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Working paper

Household Energy Burdens in Europe following the Russian Incursion into Ukraine

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Abstract

Recent global events such as the COVID-19 pandemic and the Russian invasion of Ukraine have worsened the already difficult situation of households at risk of energy poverty in Europe. Estimates for 2020 suggest that 43% of natural gas in the EU was supplied by Russia, a substantial share of which met household heating and cooking energy needs. Severe supply constraints and corresponding price volatility following the Russian invasion of Ukraine have substantially affected household energy affordability across Europe.

In this work, we quantify how the prior dependence of European countries on gas imports from Russia affected the direct energy burdens suffered by households following the Russian offensive. We then consider how these energy burdens may evolve under different scenarios of the duration of the conflict. We use microdata from the European Household Budget Survey (HBS) from 2010 and 2015 to analyze household energy burdens, measured in terms of the share of the total household budget spent on energy, and the factors affecting these across EU countries and across income levels within countries. We also use data on national energy price trajectories from Eurostat and time series autoregressive integrative moving average (ARIMA) models to predict future energy prices under alternative scenarios of the length of the conflict. Finally, to predict changes in the energy burden of European households under these alternative scenarios, we use XGBoost (eXtreme Gradient Boosting) a state-of-the-art machine learning algorithm.

We find that households that use gas tend to have a higher energy burden than those that do not. Moreover, for households that live in a country where most of the gas imports come from Russia, this is exacerbated, particularly for those at lower income levels. Under alternative scenarios of the length of the conflict, we find that that low-income households would be the most affected, with a longer war likely to raise the energy burden across all income groups.

Our findings are useful to inform policies to address energy poverty, particularly households most vulnerable to energy price volatility in Europe. In the short-term, targeted transfers and assistance hold promise and are necessary to address the exacerbated energy poverty burden, particularly for low-income and vulnerable households. However, in the longer term, efforts to improve the efficiency of the European building stock and heating systems, as well as to enhance energy security will likely be needed.

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Introduction

The most recently available estimates suggest that about 8% or approximately 35 million EU citizens were unable to keep their homes adequately warm in 2020 (EUROSTAT, 2021). The Fit for 55 package, adopted by the EU in July 2021, clearly mentions measures to identify fundamental drivers of energy poverty risks for households, including high energy prices, low household incomes, and inefficient buildings and appliances. The Energy Poverty Advisory Hub (EPAH), launched by the European Commission in 2021, aims to alleviate energy poverty in Europe. Recent global events such as the COVID-19 pandemic and the Russian invasion of Ukraine have worsened the already difficult situation of households at risk of energy poverty in Europe.

Russia's invasion of Ukraine shocked the global economy. In response to the military offensive, several countries imposed heavy economic sanctions, and many global companies closed their national operations in the affected countries. Subsequently, Russia started limiting the exports of natural gas, creating a ripple effect across all commodities. Oil prices increased worldwide, increasing not only energy prices, but also the cost of transportation, and creating an inflationary spiral. Several countries in Europe have been particularly dependent on Russian natural gas for their energy needs, a substantial share of which go to meeting household heating and cooking energy needs. Estimates for 2020 suggest that 43% of natural gas in the EU was supplied by Russia (EUROSTAT, 2023c). Fortunately, the most severe supply constraints and corresponding price volatility occurred towards the end of winter 2022, mitigating to some extent downstream effects on household energy burdens. Nonetheless, the severity of the artificial gas supply constraints has substantially affected household energy affordability across Europe. In this context, understanding how these burdens may evolve into the future is essential to inform possible energy poverty policies addressing the most vulnerable households.

Here, we attempt to quantify how the prior dependence of European countries on gas imports from Russia affected the direct energy burdens suffered by households following the Russian offensive. We then consider how these energy burdens may evolve under different scenarios of the duration of the conflict.

To do so, we use microdata from the European Household Budget Survey (HBS) and quantify the energy burden of households as the amount of money spent on energy as a ratio of total household income. We use a time series autoregressive integrative moving average (ARIMA) model to predict future energy prices under alternative scenarios of the length of the conflict and use machine-learning algorithms to determine changes to the household energy burden given alternative future energy price trajectories.

We find that households that depend on gas for their energy needs tend to face a higher energy burden than households that do not use gas, and that, among those who use gas, households in countries that depend on Russian gas imports have a higher energy burden. Furthermore, we find that for lower income households, given their stringent budget constraints, the spread of the energy burden is lower, whereas the opposite is the case for higher income households.

Background & literature review

Household energy poverty in the European Union has been defined and measured in terms of absolute expenditure thresholds (expenditure approach), subjective perceptions of affordability and access (consensual approach), and to a lesser extent measures of indoor air temperature (direct measurement) (Thomson et al., 2017). These measures are typically concerned with cooling and heating space, water, and food. The European Household Budget Survey (HBS) provides the most complete pan-European dataset describing energy expenditures, although it remains limited in its ability to capture other multi-dimensional vulnerabilities (EUROSTAT, 2023b; Thomson et al., 2017). Analysis using the HBS typically concerns itself with the 'energy burden' defined as the ratio of energy expenditures to overall household expenditures. Despite its limitations as a measure of multi-dimensional energy poverty, the distribution of energy burden provides a good understanding of the trade-offs and vulnerabilities faced by households as wealth, appliance and building thermal efficiencies and fuel prices evolve.

The Russian invasion of Ukraine has significantly stressed household budgets and exacerbated energy burdens not just in Europe but around the world. Rapidly rising international prices for energy, food and basic goods and services have culminated in a severe cost-of-living crisis in many regions. This has prompted policymakers to consider a range of options, ranging from mitigating the price pass-through on the supply side, to directly supporting households through cash transfers on the demand side (Amaglobeli et al., 2023). In the European Union, the Russian invasion of Ukraine has also raised difficult questions about short-term energy security, with some fears of knock-on effects delaying the necessary energy transition (Żuk & Żuk, 2022). All of this is occurring in a challenging policy environment created by several recent and ongoing crises, including the COVID-19 pandemic, international population displacement and the accelerating impacts of climate change (Van Daalen et al., 2022).

