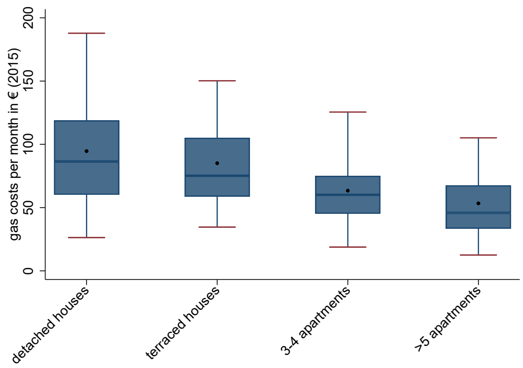


(b) Difference in gas costs for tenants and owners along income deciles and share of tenants/owners

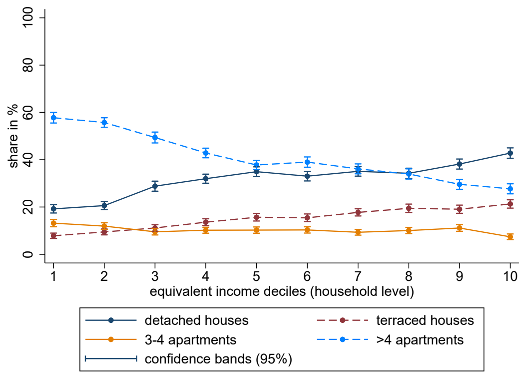
Own calculation based on SOEP v37 using the restricted working sample. Fig. (a) shows the yearly gas costs per square meter for tenants and owners. Boxes indicate the 25^{th} to 75^{th} percentile of the distribution. Whiskers indicate the 5^{th} till 95^{th} percentile. Points represent the mean value and horizontal lines represent the median value. Fig (b) shows the median yearly gas costs per square meter across income deciles. Confidence bands indicate the 95^{th} percent around the median value and are based on bootstrapped standard errors with 500 replications. Median value by equivalent income decile are shown by the line graph. The share of tenants and owners along income deciles on the right y-axis is represented by the blue and red boxes.

Figure 3: Gas expenditures and home ownership

with higher income are more likely to live in detached or terraced houses rather than apartments. These are expected to have higher gas price costs due to larger square footage and greater heat losses through outside walls.[7]



(a) Gas costs by building type



(b) Share of building type by equivalent household income

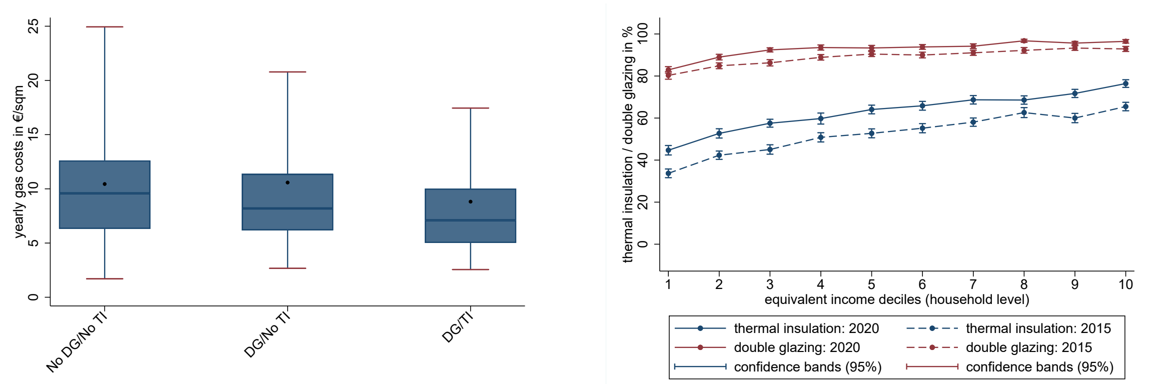
Own calculation based on SOEP v37 using the restricted working sample. Fig. (a) provides the monthly gas costs for different building types in 2015. Boxes indicate the 25^{th} to 75^{th} percentile of the distribution. Whiskers indicate the 5^{th} till 95^{th} percentile. Points represent the mean value and horizontal lines represent the median value. Fig (b) shows the share of building types along household deciles. Confidence bands indicate the 95^{th} percent around the median value and are based on bootstrapped standard errors with 500 replications. Median value by equivalent income decile are shown by the line graph.

Figure 4: Gas expenditures and building type

[7]Note that the figures here are based on the year 2015, as information on building types is not available in 2020.

4.2.3 Natural gas expenditures and energy-efficiency measures

The sections above show distributional differences in natural gas expenditures for home owners and tenants across different building types. We argue that this due to more energy-efficient housing for home owners and households at the upper end of the income distributions. As the SOEP provides detailed information on energy efficiency, specifically on double glazing and thermal insulation. The first panel of Figure 5 shows that more insulation corresponds with lower gas expenditures costs. Buildings that are both thermally insulated and double glazed exhibit significantly less variance in gas costs per square meter, which is achieved by limiting cases of very high gas costs. Additionally, the energy efficiency measures shift the distribution of gas costs downwards leading to lower median gas costs per square meter as well as lower costs for the 25th and 75th percentile. The second panel of Figure 5 confirms that energy efficiency measures are a more common feature of high-income household's accommodation. While double glazing of windows is very common for all types of households in Germany, thermal insulation is very unevenly distributed among income deciles. While only 45 percent of the poorest households live in insulated homes, more than 76 percent of the highest income decile inhabit such buildings. The differences between 2015 and 2020 show that there have been improvements over time, especially for thermal insulation, and they are evenly distributed along income deciles.



