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Abstract

Two exogenous events, coupled with substantial data on individual household electricity and gas usage, enable us to examine detailed consumption effects of recent rises in gas and electricity prices in Britain resulting from the Russia-Ukraine conflict. We isolate two samples of consumers with similar characteristics, all initially on fixed price contracts. One group, forcibly moved to variable prices, suffered the price shock, the others remained on fixed prices. Our diff-in-diff framework captures the impacts on the former group, finding significant consumption effects, particularly regarding gas usage. Differing effects across richer and poorer households are revealed, the poorest greatly reducing consumption.

Keywords: Energy consumption, difference-in-differences, energy crisis, smart meters.

JEL codes: L94, E31, D12, I19

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1. Introduction

Like other European countries, Great Britain (GB) has experienced significant shocks to energy prices and suppliers' profitability over recent years. Starting with a smaller shock triggered by sudden increases in the world demand for gas in October 2021, then following a much larger shock related to the invasion of Ukraine by Russia in February 2022, gas prices rose sharply in the GB wholesale market. Since gas is normally the marginal fuel in electricity generation (Beltrami et al., 2020), electricity prices similarly rose sharply for domestic and business consumers. Over the same period, Britain's domestic consumers (referred to as households hereafter) have experienced a decline in their energy consumption faced by mounting cost-of-living pressures, including energy bills; following a 6% increase in domestic energy consumption in 2021, there was a considerable fall in energy use in 2022, amounting to a 15% decrease in energy consumption (UK Parliament, 2024). Whilst this reduction has been attributed loosely to higher prices as households cut back on energy use in response to surging bills, we investigate the detailed picture. We contribute to the literature by assessing, in more depth, how different household types reacted to unprecedented increases in energy prices in the absence of alternative market options.

We exploit an exogeneous energy price shock to energy consumption patterns caused by the gas market volatility which followed the invasion of Ukraine in 2022. In order to make causal inferences about the effect of this considerable price shock we use a previous event which caused a large number of GB households to move from a fixed price contract to a variable tariff, resulting from market developments in 2021. We leverage these key events in the energy markets to gain insights into how households respond to rising energy prices, relying on accurate information on households' prices and consumption, available from a large sample of smart meter users.

We take advantage of the quasi-randomisation of households' allocation across suppliers and tariffs. The collapse of over 20 suppliers in 2021 not only forced over 4 million households onto a different energy supplier but also exposed them to variable prices. It also massively reduced the options available to households seeking a fixed-price contract. Importantly, and a key feature for identification in our empirical strategy, households were unable to apply for a fixed tariff between October 2021 and June 2023[1].

Around 13,000 households with smart meters were recruited by a research team at UCL's Smart Energy Research Lab (SERL) and have allowed access to their data for research purposes. We were able to use this information on actual consumption and prices, which is not available via the UK's national household surveys[2], for our analysis.

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[1] Whilst it is plausible some households actively switched by directly contacting energy suppliers about non-price factors, such as quality of service (Deller et al., 2021), the new contract will be a standard variable tariff regardless.

[2] For example, the National Energy Efficiency Database (NEED) contains information on energy consumption but not prices. The consumption data obtained from SERL is consistent with the NEED data (Few et al., 2024).

We rely on SERL’s large dataset to evaluate the households’ reactions to significant and unprecedented price changes to their energy bills by comparing the behaviour of a treated group of households who were moved to a variable tariff, thus experiencing the price rises, with a control group who were on a fixed-price contract over the period of the energy price crisis. Upon refining the dataset in line with our empirical strategy our sample contains around 3.2 million observations (covering around 3,000 households) for electricity and about 1.5 million observations (almost 1,400 households) for gas.

Our results, based on a difference-in-differences (diff-in-diff) approach, rigorously establish that households who were moved to a variable tariff reduced their consumption by significant amounts compared to the control group who remained on a fixed tariff. Our quasi-experimental approach allows us to address the endogeneity related to the presence of other competing cost-of-living pressures at the time, such as the cost of housing and food. It is therefore reasonable to expect that our estimated average treatment effects will be lower than broader assessments which do not control for confounding factors. Our estimated changes in electricity consumption at 9% and at 13% for gas are indeed lower than official estimates of temperature-adjusted average consumption at 13% and 18% for electricity and gas respectively (Bolton, 2025). When combining the information about the size of the increases in prices and the reduction in energy consumption we find that households spent around £131 extra per year on electricity and gas consumers spent around £201 extra per year during the energy crisis.

We investigate heterogenous effects, finding that for both electricity and gas the observed reduction in consumption is consistent with the households’ stated energy saving behaviour. Our results indicate that the average treatment effects (ATEs) are associated with the households who state that they regularly engage in energy saving behaviour, particularly by switching off lights and using extra clothing to reduce consumption.

We also explore the distributional effects of the energy price crisis by breaking down our sample according to the Index of Multiple Deprivation (IMD). Our results show that electricity consumption fell in response to the energy price crisis in the lowest two and in the highest two quintiles, while the largest estimated changes in gas consumption were observed for the first two quintiles representing the greatest degree of multiple deprivation. Overall, the ATE for the first two quintiles is numerically larger (at 22%) than in our main findings, a result which is concerning from a social welfare perspective.

This work contributes to the general economic literature on price elasticity of energy demand, which counts amongst its seminal contributions the GB study by Baker et al. (1989) and the US study by Reiss and White (2005). Recent related studies of energy consumption in GB include those by Druckman and Jackson (2008), Fuerst et al. (2015) and McIntyre (2018). These studies have generally investigated economic aspects of energy consumption at times of relatively stable conditions in energy markets, with limited price variations over relatively long periods of time.

Recent events in the European energy markets have however caused unprecedented increases in the level and volatility of energy prices, leading to an emerging strand of literature that investigates the economic impact of the Ukraine war. This strand of literature includes a small number of contributions with a related focus to ours, namely the economic impacts of the Ukraine war, and of the policy interventions which followed, on the GB retail market. Fetzer et al. (2022) and Braakmann et al. (2023) assess the implications of the unprecedented increases in energy prices for households' decisions regarding investments in energy efficiency, which could shelter households from future high bills. Fetzer et al. reach the conclusion that Government interventions to protect households were a lost opportunity to promote awareness of the benefits of energy efficiency, both in economic and in environmental terms. Braakmann et al. on the other hand conclude that GB households perceived the price increases as being temporary, thus failing to attach a monetary premium to properties characterised by high levels of energy efficiency. However, they identify a small penalty being attached to relatively less efficient properties. Alpino et al. (2024) investigate the impact of energy price shocks on Italian industrial firms at the start of the energy crisis using an econometric method similar to ours but rely on a less rigorous identification strategy.