Increases in international primary energy prices have had heterogenous effects on household budgets (Guan et al., 2023). Differences across countries are associated with differences in sectoral production structures and patterns of consumption, the latter strongly related to within- and across-country income inequality. In poorer countries, broader trends suggest that consumption patterns of wealthier households were more severely affected, likely due to already existing suppressed consumption among poorer households. In wealthier countries, the inverse is found, such that poorer households faced larger increases to household expenditures for the same basket of goods (Guan et al., 2023).

In both contexts, wealthier households typically experienced these price increases through their direct and indirect effects on value-added goods and services, whereas poorer households typically experienced these through their direct effects on daily basic needs such as heating and cooking.

Similar patterns have been identified within the European Union, with the additional modifying effect of countries' heterogenous direct dependence on Russian gas (Steckel et al., 2022). In this geographic context, natural gas price increases were found to contribute most to household expenditure increases in the countries most affected by primary energy price increases. Overall, households reliant on gas for space heating were the most severely affected. To balance heterogeneous effects of fuel prices with the need to maintain price signals motivating conservation of gas, targeted direct transfers to poorer gas-users in Europe appears promising (Steckel et al., 2022), aligning with recent literature (Celasun et al., 2022; Amaglobeli et al., 2023).

We contribute to addressing two main gaps in the rapidly developing literature discussing household energy burdens caused by the Russian invasion in Ukraine. First, we model household fuel price elasticity. The literature thus far has focused primarily on the immediate changes in household burdens assuming inelastic responses to changes in fuel prices. This is an arguably robust assumption in the short-term, given that for most European households, the fuel price feedback is somewhat hidden due to annual billing cycles. Nevertheless, the messaging surrounding primary price increases and the length of the conflict likely plays an important role in household behavior and resulting energy burdens. Second and somewhat relatedly, we consider the evolution of prices as a function of conflict length. The literature typically uses scenarios that describe fixed increases in prices, rather than how these may evolve over different lengths of conflict. Understanding possible scenarios of dynamic fuel price evolution and its effects on household energy burdens is important to develop long-term policy responses to the immediate crisis.

Methods and data

We use data from the European Household Budget Survey (EUROSTAT, 2023b), a rich quinquennial meta-dataset of micro-level household budget surveys from 26 countries in the European Union. We use the last two available waves, corresponding to the years 2010 and 2015 in different parts of the analysis, specifically, we use the latest wave of 2015 for the estimation, and the oldest wave of 2010 for testing the model fit. Due to missing data, we remove some of the countries for the analysis, ending up with 20 countries in the 2015 sample, and 22 countries in the 2010 sample. Some descriptive statistics of both samples can be found in Table 1.

Table 1 – Summary counts, proportions, and averages for the years 2015 and 2010 of the EUROSTAT HBS microdata

Year	*Country*	*Obs.*	*Perc Urban*	*Perc Male-headed*	*Perc Married*	*Perc Head with at most High School*	*Perc Where Head Works*	*Household Size*	*Net Income*	*Exp. on Electricity*	*Exp. on Gas*	*Total Exp.*
2015	BE	6,128	92.3	59.9	55.7	53.7	63.5	2.6	39,939	876	513	39,034
2015	BG	2,955	66.8	61.3	60.9	74.7	42.1	2.4	5,051	357	13	5,539
2015	CZ	2,845	66.2	50.5	NA	84.4	76.4	2.4	13,784	509	332	10,030
2015	DE	50,806	89.1	61.5	54.3	41.6	62.9	2.1	37,301	NA	523	34,114
2015	DK	2,248	62.6	18.4	48.8	58.9	55.4	2.2	61,761	1,066	300	43,627
2015	EE	3,271	35.0	52.3	45.4	59.8	66.1	2.6	13,779	472	50	11,182
2015	ES	21,688	71.1	68.4	63.7	69.1	56.9	2.7	23,879	771	290	29,031
2015	FI	3,662	67.4	62.1	50.1	57.7	57.2	2.2	43,586	1,059	14	40,141
2015	FR	16,430	69.3	55.3	42.4	48.0	54.7	2.5	35,426	873	231	29,826
2015	HU	7,126	46.7	52.6	44.3	74.5	50.8	2.3	8,226	323	347	8,567
2015	IE	6,650	63.0	58.4	55.3	46.2	61.1	2.7	47,148	964	384	41,424
2015	IT	14,778	74.7	68.2	61.9	87.4	49.9	2.4	40,435	590	742	30,203
2015	LT	3,423	42.2	49.4	62.2	48.6	58.1	2.3	8,142	234	102	10,287
2015	LV	3,839	52.3	45.8	45.6	63.5	60.7	2.3	8,327	303	91	9,161
2015	MT	1,741	100.0	78.1	76.2	65.7	93.6	3.1	33,738	655	78	28,656
2015	NL	14,371	89.7	70.5	59.0	NA	66.2	2.4	47,772	653	1,115	41,732
2015	PL	34,786	58.3	61.6	67.0	75.3	62.6	2.7	10,852	389	210	9,885
2015	PT	11,311	66.9	58.4	57.6	67.9	55.2	2.6	18,077	712	394	19,118
2015	RO	29,822	55.5	63.7	55.5	81.3	55.2	2.1	4,541	235	187	5,242
2015	SK	4,633	72.0	57.3	55.1	78.5	60.0	2.5	12,944	496	435	11,501
2010	BE	7,142	95.7	62.8	51.7	48.6	61.8	2.3	35,634	732	630	34,569
2010	BG	2,937	62.5	64.3	59.5	83.4	33.6	2.5	3,908	285	12	4,410
2010	CZ	2,885	62.1	71.1	NA	86.2	72.5	2.4	13,920	549	346	10,226
2010	DE	52,711	89.6	64.3	60.2	43.2	64.7	2.3	37,630	776	519	33,981
2010	DK	2,448	53.3	64.7	52.9	NA	61.9	2.2	54,278	1,086	360	42,823
2010	EE	3,503	29.2	50.9	47.7	69.4	62.4	2.6	9,170	355	30	8,247
2010	ES	21,959	68.7	72.5	67.3	56.8	58.7	2.8	24,151	750	254	30,810
2010	FI	3,482	77.7	62.5	55.7	NA	60.2	2.4	41,809	1,078	0	37,969
2010	FR	15,241	69.1	59.8	44.4	33.5	57.3	2.6	32,996	709	258	29,967
2010	HU	9,904	54.4	52.6	48.0	73.6	56.1	2.5	8,315	431	452	8,471
2010	IE	5,800	68.3	52.3	51.0	46.0	59.5	2.7	46,993	833	445	39,028
2010	IT	22,224	80.7	69.5	62.7	88.9	50.4	2.5	38,979	566	761	29,063
2010	LT	5,938	36.3	57.3	66.9	52.1	63.7	2.6	8,469	201	104	8,722
2010	LV	3,733	43.4	30.4	49.6	68.3	49.0	2.5	6,620	219	87	7,579
2010	MT	2,164	100.0	89.2	90.2	NA	96.1	3.3	25,948	602	34	24,860
2010	PL	34,470	54.7	61.7	65.2	78.0	65.6	2.9	9,764	375	205	9,339
2010	PT	9,411	63.3	63.1	65.0	77.0	54.3	2.6	17,565	566	392	18,520
2010	RO	30,287	NA	63.9	58.2	63.3	56.1	2.3	3,913	180	162	4,792
2010	SE	1,869	38.6	66.0	56.3	NA	NA	2.8	42,493	NA	NA	35,033
2010	SI	3,879	50.8	45.1	64.4	NA	53.0	2.9	22,072	650	186	24,069
2010	SK	5,909	46.6	56.3	59.0	85.3	61.5	2.8	10,931	505	434	9,907
2010	UK	4,924	84.8	61.4	60.6	NA	59.4	2.3	35,683	644	627	25,637