(a) Gas costs depending on thermal insulation (TI) and double glazing (DG)

(b) Level of thermal insulation and double glazing along income deciles

Own calculation based on SOEP v37 using the restricted working sample. Fig. (a) shows the yearly natural gas costs per square meter for houses with different levels of energy efficiency. Boxes indicate the 25th to 75th percentile of the distribution. Whiskers indicate the 5th till 95th percentile. Points represent the mean value and horizontal lines represent the median value. Fig (b) provides the share of efficiency measures across income deciles. Confidence bands indicate the 95th percent around the median value and are based on bootstrapped standard errors with 500 replications. Median value by equivalent income decile are shown by the line graph.

Figure 5: Gas expenditures and energy-efficiency measures

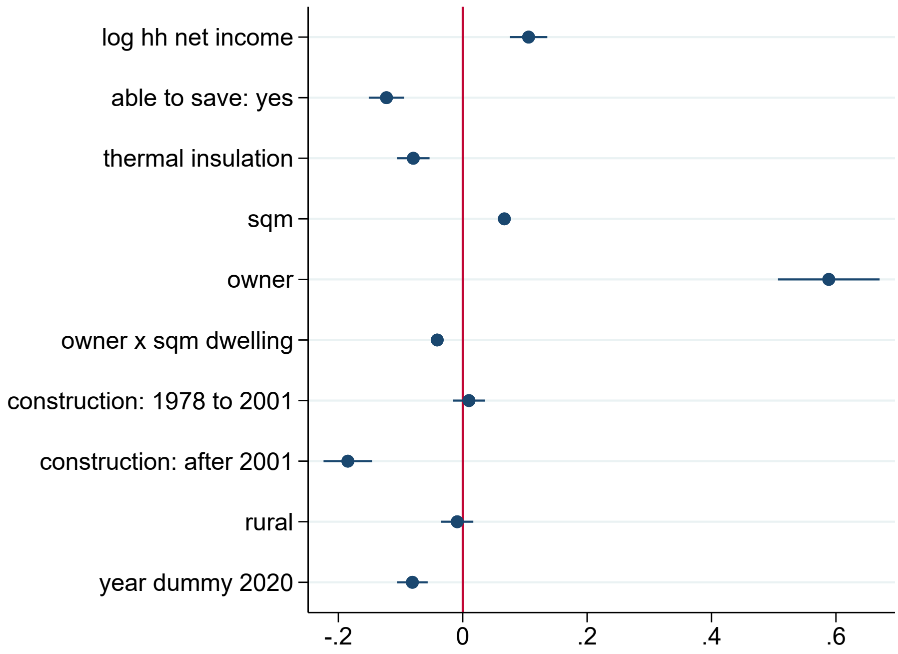
4.3 Regression analysis

After investigating how some common factors of heating costs exposures relate to a household's equivalent income, we conduct a regression analysis to further investigate how the above discussed factors interact and correlate with gas expenditures. As the estimates do not allow for causal interpretation, the regression is meant to further illustrate those factors that potentially drive gas price exposure using the log of monthly gas expenditures as dependent variable.

Figure 6 shows the beta coefficient with 95 percent confidence intervals for some selected regression coefficient. Additionally, we control for the household size, the region, and the survey year. The detailed table with the regression results is provided in the appendix. We see a positive association between *household income* and absolute natural gas expenditures. As we show above, however, natural gas costs increase relatively less than income across the income distribution. This finding is supported by the effect of *households ability to save*, an economic welfare indicator collected as part of the SOEP in which households are asked if they are able to save money on a monthly basis. Those who say yes face 12 percentage points lower gas expenditures. As expected, an energy efficiency measure such as *thermal insulation* is negatively and dwelling size measured in *square meters* positively correlated with natural gas expenditures. The beta coefficient of square meters represents a 10 square meter increase of the dwelling. While there is a positive estimate of ownership on absolute heating costs, this effect is due to a high correlation of ownership and housing size. When interacting ownership and square meters of the dwelling, we obtain a negative beta coefficient.

We see that even after controlling for income, both the variables *thermal insulation* and *construction after 2002* lead to significantly lower heating costs. More modern houses seem to enhance energy efficiency with means we cannot observe here, e.g., by including more efficient heating systems. The estimates show that a house *built after 2001* (i.e., after the ratification of the German energy savings ordinance [german: "Energieeinsparverordnung"]) incurs 18.5 percentage points lower gas expenditures than a house build before 1978. We return to this aspect in more detail in the next section. Interestingly, *rural areas* do not seem to be economically or statistically significant after controlling for household and building characteristics. The natural gas expenditure in 2020 was significantly lower than in 2015.

The regression analysis confirms most of the previously discussed results. Overall, the descriptive analysis shows that families in the lowest income deciles have significantly higher relative gas costs. This makes them vulnerable to gas price increases, since these



Regression analysis based on SOEP v37 using the restricted working sample pooling 2015 and 2020 data. The dependent variable is the absolute monthly gas expenditure. The figure provides selected beta coefficients. Additional control variables are household size, a regional nuts1 indicator. Full tables are provided in the Appendix. Dots represents the size of the effects estimated by the regression analysis. Lines indicate the 95-percent confidence interval