Closest in subject to our analysis are Frontier Economics (2023) and Levell et al. (2024), in that they investigate the impact of price changes on energy consumption and assess the distributional implications of the energy price crisis. The report on Frontier Economics' Project VENICE contributes to the literature as it relies on micro-data from smart energy meters and on a specially developed survey of households with a focus on specific actions taken by them to cope with increased prices, rather than limiting their analysis to the changes in prices and income. However, their study, although extensive, relies on a simulated control group strategy using previous weather corrected consumption. They utilise data from Autumn 2021 to the end of December 2022, making comparisons between predicted consumption from October to December 2022 based on 2021 data, rather than the contemporaneous diff-in-diff econometric approach we take using the same data source extended in time to the end of 2023. They supplement this with survey data to gain an understanding of actions that a subset of their households took in response to the price rises. Among their results, they point out that many households have limited awareness of the most effective coping strategies and actions.

Levell et al. (2024) rely on energy bills from bank accounts over the period June 2021 to May 2023 to estimate changes in consumption and energy demand elasticity using a flexible (Exact Affine Stone Index) demand model and focusing on the subset of households (around 40%) who pay month by month according to consumption, rather than those whose energy supplier aims to even out bills over the year based on estimated consumption. Theirs is a much more structured econometric analysis than the Frontier study, meaning that they can investigate counterfactuals in the structural analysis. However, because they leverage a particular source of bank account data, and most households consuming energy have the same supplier for both gas and electricity, they can only observe total energy expenditure and therefore are not able separately to identify impacts on gas and electricity consumption, something that turns out to be important in both our analysis and the Frontier study. Levell et al. identify significant changes in consumption reflecting high levels of demand elasticity; they report that the largest responses were observed for households with the highest levels of pre-crisis consumption, and that the introduction of Government subsidies prevented significant monetary losses for most households.

Our findings, like the Frontier Economics' study, rely on actual prices together with consumption levels as recorded by smart meters, rather than on estimated consumption based on regional price indexes, allowing us to estimate changes in consumption based on observed price variations. Importantly, we establish a causal link between price variations and changes in consumption, thus extending our understanding of the impact of the energy crisis. This is achieved by comparing the behaviour of households remaining on fixed contracts with that of households who were forced by external events to move from a fixed to a variable tariff at a time preceding the Ukraine war.

We also face data limitations concerning the specific tariffs that households had subscribed to, preventing us from undertaking an even more detailed analysis of the effect of variable tariffs and specific long-term contracts held by the households in our sample, although the presence of binding price-caps during the period of analysis has mitigated the effects of this potential issue.

Our ability to control for socio-economic characteristics and to investigate differences in household behaviour across socio-economic groups was limited by the amount of information available about these household features in the questionnaire administered to participating households at the time of joining the research sample. Some additional information about socio-economic characteristics and actions taken to mitigate the impact of price rises was contained in a more recent survey in 2023, but only about half the sample took part, thus limiting our ability to investigate the interaction between the reduction in energy use and the adoption of other energy saving actions.

The rest of the paper is organised as follows: section 2 presents the institutional framework of the GB energy market, while the empirical strategy and key features of the data are described in section 3. The main results are discussed in section 4 and section 5 offers conclusions and recommendations. The Appendices contains more details about the data and different aspects of the statistical analysis.

2. Background

There is substantial competition in electricity and gas supply to domestic households in Britain. Suppliers principally compete for customers through price and contract type – usually, households choose either a variable tariff or a unit price fixed for a period of up to three years. Most households obtain their electricity and gas from the same supplier.[3] Competition is subject to unit prices not exceeding a regulated price cap set biannually by the energy regulator, OFGEM, until October 2022 and quarterly afterwards. Households who fail to exercise a choice commonly find themselves paying the capped price – the Standard Variable Tariff (SVT).

One important role of suppliers is to shield households from the substantial fluctuations in the wholesale market – typically they do this by purchasing a portfolio of future contracts with wholesalers and generators. Clearly, if a supplier fails to hedge appropriately but has a portfolio of customers principally on fixed-price contracts, the supplier is vulnerable to significant upswings in energy prices. This happened in October 2021, when wholesale prices rose significantly following the removal of most restrictions imposed during the COVID-19 pandemic. A total of twenty-nine suppliers, serving over 4 million households, experienced severe financial difficulties and exited the market. In such a circumstance, OFGEM arranges for affected households to be moved to a specific alternative supplier, but inevitably, they will only be offered an SVT. Normally, households can choose their tariff type freely, but as a result of subsequent price rises, new fixed tariffs became unavailable.

There has been a significant programme of "smart meter" rollout; by the end of 2023, 61% of households have had either a smart or advanced meter, 54% of which were operating in smart mode (DESNZ, 2024a). These enable the supplier to measure consumption and so to calculate the household's bill without the need to estimate or visit the premises. A representative sample of households has agreed to allow consumption data from their smart meters to be used for research purposes, subject to strict privacy protocols. This sample forms the basis of our data.

Much of Europe's natural gas requirement has traditionally been accessed through pipelines from Russia. Following the Russian invasion of Ukraine in February 2022, this source was significantly restricted, leading to wholesale price rises. Gas also acts as the marginal fuel in electricity generation in Britain, meaning that wholesale electricity prices also rose significantly. When OFGEM set its April 2022 SVT, it marked a very large increase over the previous value.

Within our sample of households, we selected all those initially on a fixed tariff prior to April 2022. We define those remaining on the fixed tariff after that date as our control group. The treated group comprises those who were moved off a fixed tariff onto a variable tariff on or after April 2022. We examine differences in their consumption patterns using a diff-in-diff framework.

As economies worldwide started opening up following the removal of COVID-19 restrictions, excess energy demand led to global gas prices rising by around 50% (Ofgem, 2021) and caused the GB energy price-cap, set by OFGEM, to increase by about 12% in October 2021. This price shock initiated a wave of energy suppliers exiting the retail market. The collapse of around twenty-nine suppliers between

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[3] All households have access to an electricity supplier, but not all have access to a gas supplier since the gas network is not universal. Gas is the most common fuel for space heating.