Data on price trajectories is obtained from Eurostat. We use time series from the Harmonised Indices of Consumer Prices (HICP) on total prices, energy prices, and prices of electricity and gas from January 2000 to March 2023 (EUROSTAT, 2023a).

Depending on how long the war extends we create (using forecasting) two scenarios of prices: one where the war finishes by the end of 2023, and one which continues into the future. For scenario development, we use two alternative techniques. We use reg-ARIMA models to forecast price trends by the end of the year 2025 (Hyndman & Khandakar, 2008). Using a dummy variable to represent the war, we forecast inflation pathways for gas, and, posteriorly, we use this forecast as an additional variable to forecast electricity prices and overall inflation, to account for the indirect effect of gas price hikes on other goods.

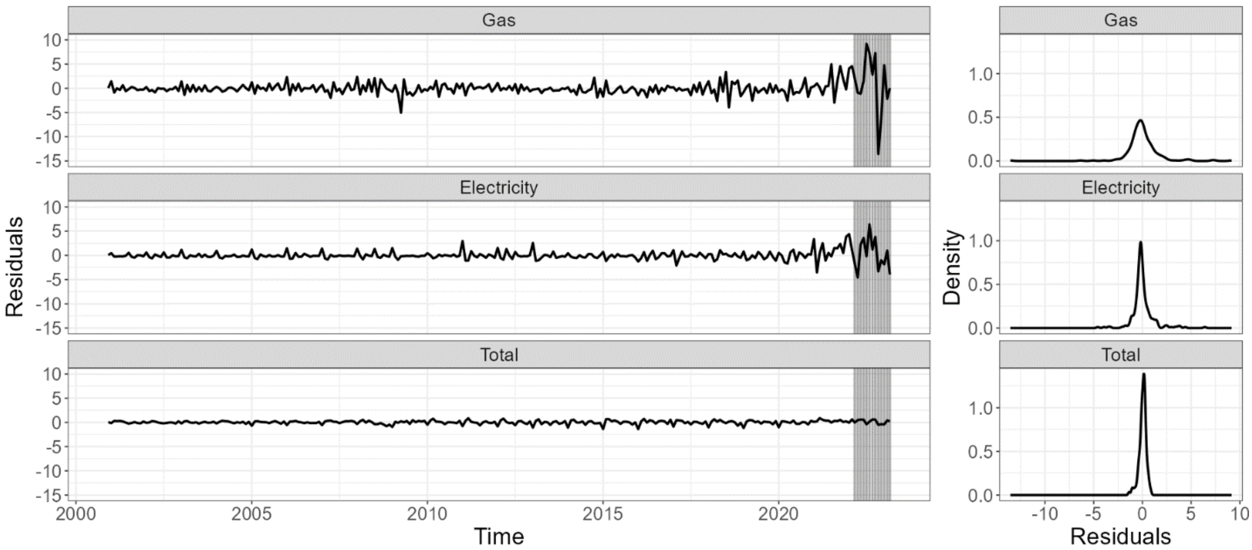

Figure 1 - Residuals of the reg-ARIMA models used to forecast prices

The forecasting models are able to fit the historical trends appropriately even since the onset of war, as can be seen in Figure 1, only having some trouble predicting the prices at the end of 2022, where some country-specific governmental measures (which were not added to the model due to their highly disparate nature, as will be seen posteriorly) were put in place to ameliorate the gas price hikes.

For predicting changes in the energy burden of European households as presented in HBS we use XGBoost (eXtreme Gradient Boosting) a state-of-the-art machine learning algorithm notable for its predictive capacity (Chen & Guestrin, 2016). We use as explanatory variables expenditures on total goods, electricity, and gas, as well as an array of other sociodemographic covariates. The estimation is performed on data from the 2015 wave of the HBS. To prevent overfitting and to test the predictive capacity of the model, we randomly split the 2015 HBS sample in a training and a test dataset, corresponding to 90% and 10% of the total sample, respectively. In a second, and much more ambitious test, we use the model estimates on 2015 data to predict the energy burden on data for the year 2010, to assess the predictive capacity of the model in a very different time slice.

We see that, of the variables modelled, total expenditure has the biggest effect of all factors (Figure 2), and is in a class of its own, followed by the expenditure on gas and electricity, which are clustered together by the algorithm. Following these. appear other controlling factors, grouped in two clusters, the most important being, in descending order, having a non-working household head, being widowed or divorced, the size of the household, whether the dwelling is in an urban area, and whether the household head is retired. The joint impacts of these factors can be seen in the remaining subplots, with negative impacts of total expenditure largely associated with negative impacts of electricity expenditure on the energy burden.