Figure 6: Regression coefficient plots: OLS

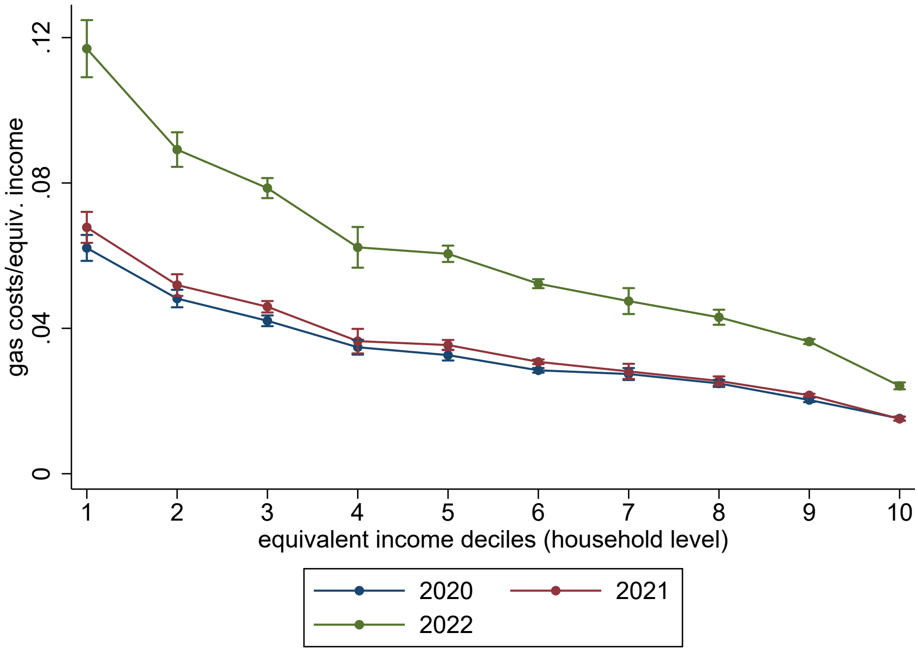
households have limited options to shift consumption around. We also show that there is a large variance of exposure to gas price increases within respective income groups and also show how dwelling characteristics, such as thermal insulation, single vs. multi-family housing and construction date, affect heating costs. This variance indicates the need for targeted policies, which we further investigate in the next section.

5 Policy Analysis

The descriptive analysis shows that poor households are more likely to be affected by natural gas price shocks due to their larger exposure to heating costs. The 2022 developments in relation to the Russian-Ukraine-conflict can be seen as such a natural gas price shock. Even before the Russian invasion, international gas prices had been close to an all-time high. For the subsequent analysis we assume a wholesale gas price of 65 Euro per MWh, which translates to household gas costs of 126.6 Euro per MWh.[8] This equals a household gas price increase of approximately 90 percent compared to 2020 (67.1 Euro

[8]Our calculation of household prices for gas follow the approach in Neuhoff et al. (2022a). We assume the following, proportional add-ons to the spot market price according to Agency for the Cooperation of Energy Regulators (2021): Retail mark-up (19 Euro/MWh), value-added tax (19 percent), other taxes (11 percent) and network tariffs (26 percent).

per MWh) and is a conservative assumption compared to gas price levels in the summer of 2022.[9]



Own calculation based on SOEP v37 using the restricted working sample. Lines indicate median value of relative gas expenditures per household equivalent income deciles. Confidence bands indicate the 95^{th} percent around the median value and are based on bootstrapped standard errors with 500 replications. Simulations are based on wave 2020 in the SOEP. Increase in gas expenditures is calculated by using the TTF index.

Figure 7: Simulated price increase and relative gas expenditures across household deciles

5.1 Distributional effect of the natural gas price increase

We first analyze how a gas price increase disproportionally affects poor households. Figure 7 shows the distribution of natural gas costs for 2020, as well as our extrapolation for the subsequent years 2021 and 2022. While gas expenditures remain relatively constant in 2021, they substantially rise in 2022. The increase in gas prices translates into an average 79 percent increase in relative gas expenditures. The gas price shock most strongly affects the poorest households. In the lowest income decile, the median relative gas costs increase from 6.21 percent to 11.70 percent of the equivalent income. In absolute terms their median gas expenditure would increase from 49.70 Euro to 94.27 Euro per month. Meanwhile, for the highest decile, the median gas expenditure change from 1.52 (71.00 Euro per month) to 2.41 percent (134.67 Euro per month) of equivalent income.

[9]The exact size of the price increases will depend on the hedging structure of gas suppliers and their ability for cost pass-through to the consumers. This scenario here implies an increase of wholesale prices by approximately 500 percent compared to the 2020 levels.

We refer to the scenario above in our main analysis, which includes a rather conservative level of price shocks. We also provide the estimates for an increase of the households' gas price by 150 and 200 percent compared to 2020 in Figure 13 in the Appendix. It shows that natural gas price increases become more regressive at higher price levels. The lowest decile faces relative gas expenditures 15.4 and 18.5 percent in these scenarios. However, the effect on household expenditures depends substantially on the consumers gas contract period. Those needing to renew contracts in 2022 will be immediately affected and potentially by higher increases than in our baseline scenario. Contrarily, households with longer contract periods are less affected by the price shock. We see this as another reason to use the lower bound of a 90 percent decrease in our main analysis.

These simulations neglect the behavioral response of households to increases price shocks. We address this by including elasticities in Figure 14 in the Appendix. These estimates require two strong assumptions: first, we only observe expenditures, which include retail mark-up, value-added tax, network tariffs, and other taxes. Therefore, we assume 50 percent fix costs that cannot be reduced by individual behavior. Second, we apply gas price elasticities by gas expenditure quantiles, provided by (Schmitz and Madlener, 2020) for Germany. The study finds relatively stable estimates, where a 1 percent increase in gas prices reduces the gas expenditures by -0.33 for the lowest quantile, and -0.36 for the median.[10] Figure 14 shows that behavioral responses decrease the relative gas costs for all households similarly. While this can affect our absolute measures, our distributional findings remain straightforward.