August and December 2021 forced approximately four million households to join a different energy supplier (House of Commons, 2022; NAO, 2022), typically one of the so-called ‘Big 6’[4], and onto a new SVT – also called a ‘default’ tariff – which tracks movements in the regulatory price cap (OFGEM, 2024a). The second and more extreme energy price shock is exploited in order to measure the causal effect of the energy price crisis on gas and electricity consumption. This price shock was caused by the volatility in energy markets around the time of the Russian invasion of Ukraine, which sent wholesale gas prices spiralling across Europe. Like the previous energy price shock, the gas price increase fed into OFGEM’s calculations of the subsequent price cap in April 2022. Unlike the previous shock the increase in prices did not lead to further exits of energy suppliers, instead it exposed households who were on variable tariffs to a substantial increase in energy prices, while those on a fixed deal were protected.

The rapid rise in the price of fixed tariffs, far above the SVTs protected under the cap[5], limited the offer of switching options, especially price-based ones[6]. Indeed, switching rates dropped by around 80% from the hundreds of thousands in 2021 to tens of thousands in 2022 and neither fixed rates nor switching rates have returned to pre-crisis levels (Figure A1, Appendix A; OFGEM, 2024b).

In addition, our time period of interest includes the time of the second national COVID-19 lockdown (January-July 2021), as well as the Government’s main policy instrument to support households during the energy price crisis – the Energy Price Guarantee (EPG) – which was a *universal* subsidy preventing suppliers from charging households above a defined rate for each unit of gas and electricity between October 2022 and June 2023. The advantage of using a diff-in-diff approach is that the effects of the lockdown and the EPG on consumption will have affected both the treatment and the control group in a similar way.

3. Empirical strategy and data

The quasi-random allocation of households that originally chose fixed tariffs, yet ended up on an SVT, is crucial to our approach because it prevents self-selection back into fixed tariffs. This allows us to define our control group (FF) – i.e., any household that remained on a fixed tariff throughout 2021 to 2023 – and the treatment (FV) group – i.e., those who moved from fixed to an SVT and were therefore exposed to future energy price shocks for the reasons discussed above.[7] Crucially, the concomitant change in the level of fixed tariffs and the lack of switching opportunities prevented households from

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[4] The ‘Big 6’ includes the legacy suppliers Centrica (aka British Gas), EON, Scottish Power (now owned by OVO), EDF and SSE, and the new entrant Octopus Energy.

[5] See Figure A2 in Appendix A.

[6] As illustrated in Figure A2 from July 2021 fixed price contracts started moving well above the price-cap level. Between July 2022 and June 2023 no fixed-price contracts were offered and after that time their price settled at similar levels to the SVTs and the price cap.

[7] There is also a large group of households on SVTs throughout (the VV group) as we mention briefly later in the paper.

selecting into the (FF) control group and as a result makes the pool of households moved onto variable tariffs look remarkably similar to those who, through good fortune or luck, remained on a fixed tariff throughout the crisis – as discussed in detail below.

We employ a diff-in-diff framework with the aim of estimating the causal effect of the energy price crisis on domestic electricity and gas consumption. The general econometric specification can be defined as follows:

$$C_{itj} = \beta_0 + \beta_1 FV_{ij} + \beta_2 PC_{it} + \beta_3 FV_{ij} \cdot PC_{it} + \omega_t + \mu_r + \alpha_i + \varepsilon_{itj} \qquad (1)$$

where C_{itj} is energy consumption for household i on day t. We estimate separate equations for gas and electricity, reflected in the j index. We are primarily interested in β_3, the average treatment effect (ATE) on the interaction between the indicators FV_{ij} and PC_{it}. The FV_{ij} indicator is set equal to 1 if the household is on an SVT during the energy price crisis but was previously on a fixed tariff and 0 otherwise. The treatment indicator PC_{it} is set equal to 1 for days following April 1st 2022, and 0 for previous days. The ATE captures the additional impact of the energy price crisis on those exposed to price shocks during this period (i.e., FV) compared to those protected by their fixed rates (i.e., FF). Whilst the coefficient β_2 is of lesser interest, it allows us to infer the general trend of household energy consumption in absence of a forced move to a variable tariff.[8] In equation (1) ω_t is the vector of time effects[9] capturing the seasonality in C_{itj}, while μ_r represents the vector of regional effects, α_i denotes the time-invariant unobserved household fixed effects. Finally, ε_{itj} denotes the idiosyncratic error term, clustered at the household level.[10]

Equation 1 is estimated using both pooled OLS and fixed effects models. Alongside a battery of robustness checks, we include a vector X_{it} which contains a standard set of socio-demographic and housing characteristics in the pooled OLS (robustness) specifications (see Table A1, Appendix A).

In order to interpret the findings as a causal effect, we demonstrate that our groups (FV and FF) satisfy the parallel trends assumption, i.e., that they would have followed an identical trend in consumption had the energy price crisis not occurred. While this counterfactual is unobserved, we explore, as is typical in diff-in-diff frameworks, the trends prior to treatment to make inferences about what would have happened in the absence of the treatment. Indeed, as we show, the two groups exhibit patterns of electricity and gas consumption that clearly follow similar trends over an extended period (January 2021-April 2022). Therefore, we assume that, all else constant, there is no reason other than the energy price crisis for the groups to deviate from their common trend. Whilst there are shallow fluctuations around these trends, we show later that any deviation prior to April 2022 is not significantly different

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[8] β_1 is anticipated to statistically insignificant from zero provided the treatment and control groups are sufficiently similar in their socioeconomic and demographic characteristics, pre-energy crisis.

[9] Time effects include monthly indicators and the interaction between day of month and day of week indicators, unless stated otherwise.

[10] The main analysis holds using robust standard errors and clustering at the local authority level.

from zero by estimating ATEs for each month relative to the baseline treatment window. Some details of our econometric strategy will be presented later, after the description of the data.