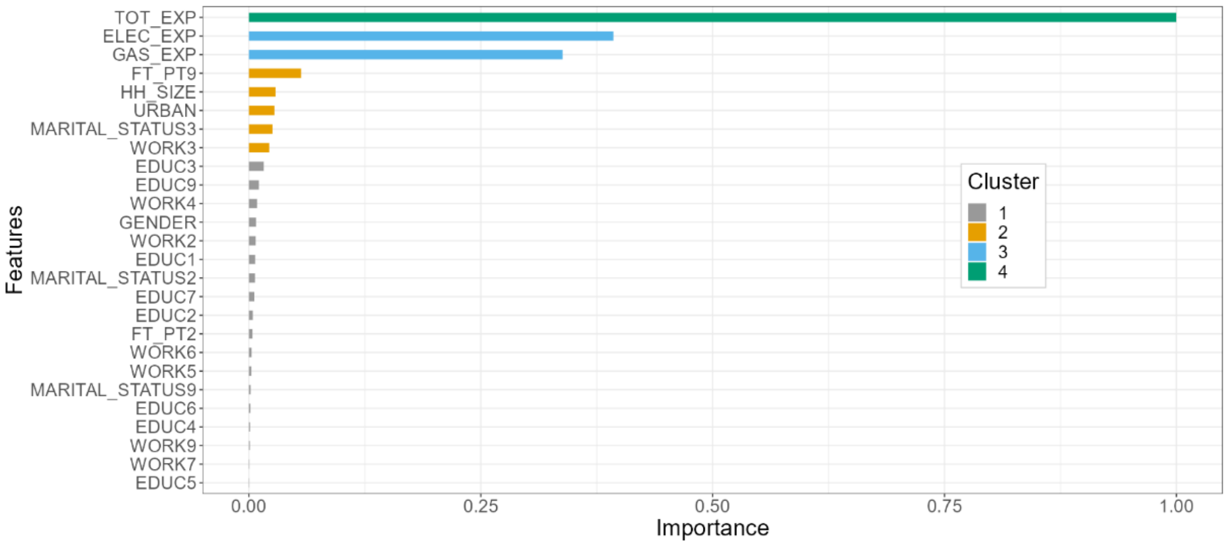

Figure 2 – Relative importance of model features as used in the burden prediction XGBoost model.

Figure 3 shows the fit of the estimation model in all samples. The model does an outstanding job predicting both within and out-of-sample, with coefficients of determination above 0.92. This gives enough confidence in the model to be used for out-of-sample estimations, something that is not always straightforward to do with machine learning models that usually overfit.

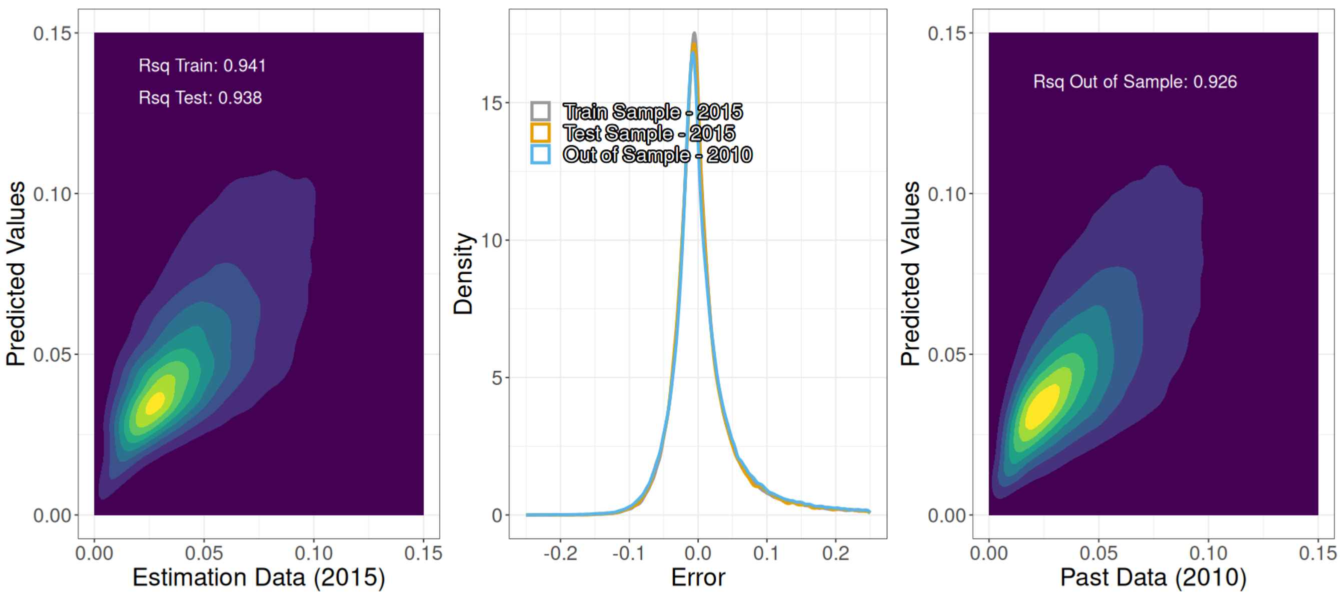

Figure 3 – Two-dimensional density maps of data vs predicted values for the estimation sample (left panel) and out-of-sample (right panel) and density plots of the distribution of errors for training, test, and out-of sample (center panel)

Gas usage, Energy Prices, and the Energy Burden of European households

We distinguish countries depending on their dependence on Russian gas imports. We define a country as being "dependent" on Russia, if Russia is the main source of gas. Table 2 shows statistics for the countries in the estimation sample of 2015.