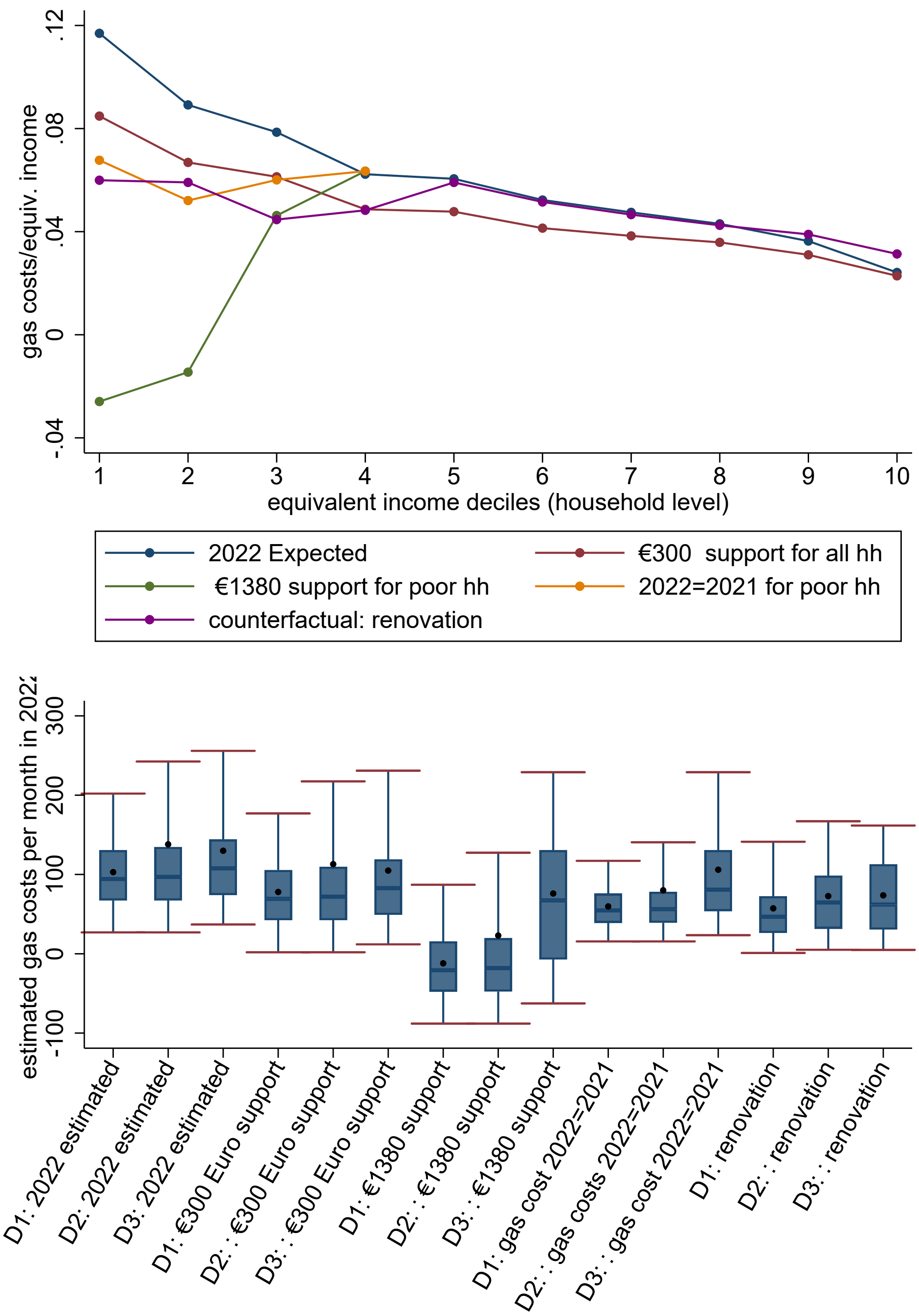
5.2 Effect of policy interventions

5.2.1 Short-term financial transfer

We investigate four policies that could be used to alleviate the cost of gas price shocks: A *lump sum transfer*, a *targeted transfer*, a *means-tested benefit program*, and a *renovation program*. All policy options lead to at least some reduction of the inequality caused by the gas price shock. Figure 8 presents the gas costs as a share of the equivalent income for all policy options while Table 2 shows how the policy options affect the Theil index. The Theil index is an entropy measure that ranges between 0 (total equality) and the $ln(n)$ (total inequality), with n describing the number of observations in the dataset. We use the Theil index because the index can be decomposed into subgroups (Theil, 1992). As our working sample includes only households with natural gas expenditures, applying

[10] These elasticities describe long-term reactions by households and do not realistically apply in our context. Therefore, our assumption setting fifty percent of the price as fix costs naturally reduces the overall elasticity to comparable levels of short-term demand elasticities to comparable levels described in the literature between -0.242 and -0.091 (Neuhoff et al., 2022b).

the Theil index is a more appropriate measure of inequality compared to, for instance, the Gini index.



Own calculation based on SOEP v37 using the restricted working sample. The top panel shows the median values of relative natural gas expenditures per household equivalent income deciles. The "2022 expected" scenario represents our base line scenario. The policies include a €300 reduction for all households, a €1380 reduction for households below the poverty line, a reduction to the 2021 price levels for households below the poverty line, and the effect of a long renovation policy. The lower panels provide the box plots of the simulated, absolute gas costs for the lowest 3 deciles (D1 - D3). Boxes indicate the 25^{th} to 75^{th} percentile of the distribution. Whiskers indicate the 5^{th} till 95^{th} percentile.

Figure 8: Relative and absolute gas cost after policy interventions

First, we consider a *lump sum transfer* of 300 Euro for all households. This policy is similar to the 2022 energy price transfer implemented in Germany. However, we abstract by assuming that the transfer is not subject to income taxes and by assuming that the transfer is paid per household and not on an individual basis.[11] The policy has a slightly progressive distributional effect, since higher income household have larger gas costs in absolute terms. Thus, the lump sum leads to a stronger relative reduction for poorer households. However, some inequality remains: While the highest decile has post-policy median gas costs equivalent to 2.28 percent of equivalent income, the median for lowest two deciles are 8.49 and 6.68, respectively. This still implies an increase of 25.15 percent (or 234.84 Euro per year) for the poorest households compared to their 2020 expenditure. The lower panel of Figure 8 shows the distribution of gas costs after the policy intervention. Despite the lump-sum payment, more than 25 percent of households in the lowest-income decile have gas costs above 100 Euros per month. Thus, the 300 Euro payment does not manage to eliminate the social hardship for all households.