Another potential threat to our identification strategy lies in whether households anticipated the energy price crisis that emerged post April 2022. Evidence to the contrary has been provided by Braakmann et al. (2024) who suggest that, based on Google Trends data from January 2021 to July 2022, British households' awareness of, and interest in, energy bills increased over time *in response to* price increases, rather than anticipating energy price increases.[11] Extending Braakmann et al.'s period of analysis we find interest was relatively low until a surge later in 2022, around the time of the October price cap adjustment (see Figure A3 in the Appendix A). This evidence is consistent with the "normal" level of switching observed before the end of 2021 (Figure A1, Appendix A), not least because, had well-informed households anticipated the first energy price shock, there would have been a more pronounced spike in switching when the opportunity to switch was still available. Households' lack of anticipation of price increases bolsters a causal interpretation of our findings.

A final potential concern regarding our empirical strategy relates to the dynamic movement of households from fixed to variable tariffs, which occurs at different times between the April 2022 price cap change and the end of our sample. We address this concern using a staggered diff-in-diff approach (Callaway and Sant'Anna, 2020). This approach accounts for households who switch to a variable tariff after 1st April 2022, either when they leave a supplier that exited the market or at the end of a fixed-term energy contract.

To ensure that this staggered analysis is empirically tractable our daily consumption data is aggregated at the monthly level, allowing us to evaluate the impact of the energy crisis on households who switched between key two periods: April 2022-March 2023 and April 2023-December 2023. These timepoints separate those switching after the first main price rise in April 2022 from those switching following the second substantial price increase in April 2023. At this level of aggregation, we first estimate the ATEs using the baseline approach (i.e., the 2x2 treatment with April 2022 as the only timepoint) in order to test whether the main findings are robust at the monthly level[12]. Following this analysis, we estimate the ATEs formally accounting for staggered movements in the treatment within the two specified timepoints. Our ATEs are estimated at several levels using the doubly robust diff-in-diff estimator (Sant'Anna and Zhao, 2020): a simple (2x2) average, group average and group-specific average to further test the robustness of our findings. Standard errors are clustered at the household level.

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[11] The authors used the search terms "energy saving", "energy price cap" and "energy bill".

[12] Estimating our results at a higher level of aggregation also serves as an additional robustness check which alleviates potential concerns about whether the time series data generating process affects the causal identification in our baseline results.

Data

Our data has largely been obtained from SERL, a panel observatory managing smart meter data, which is maintained by the UK Data Service (UKDS) (Elam et al., 2023). The most recent (6th) edition of the data contains a large representative panel of daily gas and electricity consumption and price information for approximately 13,000 GB households (Webborn et al., 2021; Few et al., 2024).[13] SERL's consumption data starts in 2018, while the tariff information (specifically prices), collected from 2020, has only become available to researchers in late 2022. We utilise information from several other datasets that are linked (by the SERL research team) to the smart meter data in the core panel, including temporal data (such as weather conditions) and static data that provides additional contextual information about the household and housing characteristics. The availability of this data set offers a novel opportunity to explore the impact of the energy price crisis on daily household energy consumption between January 2021 and December 2023.

The raw panel is unbalanced; therefore, given our empirical strategy outlined above, we restrict our final sample to include only those households with consumption values observed for at least 2.5 years, ensuring that the households are observed pre- and post-crisis – we later relax this condition to households being observed for at least one year with the results remaining qualitatively the same. Upon adjusting the dataset in line with our empirical strategy and including only valid meter reads[14], the sample used in the main analysis of electricity consumption contains around 3.2 million observations (covering around 3,000 households) and about 1.5 million observations for gas consumption (covering almost 1,400 households). To be clear, this translates to over 100 households (around 111,000 observations) in our control group and nearly 3,000 households (with roughly 3.1 million observations) in our treatment group for electricity, and 86 households (with about 86,000 observations) in our control group and 1,300 households (with roughly 1.4 million observations) in the treatment group for gas consumption[15].

Table 1 provides the summary statistics for electricity and gas consumption and prices. Between 2021 and 2023 households typically consumed around 8.8 kWh of electricity[16] and 32.8 kWh of gas per day

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[13] SERL is a proprietary data source and access to it is restricted but made available to approved researchers in a secure environment under strict conditions through the UK Data Service's secure access program, collected through the Data Communications Company (DCC) gateway. The random sample of GB households with smart meters is stratified by Index of Multiple Deprivation (IMD) and region see, e.g., Webborn et al., 2021.

[14] It is important to mention here that SERL researchers flag consumption data that may be considered invalid. This includes meter reads that have been recorded as the maximum (or very high), electricity consumption recorded in the incorrect unit, values exhibiting invalid read times but valid reads, as well as suspicious zeros; in addition, we rely on valid half hourly reads that have been aggregated in order to impute missing daily reads. Zapata-Webborn et al. (2024a) provide further details on data collection and error flags.

[15] Similar results are observed in our main analysis when expanding these groups, by allowing for a more unbalanced panel or by moving households from the control to treated group in a staggered approach after the start of the energy crisis.

[16] For homes equipped with photovoltaic (PV) panels, the electricity consumption is reported as net demand from the grid, reflecting the difference between electricity imports from and exports back to the grid.

(equivalent to around 3,200 kWh/year of electricity and 12,000 kWh/year of gas).[17] Average daily electricity consumption has decreased year-on-year with consumption falling from 9.6 kWh in 2021 to 8.3 kWh in 2023. Similarly daily gas consumption has declined from 38.3 kWh in 2021 to 29.1 kWh in 2023.

Unless otherwise stated we interpret our findings as elasticities, and to achieve this we use the inverse hyperbolic sine (IHS) transformation of gas and electricity consumption. This transformation has the benefit of approximating a natural logarithm transformation and the added advantage of maintaining zeros.[18]

Table 1. Summary statistics for electricity and gas.