Table 2 – Sample proportions and averages for countries in the estimation sample of 2015

Depends on Russia	*Country*	*Percentage of Households Using Gas*	*Percentage of Gas Expenditure in Total Fuel Expenditure*	*Average Energy Burden*
No	BE	52.7	27.7	6.3
No	DK	25.3	10.1	6.6
No	EE	19.7	3.9	10.1
No	ES	56.6	20.8	6.5
No	FR	63.5	19.5	5.0
No	IE	37.6	17.9	6.2
No	LT	66.7	12.3	13.2
No	MT	14.4	7.7	2.9
No	NL	100.0	64.2	5.0
No	PT	88.5	33.9	10.0
No	RO	80.0	34.4	15.2
Yes	BG	18.6	2.1	13.6
Yes	CZ	69.8	24.7	10.0
Yes	DE	45.2	24.1	6.8
Yes	FI	1.8	0.6	3.8
Yes	HU	94.1	36.0	14.4
Yes	IT	91.7	46.7	4.2
Yes	LV	78.6	10.4	13.4
Yes	PL	68.0	23.7	11.9
Yes	SK	83.8	26.4	14.0

We do not observe any distinct patterns between the prices of gas and electricity, nor on the gas expenditure behavior of households in countries that are dependent on Russia and those that are not, but we observe that households that use gas tend to have a higher energy burden than those that do not (Figure 4). Moreover, we observe in the whole sample that, regardless of the country and income level, households that use gas (meaning having non-zero gas expenditures) have a higher energy burden than those that do not use gas, and that for households that live in a country where most of their gas imports come from Russia, this is exacerbated, particularly for those at lower income levels (Figure 5).

It is important to remark here that this represents direct expenditure on gas and therefore, for example, households that receive and pay for central heating which may or not be based on gas are not reflected here. Nevertheless, this stylized fact justifies the concerns around increasing energy poverty for those in a more precarious economic situation.

Energy prices within the EU zone have been characterized by limited volatility in the price of electricity, and a somewhat larger volatility in the price of natural gas, which seems very much linked to business cycles. However, already in the second half of 2021, prices started substantially increasing, mostly due to low gas storage levels (European Commission, 2021). At that time, Russian gas exports worked as a moderating factor, temporarily increasing their flows to the EU. However, since the onset of the war In Ukraine, this has suddenly stopped, and the Russian policy has been to constrain supply as a retaliation to the EU's response to the attacks in Ukraine, generating a price escalation that has affected both countries that depend and do not depend on Russian gas. Since then, some countries have since adopted their own specific measures to counterbalance the rise in prices (reflected in the largely heterogeneous drops in prices starting around the second quarter of 2022, see Figure 6), but the effect of this rapid change in prices is still large.

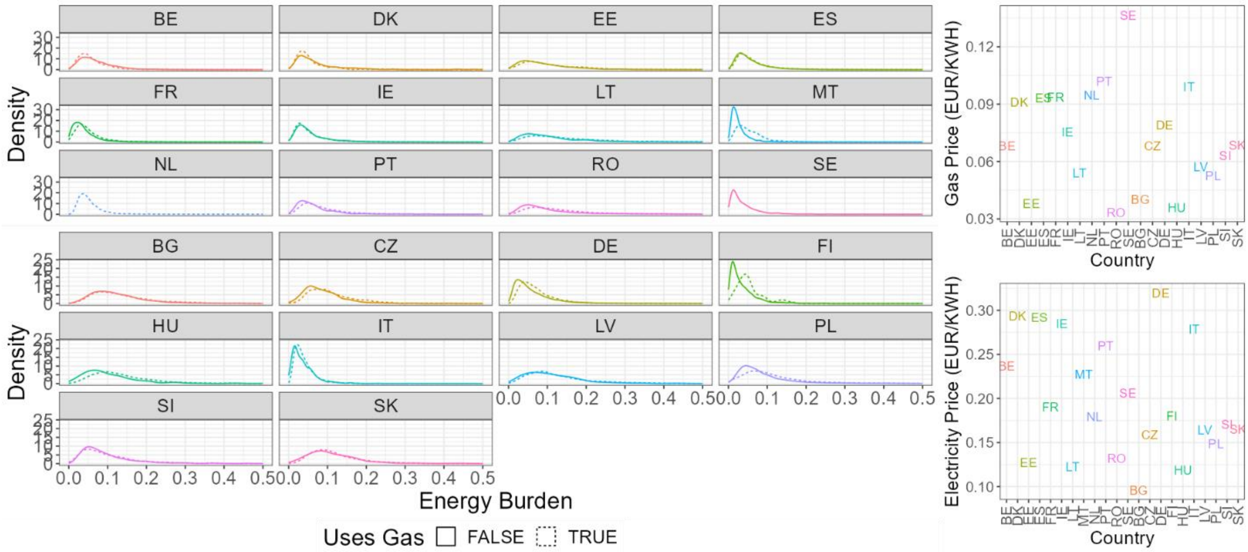

Figure 4 – Density plots of energy burden for households that do and do not use gas (left panel) and gas (top-right) and electricity (bottom-right) prices for countries in the estimation sample