Second, we investigate the effect of a *targeted transfer* for all households below the poverty line.[12] To ensure comparability, the policy is designed to result in the same government expenditure as the lump sum transfer to all households, resulting in a payment of 1380 Euro per year. The total expenditure would be around 4.7 billion Euro.[13] The targeted transfer clearly overcompensates poor households leading to negative median gas costs in the lowest two deciles. Considering the lower panel of Figure 8, we see that the policy successfully reduces social hardships for the lowest income deciles and the extreme price increases over 100 Euro per months are mostly eliminated.

We introduce a third option, a *means-tested benefit program* for heating costs of poor households. For this, we assume that the government covers the heating costs above the 2021 level for all households below the poverty line. This scheme would extend the existing system of covering the heating costs of recipients of social security benefits. As several household do not qualify for the original scheme due to, e.g., positive net wealth balances, our scheme would extend eligibility to all households below the poverty line.[14] The program completely alleviates the excess burden of increased heating costs for poor households in 2022, while at the same time avoiding overcompensation. The means-tested

[11] For an extensive discussion of the distributional effect of the 2022 German policy package consider Bach and Knautz (2022). For the lump-sum payment of 300 Euros, considering effects of taxation, the authors find that the policy benefits the middle class most strongly, since they have a higher share of employed individuals compared to the lower classes but are subject to lower taxes than the highest income deciles.

[12] The income of these households lies below 60 percent of the median income of total population.

[13] These estimates only include households from the working sample, i.e. households that use gas as their primary source of heating and, thus, are not directly comparable to estimate the cost of supporting for the entire population.

[14] For Germany, in particular, this could be imposed by extending heating costs coverage in the housing allowance ("Wohngeld").

benefit program would lead to a lower government expenditure of 2.1 billion Euro compared to 4.7 billion Euro for the first two policy options. However, the administration of the program is potentially more expensive since it requires additional management and organization of the households' heating bills, compared to a simple lump-sum payment. Additionally, high compensations for heating costs reduce the incentive for the tenants to reduce energy consumption or, for homeowners, to improve the energy-efficiency of buildings.

Additionally, we provide several Theil index measures of the disposable income distribution for the different policies in Table 2. The disposable income is calculated by subtracting the natural gas costs from the households' equivalent income. We see that while all policies decrease the inequality of disposable incomes, targeted policies are more effective with a reduction of more than 7 percent (but they also overcompensate some households). The renovation policy reduces inequality by around 4.6 percent, since it has a more moderate effect on low-income households. Still, the renovation policy leads to a significantly larger reduction in inequality than the simple lump sum transfer. This policy is discussed in more depth in the next subsection.

	Theil index	Change (%)
2022	0.142	
	(0.0045)	
300 Euro support for all hh	0.139	-2.29
	(0.0044)	
1380 Euro support for poor hh	0.131	-7.60
	(0.0044)	
Gas costs 2022=2021 for poor hh	0.138	-2.85
	(0.0044)	
Counterfactual: renovation	0.135	-4.63
	(0.0044)	

Table 2: Theil of disposable household income 2022

Own calculation based on SOEP v37. The table provides the Theil index for disposable household equivalent income after subtracting gas expenditures. Bootstrapped standard errors based on 500 replications are provided in parenthesis.

5.2.2 Renovation program and minimum standard

The alternative policy, a *renovation program* for the most energy-inefficient houses, cannot alleviate the short-term effect of price increases but can make households more resilient to price shocks in the long-run. Countries like France and the UK have already introduced a minimum energy efficiency standard, which shall ensure that the most inefficient houses are renovated by a certain target year. The introduction of Minimum Energy Performance Standards (MEPS) is part of the revision of the European Buildings Performance

Directive (EBPD) and is expected to be introduced at the EU-level.[15] In this analysis, we are interested in the distributional consequences of such a renovation program. The policy outcome is calculated by using the regression model in the section above. Specifically, we predict counterfactual household natural gas costs for the case that all houses built before 2002 are now assumed to be built in or after 2002. This means that buildings are renovated to reach the standard of buildings built after 2002 (the so-called "Minimum Energy Performance Standard"). Hence, we use the construction year as an indicator for the level of overall energy efficiency of the house. Given that the "Energy Savings Ordinance" reform was passed in this year, we see this a valid proxy. We learn from the regression analysis that, on average, houses built after 2001 incur on average 18.5 percent points lower natural gas costs.[16]

The renovation policy significantly reduces the effect of gas price shocks for poor households while having almost no effect for households above the median income level. The reason for this is that most of these households already live in more recently built (or renovated) buildings.[17] After the policy is implemented, the gas cost expenditure after the gas price shock equals approximately 6 percent of equivalent income for both the first and the last income deciles. Figure 8 illustrates that the renovation policy reduces the range of expenditures by eliminating extreme price increases for the lowest income groups.

Since this is a long-term policy, the costs of a renovation program are significantly higher than the cost of the transfers, which are annual payments. For the case of Germany, Kreditanstalt für Wiederaufbau (2021) calculate that achieving climate neutrality in the building sector would cost 636 billion Euro (or around 25 billion Euro per year until 2045). However, the benefits of a more even distribution of gas price shocks would accumulate over multiple periods since renovation increases the long term resiliency of the system and avoids the need for transfers in the future. Additionally, the program would incur an extensive economic stimulus for the construction sector with potentially considerate positive spill-over effects at the macro economic level. Thus, the cost of these different policy options are not directly comparable due to the different time-frame in implementation and the fact that the renovation policy would lead to lower gas expenditure in the future, which has additional benefits for the government's climate objectives as it will reduce fossil fuel dependency.