Variable	Mean	Std. Dev
Panel A: Electricity		
Electricity consumption (kWh/day)	8.821	7.515
Inverse hyperbolic sine of electricity consumption	2.607	0.748
Electricity price (£/kWh)	0.233	0.116
Proportion fixed pre-April 2022 and variable post-April 2022 (FV_E)	0.965	
Panel B: Gas		
Gas consumption (kWh)	32.819	35.410
Inverse hyperbolic sine of gas consumption	3.376	1.529
Gas price (£/kWh)	0.065	0.034
Proportion fixed pre-April 2022 and variable post-April 2022 (FV_G)	0.942	

Notes: ***Electricity*** *- Number of observations underlying electricity consumption = 3,234,080. Number of individuals underlying electricity consumption (observed for at least 2.5 years) = 2,980.* ***Gas*** *- Number of observations underlying gas consumption = 1,486,428. Number of individuals underlying gas consumption (observed for at least 2.5 years) = 1,379.*

Over the same period, Table 1 also shows that the average price of gas and electricity is 6.5p/kWh and 23.3p/kWh, respectively.[19] We use gas and electricity prices to identify households who were exposed

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[17] These values fall between the typical domestic gas and electricity consumption values used by Britain's Department of Energy and Net Zero, DESNZ (13,600kWh and 3,600kWh, respectively) and Ofgem (12,000 kWh and 2,900 kWh, respectively) (DESNZ, 2024b; Ofgem, 2020).

[18] Around 2.3% and 5.8% of electricity and gas observations are zeros. Let y and x denote the dependent and independent variable, respectively. The inverse hyperbolic sine (IHS) transformation is defined as: $arcsinh(x) = \ln\,(x + \sqrt{(x^2+1)})$. For large values of the dependent variable (i.e., $\bar{y}$ roughly greater than 10) as in the case of energy consumption, Bellemare and Wichman (2020) show that the sample coefficient in the IHS transformed equation, with an indicator as the independent variable, can be interpreted as a semi-elasticity, i.e.$\hat{\xi}_{yx} \approx \hat{\beta}$. In this case, the 'exact' correction can be used with little error, and it is straightforward to check that our ATEs change little when using the exp $(\hat{\beta})$-1 correction. Given the low percentage of zeros in our sample the concerns summarised by McKenzie (2024) about the potential dominance of extensive marginal effects are unlikely to affect our ability to correctly interpret the magnitude of the estimated treatment effects. As discussed in the results section, our results are robust to using the more traditional logarithmic transformation log(y+1), the Poisson estimation method, and the removal of zeros. It is important to note however that zeroes are potentially valid if, for example, a household purchases electricity on a pay-as-you-go basis and ran out of credit (thus, self-disconnecting from supply), or uses gas for heating only but does not turn it on warmer seasons.

[19] The average price in our sample falls within one standard deviation of the overall average variable unit price of electricity (25.7p/kWh) and of gas (6.6p/kWh) reported by DESNZ (2024c). This is reassuring given that the tariff information is raw (i.e., there are no error flags or pre-cleaning done by SERL researchers) and collected less frequently than the consumption data. The latter is due to households' fixed contracts typically lasting for over a year and the price cap either being updated bi-annually (2021-2022) or quarterly (2023). McKenna (2024) provides further technical details on the tariff information available from SERL.

to the energy price crisis by using the variation in the series (or lack thereof) as a signal for those on SVTs (or fixed tariffs). The cut-off point we use as the start of the energy price crisis is OFGEM's price cap adjustment on 1st April 2022, the first time that costs fed through to households in response to the rise in wholesale prices leading up to and following the initial outbreak the Russian invasion of Ukraine on February 24th, 2022.

One concern might be that the households who were on SVTs prior to the start of the energy price crisis (the VV group) may have different characteristics from those initially on fixed tariffs. To address this issue, we build suitably comparable control and treatment groups, as discussed in relation to the balance of characteristics, by identifying households who were on fixed tariffs *prior to* the energy price crisis. That is, we categorise our control group as those on fixed tariffs prior to, and during, the energy price crisis (the 'FF' group), and the treatment group as households who were forced to move from a fixed tariff *pre-crisis* to a variable one *during the crisis* (that is, the 'FV' group).[20]

With respect to our final sample, Table 1 shows that for our main analysis around 4-6% of households stayed on a fixed tariff for the duration of our sample (FF)[21], while the remaining 94-96% comprises those moving from fixed to variable rates (FV).[22] DESNZ estimates indicate that at the end of 2021 (Q4) approximately 30% of all domestic electricity customers and 40% of all domestic gas customers were on fixed tariffs; but, by September 2023 only 10% of all customers were on fixed tariffs (DESNZ, 2024b). Similarly, OFGEM (2021) suggest that around 33% of gas and electricity customers had a fixed tariff at the start of the crisis. This is in line with the percentage of our original sample identified as varying throughout: 64% of electricity users and 77% of gas users were on variable tariffs throughout the relevant time period, while 36% and 23% respectively were on a fixed tariff at some point. [23]

Lastly, it is worth considering to what extent the proportion of our sample that moved onto a variable tariff post-April 2022 reflects either i) the number of customers that moved onto a new supplier after their supplier exited the market in 2021 or ii) customers who saw their fixed tariff come to an end during the crisis. Ignoring the largest of the suppliers that went bankrupt (i.e., Bulb, with approximately 1.5 million customers who were only offered a single variable tariff) around 2.5 million households were forcibly moved onto an SVT because their supplier exited the market (equivalent to 16% of the 15 million GB households with active smart meters). Given the FV group makes up 24% of our original sample, it is therefore possible to assume that about two-thirds of this group have been forcibly moved

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[20] We therefore exclude households that exhibited variable rates throughout 2021-2023 and households moving from a variable rates pre-crisis to a fixed rate during the crisis.

[21] The option to fix for two or three years was widely available before the onset of the first energy price shock.

[22] Whilst the available data in SERL does not contain information about the tariff beyond prices, official reports stress that using the "*attributes of tariff names provided by energy companies*" only serves as a rough guide as to whether a tariff is fixed or varying (DESNZ, 2024b, p. 10).

[23] We find a small proportion of households (3.5% and 4.8%) who switched onto a fixed tariff pre-April 2022 and remained on one throughout the energy price crisis. The total proportion of households on a fixed tariff from January 2021 to April 2022 (31%, electricity; 17%, gas).

to an SVT because their supplier exited (i.e., 16/24) and the remaining one-third of the FV group moved to an SVT once their fixed deal expired.

To show that the households in our control and treatment group can be considered alike, we check the balance of sample statistics for key socio-demographic and housing characteristics, i.e., that the difference in the sample means is not statistically different from zero.

Table 2 presents the means, as well as difference in means, of a standard set of socio-economic (age, gender, labour market status, electric vehicle owner, household size), housing (number of bedrooms, property age and type, tenure), and regional (location, deprivation, temperature) characteristics identified in the literature as determinants of household energy consumption (Huang, 2015; Piao and Managi, 2023), for the groups FF and FV.