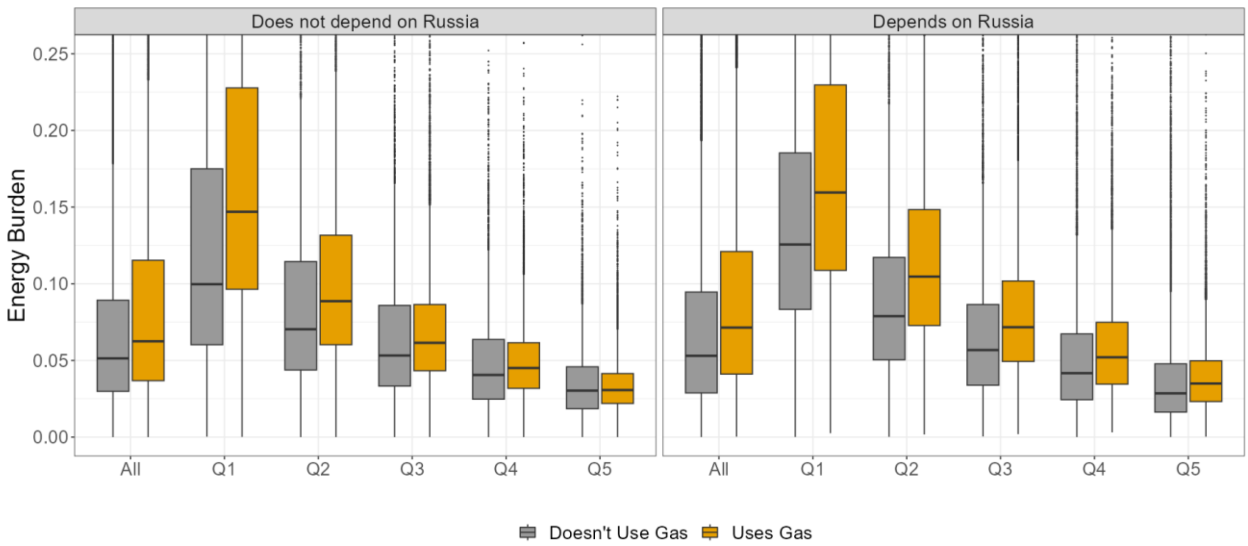

Figure 5 – Boxplots of energy burden for all households and households in different income quintiles in the estimation sample, separate for households living in countries that depend and do not depend on Russian gas

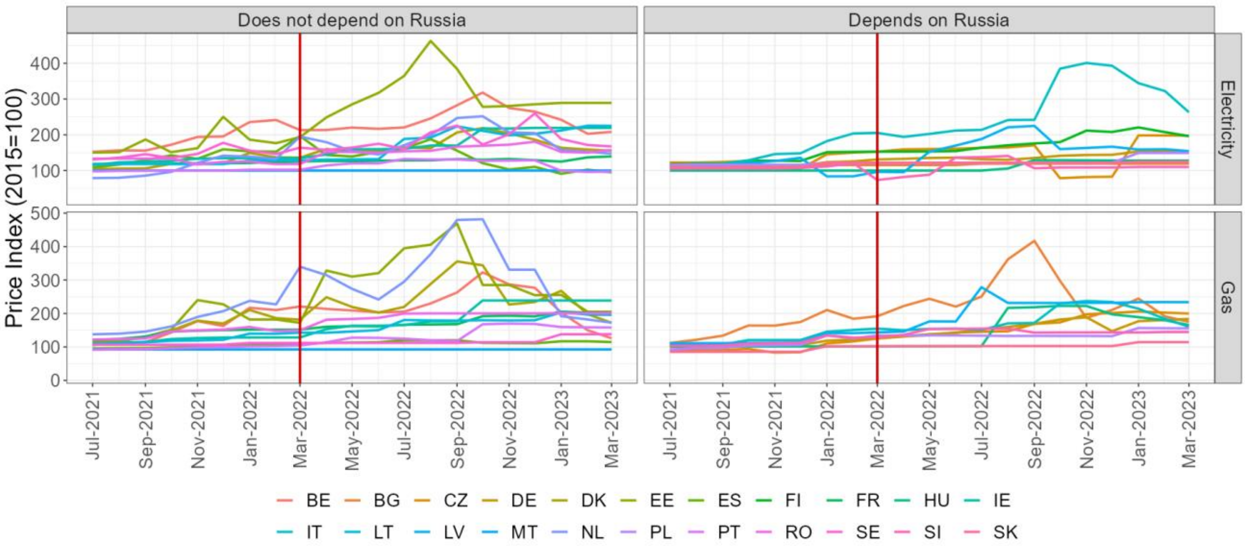

Figure 6 – Consumer price indexes of electricity and gas for countries in the sample before and after the war

Energy Prices and Household Energy Burden under Different War Length Scenarios

We create two alternative scenarios, one of a shorter war that finishes by the end of 2023, and a longer war that continues up to the end of the forecast period (January 2026). We do not model any kind of government intervention aimed at controlling prices, as these have been so far ad-hoc and hence hard to generalize across the region. Historical and forecasted pathways under the alternative scenarios can be found in Figure 7. Under our forecast, we can see that in a scenario with a shorter war the fall in the price of electricity would be larger than the fall in the price of gas compared to the longer war scenario (4.6% and 2.7% respectively). Overall inflation is more mildly affected (1.6%).

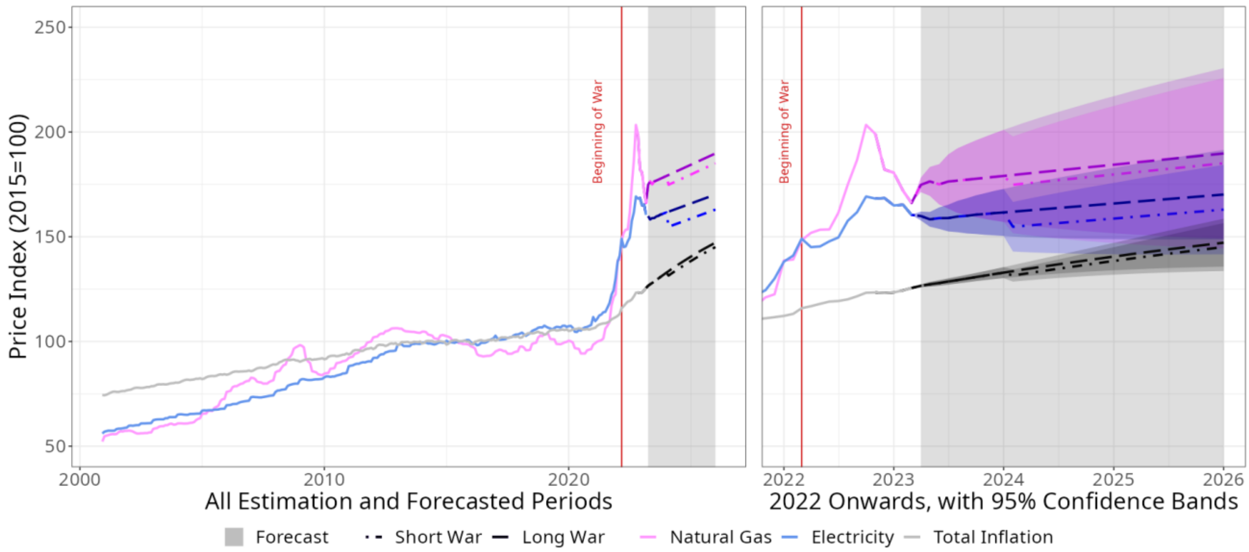

Figure 7 – Consumer price index, historical and forecasted, grey area representing forecasting periods

For the future predictions, we use the somewhat strong assumption that consumption levels remain constant, i.e., expenditures on gas, electricity and total expenditure are increased proportionally with the forecasted price changes, while keeping everything else constant. and then use machine learning to predict to what extent the energy burden of households will be affected. This provides an upper bound for the energy burden, as it is likely that households would keep similar or lower energy consumption levels as a response to the increases in prices.