[15] More details can be found on the website of the European Commission at https://ec.europa.eu/commission/presscorner/detail/en/QANDA_21_6686

[16] This is a conservative estimate since, for instance, the EU's sustainable finance taxonomy recognizes a renovation project if it leads to a reduction in primary energy demand of at least 30 percent.

[17] Figure 11 in the Appendix illustrates how the average building year increases for higher equivalent income deciles.

Contrary to the previous measures, the renovation policy would not be a short-term emergency measure but instead increase the long-term resilience of the system. A large-scale renovation program would have the additional benefit of helping to achieve climate targets (as well as geopolitical targets) in addition to alleviating the social effects of gas price shocks. In fact, achieving the European climate targets in the building sector will imply a deep-renovation of all buildings since this is a prerequisite for replacing conventional heating systems with heat pumps. To address both factors that increase the burden of a gas price increase - low income and low energy efficiency - short-term subsidies targeted at low-income households should be complemented by a minimum energy performance standard.

6 Conclusion

The soaring natural gas price in 2022 is resulting in strong negative income effects, especially for low-income households. For households in the lowest income decile in Germany, the median natural gas costs increase from 6.78 to 11.70 percent of households' equivalent income. This puts significant pressure on these households, which are already limited in their ability to save or to shift budget around. Households at the top of the income distribution as well as owners tend to have higher gas costs, mainly due to the larger living space. However, they are less affected by the gas price shock relative to their income, as they only spend around 2.41 percent of equivalent income at the median. The results show that households living in buildings that are insulated or built after 2001 have significantly lower heating costs. Poor households are more strongly affected by this, as for low income households the share of buildings with thermal insulation is only 40 percent compared to around 70 percent for high income households. The analysis in this paper is based on a household gas price increase of 90 percent.

We consider four policy options targeted at alleviating gas price shocks. We show that a means-tested benefit program for heating costs and a targeted transfer would outperform a lump sum transfer in terms of alleviating the excess burden of 2022 for poor households. A means-tested benefit program would avoid overcompensation of some households compared to a targeted transfer. However, it would still lead to negative incentives in terms of energy consumption. Meanwhile, a renovation policy bringing all houses to the standard of buildings built after 2001 (a "Minimum Energy Performance Standard") would lead to a more equal distribution of heating costs as a share of equivalent income. While renovations are not appropriate as a short-term measure, they improve the long-term resilience to gas price increases and reduce the burden on public expenses for energy subsidies.

An additional dimension of the here discussed policies is the question of incentives for energy efficiency. Subsidizing heating costs would diminish the incentives for households to reduce their costs through behavioral responses. This dimension is especially relevant in the context of the Russian war in Ukraine, which moved the question of gas savings to the forefront of the political debate. Additionally, the building sector was the one of the sectors to miss its climate targets in the most 2021 review of policy progress under the German climate policy law. This underscores the importance of action in this sector, which is the fourth largest emitter after the energy, transportation, and industry sectors. Thus, a combination of subsidies to alleviate the short-term impact of gas price increases and a renovation policy would allow the government to jointly achieve climate, social, and energy independence objectives.

Some caveats remain that offer avenues for further research. First, the existing analysis focuses on the case of a specific country, Germany, and a specific fuel, natural gas. Considering a broader scope with respect to these dimensions might increase the external validity of the findings. Second, the paper focuses on a descriptive analysis of the distributional effect of a gas price shock due to data availability at the current point in time. A future ex-post analysis should try to identify the causal effect of the 2022 heating price shock through additional econometric analysis. This would also allow to quantify the cost of the natural gas crisis on European consumers. Finally, it would be interesting to analyze the interaction between environmental and social policy objectives in the field of heating assistance.

Even though the analysis is based on German data, we see our findings can be to some extend generalized to other countries. Given the high level of natural gas dependency in Germany, comparable social policies are potentially less costly. The distributional effect of a minimum-standards for buildings is potentially similar in other Central-European countries. We see an elaborated cross-country analysis of a minimum-standard as a fruitful addition to our work.