Most variables in Table 2 are extracted from the *SERL Main Recruitment Survey* and merged using the households' pseudo anonymised participant identifier, including the IMD quintiles (1 is most deprived, 5 is least deprived). The only additional variable is 'mean 2m surface temperature' (labelled as mean temperature in the table) which is linked via grid cells using the climate data available in the SERL observatory.[24]

While the SERL observatory provides high frequency consumption and price data, the information on household, housing, and regional characteristics is collected at infrequent intervals. The main survey was circulated at the start of each of the three waves of recruitment and completed by an adult resident household member. Though responding to the main survey was not a requirement for participation, the responses cover 83% of the electricity sample and 88% of the gas sample used in our main analysis. Despite the static nature of the survey data, it allows for the comparison in the means between groups.[25] Table 2 shows that the differences in means between FF and FV are not statistically significant at conventional levels for our set of covariates, excluding mean surface temperatures at the 10% level (electricity) and 5% level (gas). Therefore, we control for temperature in all specifications unless stated otherwise.

A single follow up questionnaire to the main survey is available but only has a 45% response rate (Hanmer and Huebner, 2024). This allows us to expand the set of controls in our robustness analysis to include additional socio-economic variables (income bands and payment methods for gas and electricity), and the presence of low-carbon and energy-efficient technologies (i.e., solar panels, insulation, double-glazed windows, draught-proofing). In addition, the energy efficiency level of the

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[24] The data originates from Copernicus/ECMWF ERA5 hourly reanalysis data. Further details on the climate data can be found in Zapata-Webborn et al. (2024b).

[25] The definitions and sample summary statistics of these variables are presented in Table A1 in Appendix A.

property is captured by the rating ascribed to the Energy Performance Certificate (EPC)[26] available for the 50-60% of the housing stock properties that has one.[27] To avoid dropping over half of the sample, these additional variables are included alongside an indicator variable equal to 1 if the individual participated in the follow up survey and to 0 otherwise, as well as another indicator equal to 1 if the household has an EPC certificate and to 0 if not.[28]

Table 2. Mean values and the difference in means for our socio-demographic, housing and regional variables means by FF and FV groups.

	Electricity			**Gas**		
Variable	FV Mean (1)	FF Mean (2)	Difference (3) = (1)-(2)	FV Mean (1)	FF Mean (2)	Difference: (3) = (1)-(2)
Female	0.446	0.436	0.011	0.433	0.426	0.007
Age >65	0.439	0.448	-0.009	0.435	0.417	0.018
Employed FT	0.357	0.329	0.028	0.368	0.334	0.034
Employed PT	0.090	0.116	-0.026	0.108	0.114	-0.006
LTSD	0.040	0.021	0.019	0.028	0.035	-0.007
Unemployed	0.021	0.032	-0.011	0.018	0.035	-0.017
Retired	0.469	0.459	0.010	0.463	0.413	0.050
Other status	0.013	0.011	0.002	0.010	0.023	-0.013
Owner-mortgager	0.791	0.808	-0.017	0.872	0.863	0.008
Rent	0.209	0.192	0.017	0.128	0.137	-0.008
Household size	2.236	2.127	0.109	2.351	2.400	-0.049
Bedrooms	2.892	2.864	0.029	3.091	3.159	-0.068
Detached	0.594	0.543	0.052	0.653	0.655	-0.002
Terraced	0.226	0.234	-0.008	0.270	0.289	-0.019
Flat	0.180	0.224	-0.044	0.077	0.057	0.021
Property > 2003	0.090	0.148	-0.058	0.065	0.081	-0.016
Gas central heat	0.836	0.872	-0.037	0.973	0.931	0.042
Electric central heat	0.072	0.053	0.019	0.005	0.012	-0.007
Other central heat	0.092	0.075	0.017	0.022	0.058	-0.036
London	0.153	0.138	0.015	0.123	0.126	-0.003
IMD quintile 4-5	0.385	0.466	-0.080	0.405	0.358	0.048
Mean temperature	284.163	284.001	0.162*	284.187	283.994	0.193**
N	2,799,042	102,001		1,292,438	93,968	

*Note: * p<0.10 ** p<0.05 ***p<0.01. Number of observations observed for at least 2.5 years. Tests use bivariate regressions clustered standard errors at the individual level.*

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[26] EPC ratings provide information about the efficiency of the property and potential measures that could enhance its performance and range from G-rated (least efficient in terms of fuel costs and carbon dioxide emissions) to A-rated (most efficient).

[27] The collection of EPC data is detailed in Zapata-Webborn and Few (2024). Housing stock in Great Britain has an EPC rating when either the property owner or occupier requested it or because it was legally required to have one in order to let or sell the property (Ministry of Housing, Communities and Local Government, 2024).

[28] The definitions and sample summary statistics for this set of variables are also presented in Table A1 in Appendix A.

4. Results

The crucial assumption required for causal identification in diff-in-diff studies is parallel trends. Overall, Figure 1 shows that FF and FV groups display parallel trends in energy consumption while Figure 2 displays parallel trends in energy prices, as one would expect given that their tariffs were fixed prior to the treatment and that they share similar socio-demographic and other characteristics.

More precisely, Figure 1 (Panel A) shows that leading up to the Russian invasion of Ukraine and the subsequent increase in the energy price cap, the FV group enjoyed slightly higher levels of electricity consumption on average during 2021. This is consistent with Figure 2, showing that electricity prices for the FV group are slightly lower pre-crisis. Electricity consumption for the FV group however has since fallen below that of the FF group, except during the winter when the EPG was in operation (1st October 2022-30th June 2023). Hence, despite facing higher prices during the winter of 2022/23 (Figure 2, Panel A), the FV group were able to consume similar amounts of electricity to the FF group.

In Figure 1 (Panel B) we can also see that before April 2022 the households who moved to variable rates after April 2022 (FV) had very similar levels of gas consumption to the FF group. While gas consumption for the FV group fell below the level of those on fixed rates (FF) after April 2022, the reduction in gas consumption for FV (compared to FF) becomes most apparent once the EPG is removed at the end of June 2023. These levels of consumption are consistent with the higher prices faced by households who were not protected by a fixed tariff.