Table 3 – Mean and median energy burden for households in the estimation and the prediction periods, for all households and by income quintiles

Median Energy Burden	*2015*	*2023*	*2025 - Short War*	*2025 - Long War*
All	6.2	7,00 [6,800, 7,100]	6,600 [6,300, 6,900]	6,7 [6,4, 7]
Q1	12.0	13,300 [13,100, 13,600]	12,600 [12,300, 12,900]	12,8 [12,5, 13,1]
Q2	8.6	9,200 [9,00, 9,400]	8,600 [8,400, 8,700]	8,7 [8,5, 8,8]
Q3	6.2	6,800 [6,600, 6,900]	6,400 [6,200, 6,700]	6,5 [6,3, 6,7]
Q4	4.7	5,400 [5,300, 5,600]	5,200 [4,900, 5,500]	5,3 [5, 5,5]
Q5	3.8	4,400 [4,300, 4,500]	4,300 [4,100, 4,500]	4,3 [4,1, 4,6]

Mean Energy Burden (exp log-normal)	*2015*	*2023*	*2025 - Short War*	*2025 - Long War*
All	7,600	8,700 [8,500, 9,00]	8,300 [7,800, 8,700]	8,4 [7,9, 8,8]
Q1	12,900	14,600 [14,300, 14,900]	13,800 [13,300, 14,200]	14 [13,4, 14,4]
Q2	9,200	10,400 [10,100, 10,700]	9,700 [9,300, 10,100]	9,8 [9,4, 10,2]
Q3	6,800	8,00 [7,700, 8,200]	7,500 [7,00, 8,00]	7,6 [7,1, 8,1]
Q4	5,300	6,300 [6,100, 6,500]	6,00 [5,600, 6,400]	6,1 [5,7, 6,5]
Q5	4,200	5,100 [4,900, 5,300]	4,900 [4,500, 5,300]	5 [4,6, 5,4]

We can see the predicted results for the different scenarios in Table 3 and Figure 8. We see that low-income households would be the most affected, with their average and median energy burden rising by around 2 percent. For the highest quintile, the increase is lower, around half or less the increase of the lowest quintile. However, the higher energy burden levels, in this case, are close to that of the second-to-highest quintile in 2015, which can be seen as a moderate reduction in living standards. We expect a reduction of the energy burden by the end of 2025 with respect to the end-of-2023 predictions of at most, in the case of a long war, 0.6% of the energy burden for the lowest quintile, pointing to a slow readjustment of expenditures in households. Moreover, as countries take countermeasures against inflation, it can very well be that this effect dissipates faster than what we predict.