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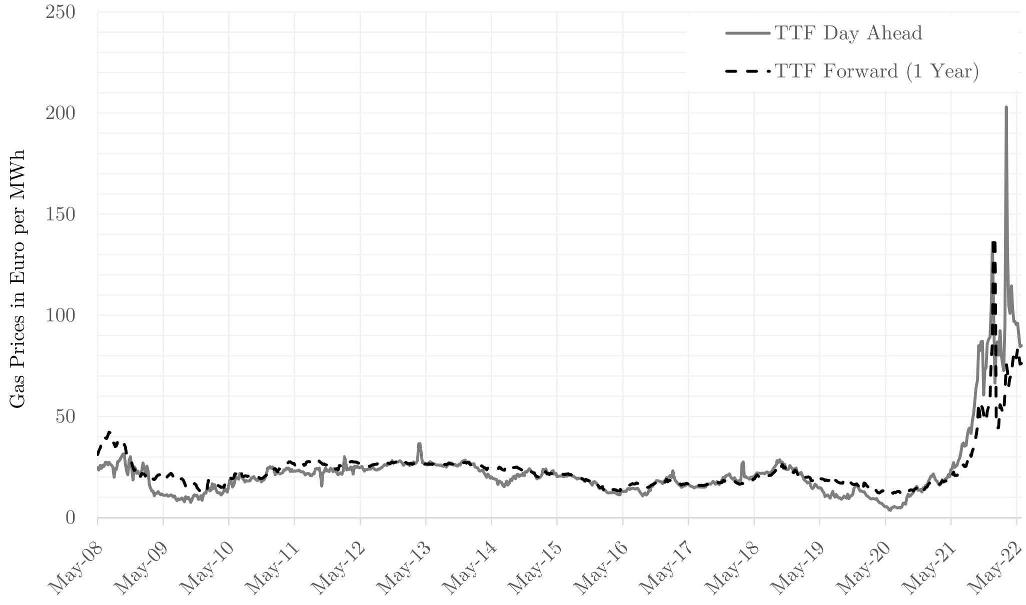
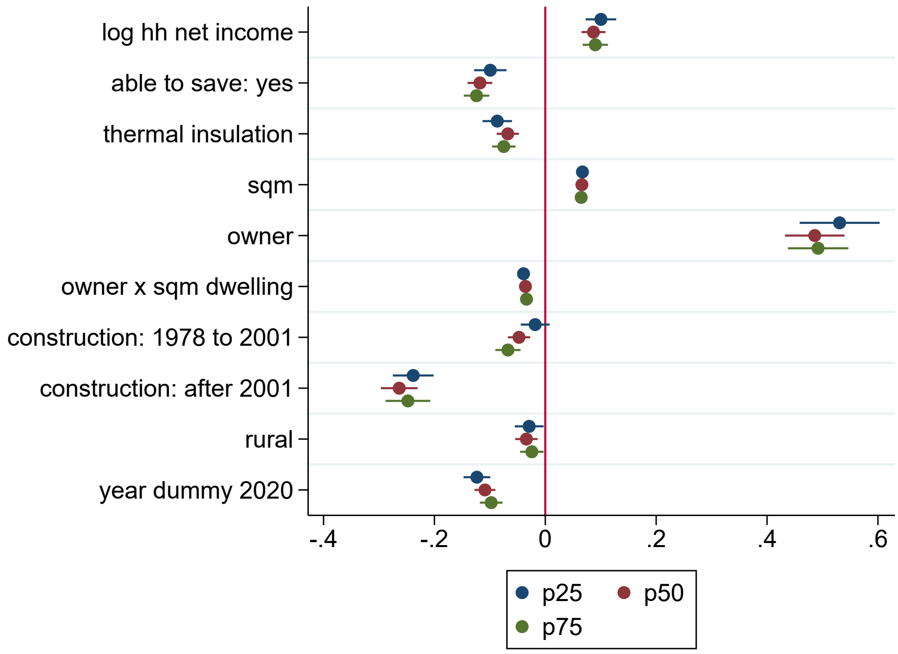
A Appendix



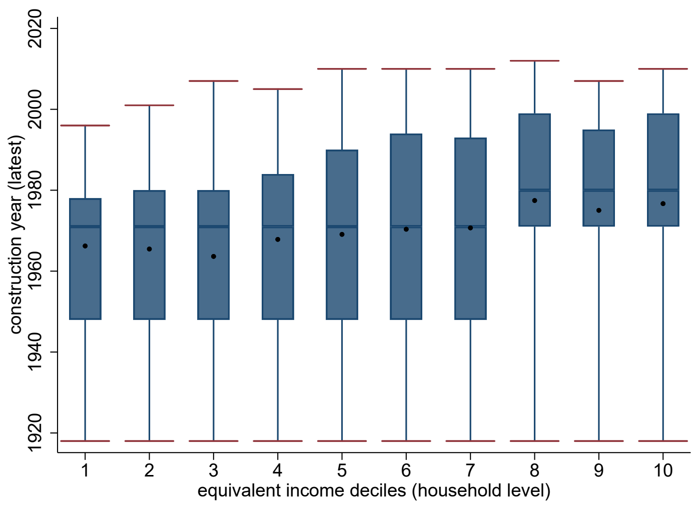
Weekly gas price in Euro per MWh for the European reference price at the virtual trading point TTF ("Title Transfer Facility") with one day and one year ahead time horizon

Figure 9: Reference gas price from May 2008-May 2022



Regression analysis based on SOEP v37 using the restricted working sample pooling 2015 and 2020 data. The depend variable is the absolute monthly gas expenditure. The figures provides selected beta coefficients resulting from quantile regression on the 25th percentile, the median, and the 75th percentile. Additional control variables are household size, a regional nuts1 indicator. Full tables are provided below. Lines indicate the 95-percent confidence interval Lines indicate the 95-percent confidence interval

Figure 10: Regression coefficient plots: Quantile Regressions



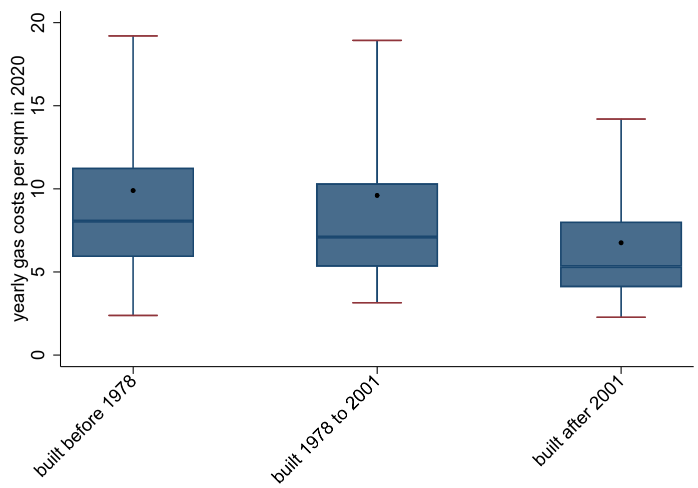
Own calculation based on SOEP v37 using the restricted working sample. The figure shows the latest construction year of the dwelling across household income deciles. Boxes indicate the 25^{th} to 75^{th} percentile of the distribution. Whiskers indicate the 5^{th} till 95^{th} percentile. Points represent the mean value and horizontal lines represent the median value.