During the 2022/23 winter, similar levels of consumption between the control and treatment groups are apparent in Figure 1. This could be due to the significant price protection households received from the UK government's EPG[29] and potentially also through the accumulation of energy-related debt and arrears which had escalated to record levels (£3.1 billion) by the end of 2023 (Ofgem, 2024b), allowing households on SVTs to potentially afford some consumption on credit during the crisis.

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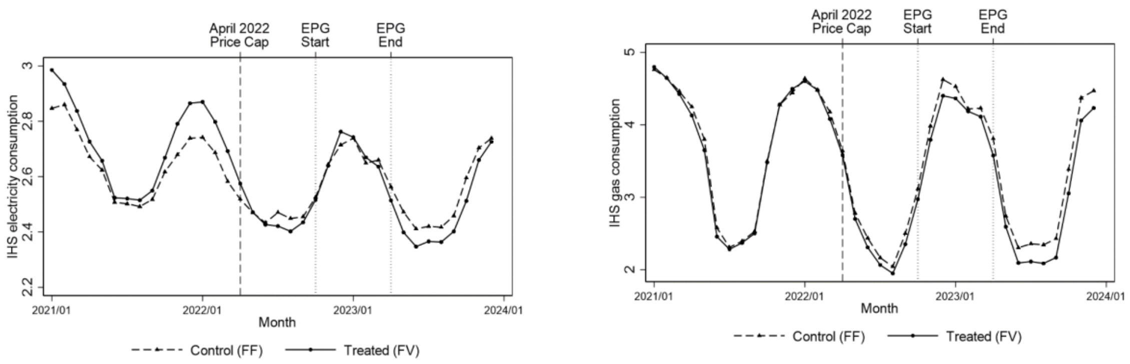
[29] Around £27 billion according to Bolton and Stewart (2024).

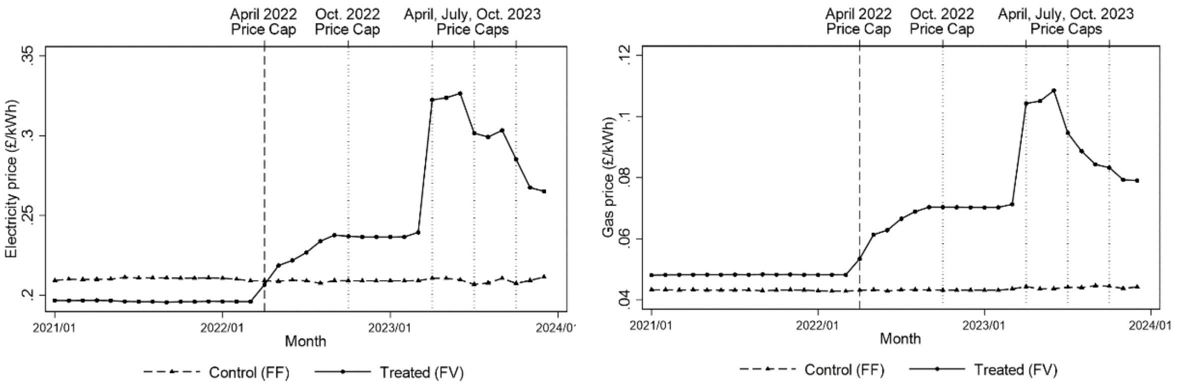
Figure 1. Monthly mean of (inverse hyperbolic sine) daily energy consumption by FF and FV groups.



Panel A. Electricity ***Panel B. Gas***

Notes: ***Electricity*** *- Monthly mean of (inverse hyperbolic sine, IHS) daily electricity consumption (kWh) between 01/01/2021 and 31/12/2023 by control group (households with fixed electricity prices,* ***FF****) and treated group (households with variable electricity prices post-April 2022,* ***FV****). N = 3,234,080 (N_{FF}=111,279; N_{FV} =3,122,801).* ***Gas*** *- Monthly mean of (inverse hyperbolic sine, IHS) daily gas consumption (kWh) between 01/01/2021 and 31/12/2023 by control group (households with fixed gas prices,* ***FF****) and treated group (households with variable gas prices post-April 2022,* ***FV****). N = 1,486,428 (N_{FF}=85,668; N_{FV}=1,400,760).*

Figure 2. Monthly mean of daily energy unit prices (£/kWh) by FF and FV groups.



Panel A. Electricity ***Panel B. Gas***

Notes: ***Electricity*** *– Monthly mean of daily electricity unit prices (£/kWh) between 01/01/2021 and 31/12/2023 by control group (households with fixed electricity prices,* ***FF****) and treated group (households with variable electricity prices post-April 2022,* ***FV****). N = 3,234,080 (N_{FF}=111,279; N_{FV}=3,122,801).* ***Gas*** *– Monthly mean of daily gas unit prices (£/kWh) between 01/01/2021 and 31/12/2023 by control group (households with fixed gas prices,* ***FF****) and treated group (households with variable gas prices post-April 2022,* ***FV****). N = 1,486,428 (N_{FF}=85,668; N_{FV}=1,400,760).*

Table 3 reports the main econometric results of the estimation based on equation (1). We are primarily interested in the ATE which corresponds to the coefficient, β_3, capturing the interaction between treatment group (*FV*) and price cap *(PC)* indicators. The dependent variables in Table 3 are the daily household electricity (Panel A) and gas consumption (Panel B), respectively which have been subject to the Inverse Hyperbolic Sine transformation. This implies that the (ATE) coefficient can be interpreted as a percentage change[30] in household electricity or gas consumption as a result of the changes in energy prices. We estimated the models using pooled OLS and fixed effects regression, controlling for time-invariant unobserved heterogeneity. Across the columns in our tables, we sequentially add control variables, including regional effects, time effects, linear and polynomial trends, as well as temperature. Time effects include monthly indicators and the interaction between day-of-month and day-of week-indicators. Overall, our results show, as expected, that the energy price crisis negatively impacted electricity and gas consumption for households who moved to a variable tariff post April 2022, compared to those on a fixed tariff throughout the sample period.