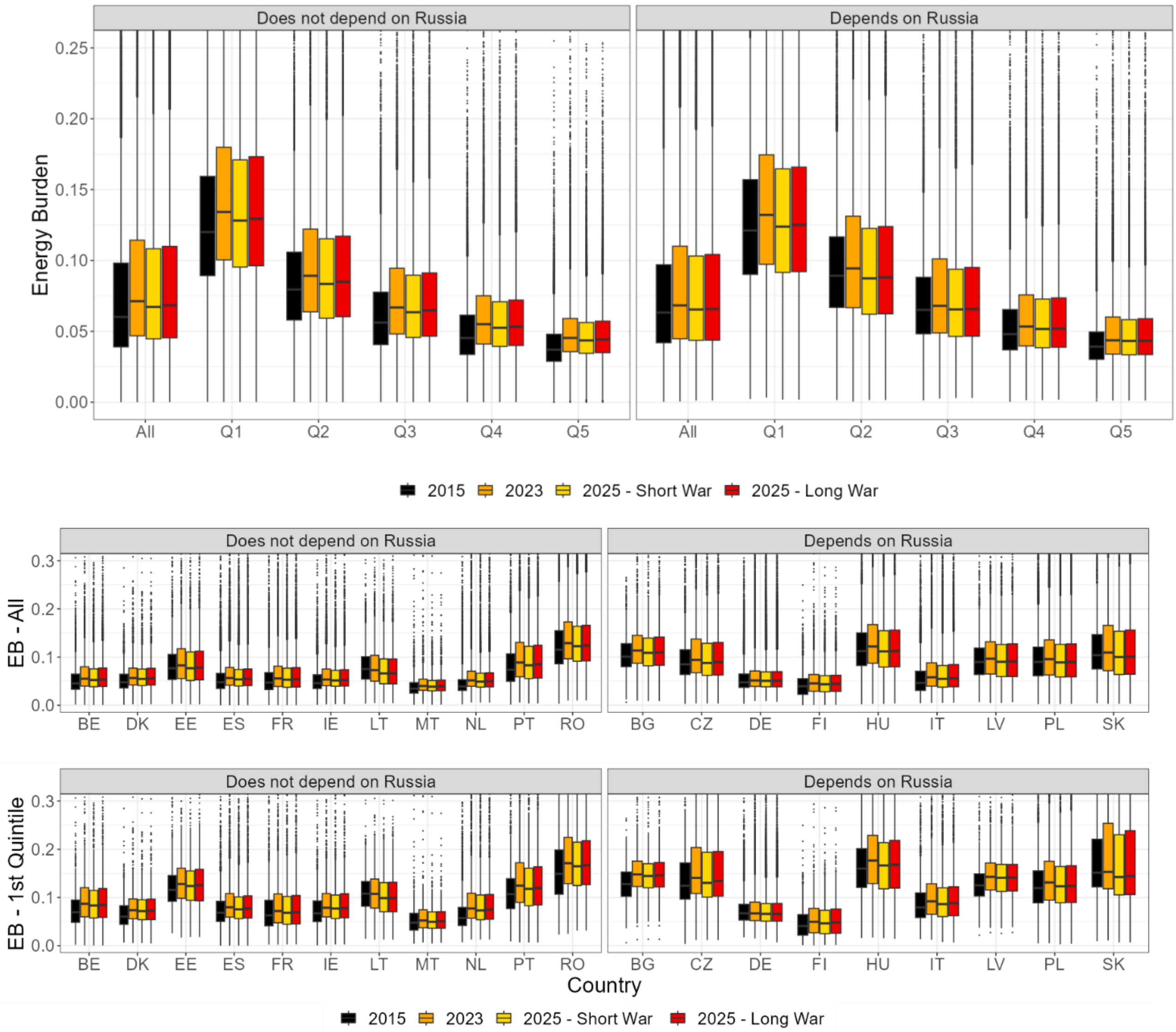

Figure 8 – Boxplots of energy burden in the estimation and the prediction periods, for all households (top panel), by country (center panel) and by country for households in the lower income quintile (bottom panel), separate for households living in countries dependent and not dependent on Russian gas

Discussion, limitations, and conclusions

Efforts to reduce energy poverty have been receiving increasing attention and energy policy focus within the EU in recent years. High and rising energy prices are a key energy poverty risk worsening the situation of already vulnerable households. Impacts of the Russian incursion in Ukraine and the ongoing conflict have led to reduced imports of Russian gas in Europe and substantial energy price volatility. With energy price volatility likely to continue, understanding the potential impact of changing prices on the extent and distribution of energy poverty in the region is essential to devise appropriate policies to address this in the immediate and longer-term.

Using recent data from the HBS, we assess the household energy poverty burden both across and within countries in Europe in this study. We consider two scenarios regarding the length of the conflict to predict future energy prices and estimate the effect of changing prices on how the household energy burden might shift. We find that both a shorter and longer conflict will worsen the energy burden for households in Europe, with countries with higher Russian gas dependency more affected, and lower-income households more affected than others. A shorter length of conflict sees more price volatility than a longer one, as one might expect.

Our results are in line with those of other recent literature on this topic that suggest that the effect of energy price rises is heterogeneous across nations and households but with gas-dependent and poorer households particularly affected (Guan et al., 2023; Steckel et al., 2022). Though we use the most recently available and comprehensive budget survey data in this work, there are some limitations of both the data and methods employed for this analysis.

Although the dataset used is, in principle, comprehensive and encompasses the whole of Europe, missing values in many countries pose an important drawback to the analysis. Also, the most recent dataset available and used is already quite dated, therefore the idea of using the older wave as a test of the applicability of the model for years far from the one used for the estimation. However, given that in recent years another large, unexpected shock affected the economy and household decisions' (the COVID pandemic), it is hard to really know how good of a representation of current conditions can be obtained from 2015 data. Finally, as stated previously, we do not model government interventions to prices due to their intractability, posing a major, but understandable limitation to the price forecasts.

While several countries in the region have taken measures to counteract the recent energy price increases and shield households from price volatility, this has impacted national budgets. In the short-term, targeted transfers and assistance hold promise and are necessary to address the exacerbated energy poverty burden, particularly for low-income and vulnerable households. However, in the longer term, efforts to improve the efficiency of the European building stock and heating systems, as well as to enhance energy security will be needed. A shift to more renewable energy can be a means to enhance energy security and meet the climate goals of lower emissions in the region, but if such a transition is accompanied by increased volatility in the energy markets in the short-term, increased budget allocations to ensure that adequate energy services at affordable prices for households will be required.

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Appendix

Table S1. Coefficients of Linear Regression on Energy Burden for the HBS Sample

	All	Q1	Q2
Intercept	-2,49628243 (***)	-1,42970637 (***)	-2,77825467 (***)
Household Size	-0,00911115 (***)	-0,03460502 (***)	0,01671586 (***)
Total Expenditure	-0,00000631 (***)	0,0000401 (***)	0,00002587 (***)
Urban	-0,24915801 (***)	-0,15833516 (***)	-0,19188672 (***)
Expenditure on Heat	0,00030463 (***)	0,00078192 (***)	0,00049023 (***)
Gender	0,08718113 (***)	0,07481689 (***)	0,06688551 (***)
Married	0,00032146 (***)	-0,03038499 (***)	0,05902812 (***)
At Most High School Degree	0,1832054 (***)	0,23686029 (***)	0,10714872 (***)
Works	-0,3548329 (***)	-0,09369501 (***)	-0,15039375 (***)
Uses Gas	0,24155733 (***)	0,41655133 (***)	0,36712335 (***)
Country Depends on Russia	0,32340511 (***)	-0,732464 (***)	0,18341157 (***)
Uses Gas and Country Depends on Russia	0,05916063 (***)	-0,15795414 (***)	-0,04491535 (***)

	Q3	Q4	Q5
Intercept	-2,79560355 (***)	-3,07192125 (***)	-3,2560999 (***)
Household Size	0,03695378 (***)	0,05256238 (***)	0,06438181 (***)
Total Expenditure	0,00001281 (***)	0,00000722 (***)	-0,00000175 (***)
Urban	-0,24267039 (***)	-0,26209177 (***)	-0,26450153 (***)
Expenditure on Heat	0,00035992 (***)	0,00034126 (***)	0,0002222 (***)
Gender	0,05164535 (*)	0,02518312 (*)	0,01466633 ()
Married	0,12253331 (***)	0,12765713 (***)	0,15549531 (***)
At Most High School Degree	0,07475941 (***)	0,07979211 (***)	0,10312222 (***)
Works	-0,20797974 (***)	-0,1990978 (***)	-0,21504981 (***)
Uses Gas	0,26010735 (***)	0,22515368 (***)	0,18934332 (***)
Country Depends on Russia	-0,14290661 (***)	-0,30543783 (***)	-0,34183857 (.)
Uses Gas and Country Depends on Russia	0,07935991 (***)	0,13030821 (***)	0,11108615 (***)