Figure 11: Dwelling building year by income deciles

	(1) OLS	(2) Quantile (p25)	(3) Quantile (p50)	(4) Quantile (p75)
log hh net income	0.1059***	0.1004***	0.0869***	0.0903***
	(0.0154)	(0.0141)	(0.0110)	(0.0116)
able to save: yes	-0.1226***	-0.0992***	-0.1179***	-0.1241***
	(0.0145)	(0.0149)	(0.0114)	(0.0117)
thermal insulation	-0.0794***	-0.0866***	-0.0676***	-0.0748***
	(0.0133)	(0.0135)	(0.0102)	(0.0107)
sqm	0.0670***	0.0670***	0.0660***	0.0648***
	(0.0034)	(0.0035)	(0.0022)	(0.0024)
owner	0.5886***	0.5309***	0.4860***	0.4921***
	(0.0417)	(0.0368)	(0.0274)	(0.0278)
owner x sqm	-0.0410***	-0.0392***	-0.0358***	-0.0339***
	(0.0039)	(0.0036)	(0.0025)	(0.0025)
construction: 1978 to 2001	0.0100	-0.0182	-0.0473***	-0.0674***
	(0.0131)	(0.0133)	(0.0103)	(0.0116)
construction: after 2001	-0.1847***	-0.2382***	-0.2634***	-0.2478***
	(0.0199)	(0.0188)	(0.0169)	(0.0206)
number of hh	0.0182***	0.0256***	0.0174***	0.0120**
	(0.0053)	(0.0050)	(0.0037)	(0.0042)
rural	-0.0088	-0.0291*	-0.0341***	-0.0242*
	(0.0132)	(0.0133)	(0.0103)	(0.0108)
year dummy 2020	-0.0809***	-0.1233***	-0.1088***	-0.0976***
	(0.0125)	(0.0123)	(0.0096)	(0.0104)
hgnuts1	0.0101***	0.0113***	0.0053***	0.0033**
	(0.0015)	(0.0014)	(0.0011)	(0.0012)
constant	2.6083***	2.4309***	2.9312***	3.2095***
	(0.1067)	(0.0986)	(0.0772)	(0.0803)
N	12,170	12,170	12,170	12,170

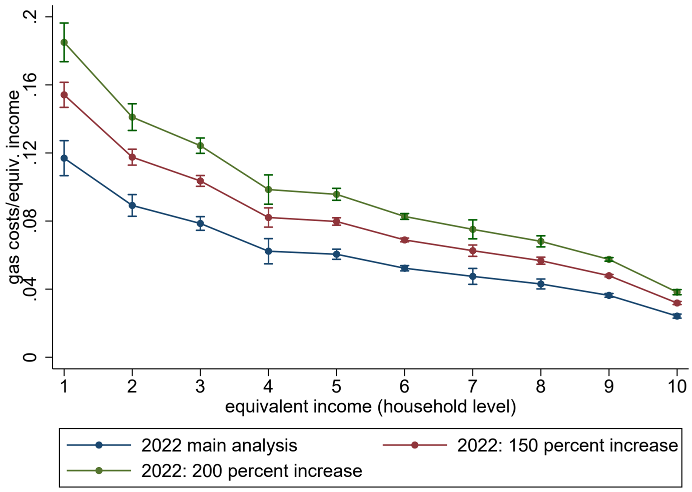
Table 3: Regression results: Quantile regressions

Notes: Own calculation based on SOEP v37 sing the restricted working sample pooling 2015 and 2020 data. The table provides the full OLS (column 1) and quantile regression (column 2-4) estimates. Robust standard errors in parenthesis.Significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.



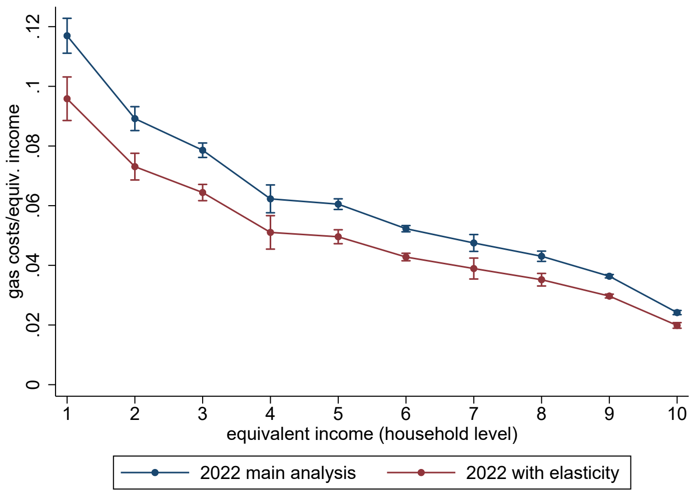
Own calculation based on SOEP v37 using the restricted working sample. The figure shows the yearly gas costs per square meter for different time frames of the construction year. Boxes indicate the 25^{th} to 75^{th} percentile of the distribution. Whiskers indicate the 5^{th} till 95^{th} percentile. Points represent the mean value and horizontal lines represent the median value.

Figure 12: Yearly gas costs per sqm by building year (in 2020)



Own calculation based on SOEP v37 using the restricted working sample. Lines indicate median value of relative gas expenditures per equivalent household income deciles. Confidence bands indicate the 95th percent around the median value and are based on bootstrapped standard errors with 500 replications. Simulations are based on wave 2020 in the SOEP. "2022 main analysis" represents our baseline simulation. Increase in gas expenditures is calculated by using the TTF index

Figure 13: Distributional effects under different gas price scenarios



Own calculation based on SOEP v37 using the restricted working sample. Lines indicate median value of relative gas expenditures per equivalent household income deciles. Confidence bands indicate the 95th percent around the median value and are based on bootstrapped standard errors with 500 replications. Simulations are based on wave 2020 in the SOEP. "2022 main analysis" represents our baseline simulation. "2022 with elasiticies" assumes household responses to the gas price shock. Increase in gas expenditures is calculated by using the TTF index

Figure 14: Distributional effects including elasticities