Specifically, we observe that the ATE in Table 3 (Panel A) is negative and statistically significant at the 1% level in all specifications. The results suggest that, on average, the energy price crisis led to a reduction in electricity consumption for households moved onto variable tariffs by around 10 per cent compared to those remaining on fixed unit rates. The effects are very similar in both the pooled OLS and fixed effects specifications, after controlling for time-invariant and several time-varying individual effects. Overall, the results reflect the negative impact of the energy price crisis on electricity consumption, over and above reductions driven by other factors, such as economic or temperature shocks.

Looking at the pooled OLS specifications in Table 3 (Panel A, columns 1-5), the additional effect of the energy price crisis for households on variable tariffs is a reduction in their gas consumption by around 13-14 per cent, compared to those on fixed rates. The results are consistent with the fixed effects estimates in columns 6 and 7. The ATE is statistically significant at the 5% level in all specifications.

Despite being protected from price increases during this period, the average reduction in electricity consumption during the energy price crisis for the control group (FF) is estimated to be around 0-5 per cent, using fixed effects regression (Table 3, Panel A, columns 6 and 7). The average reduction in gas consumption during the energy price crisis for the same group is estimated to be around 20-34 per cent using fixed effects regression (Table 3, Panel B, columns 6 and 7). These reductions reflect the continued decline in energy consumption over the period, for both groups, whereas the ATEs represent the additional impact on the treated group's consumption *caused* by the energy price crisis. Our ATE estimates are robust to further augmenting the fixed effects model with a complete set of time fixed effects, i.e., year indicators and year by month indicators, in Table 3 Panels A and B (Column 8).[31]

Comparing the impact of the price increases on gas and electricity consumption, households on variable tariffs post-April 2022 responded by reducing their gas consumption considerably more than they did for electricity consumption during the energy prices shocks. This larger average treatment effect aligns

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[30] More precisely, the approximate proportional difference in the growth rates of energy consumption across the treatment and control groups (see McConnell, 2024).

[31] The so-called *two-way-fixed-effects* (TWFE) approach absorbs the remaining time fixed effects (hence, the baseline indicator *PRICECAP* is omitted).

with a recent study that shows that households reacted to the energy price shock by reducing gas consumption more than electricity consumption (Zapata-Webborn et al., 2024).[32]

It is important to note here that the coefficient estimated on the FV indicator is not statistically significant in Table 3 (Panel A and B). This provides evidence that the energy consumption for the two groups was statistically similar prior to April 2022 leading us to expect that it would have remained similar had the energy price crisis not occurred.

It is possible to compare our ATEs to the UK Government's estimates of the change in energy consumption between 2021 and 2023 (Bolton, 2025). Before so doing, it is important to note that our quasi-experimental approach attempts to circumvent the endogeneity related to other competing rising costs of living, such as the cost of housing and food, so it is reasonable to expect that our ATEs will be *lower* than estimated changes in consumption which reflect factors other than just energy. Indeed, our estimated changes in consumption for electricity and gas (9% and 13%, respectively) are lower than official estimates of the fall in the temperature-adjusted average (mean) consumption per household for electricity (13%) and gas (18%) (see Bolton, 2025).

Alternative specifications and robustness checks

We conduct multiple specification checks to test the robustness of our results. Table 4 reports the respective electricity (Panel A) and gas (Panel B) ATEs for the pooled (OLS and Poisson) and fixed effects regressions. The ATEs remain largely unchanged and are statistically robust across a broad range of specifications.

To address the concern that the reduction in energy consumption might have been influenced by multiple cost-of-living pressures and weather conditions, and not only by the rise in energy bills, we controlled for confounding factors that might drive the results. We include socio-demographic and housing variables across all *pooled* specifications given the cross-sectional nature of the data. Whether controlling for socio-demographic and housing characteristics alongside geographical office regional (GOR) indicators (column 1) or using the more granular lower super output area (LSOA) indicators (column 2), the ATEs for electricity and for gas remain close to our main estimates discussed above (9 and 16 per cent, respectively) and exhibit the same level of statistical significance.

Turning to the fixed effects specifications in Table 4, we augment our baseline regression with region-specific polynomial trends (column 3) and temperature polynomials (column 4).[33] Also in this case our results remain consistent with the main results in Table 3.

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[32] The VV group, not a part of our controlled experiment, behaved similarly to the FV group overall in terms of their consumption behaviour following the large price rise.

[33] The GOR regional-specific polynomial trends produce point estimates and standard errors identical to models controlling instead for region by time effects (i.e., GOR interacted with day-of-week and day-of-month indicators). We report only on the former, more parsimonious, approach. The results also hold when controlling for different types of weather variables, including rainfall. For brevity these results are available upon request.

The main analysis relies on consumption data for households observed for at least 2.5 years. This requirement is relaxed in column 5, which presents the estimates for all households observed for at least one year. This specification check shows that the results are consistent despite the restriction placed on the main sample. Indeed, whilst the point estimates are slightly attenuated, it is important to note that the 95% confidence intervals overlap with the relevant estimates presented in Table 3 (column 6).

We also used the log adjusted transformation $ln\ (C_{itj}+1)$ in Table 4, column (6) instead of the IHS. These results are contrasted with specifications that a) use the IHS transformation while dropping observations equal to zero for electricity consumption only (Table 4, Panel A, column 7),[34] and b) use Poisson regression while retaining zeros for electricity and gas consumption (Table 4, column 8). The point estimates of these specifications are again similar to those obtained with the original specification and are statistically significant at the same levels.

The results are further robust to different event study specifications, including when we use a staggered treatment framework as discussed below, and to placebo tests on the pre-treatment period (see Appendix B).

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[34] This coincides with electricity consumption data with zero values identified and flagged by SERL as suspicious in their technical reports.

Table 3. Impact of the April 2022 price cap change on the inverse hyperbolic sine of energy consumption by control (FF) vs treatment group (FV).

	Pooled OLS					**Fixed Effects**		**Two-Way-Fixed-Effects**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Electricity								
FV	0.074	0.071	0.071	0.071	0.071			
	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)			
PRICECAP	-0.106***	-0.101***	-0.155***	-0.008	-0.051**	-0.010	-0.051**	
	(0.020)	(0.021)	(0.022)	(0.022)	(0.020)	(0.021)	(0.020)	
FV x PRICECAP	-0.099***	-0.099***	-0.099***	-0.098***	-0.099***	-0.098***	-0.099***	-0.099***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.020)	(0.020)	(0.020)
Panel B. Gas								
FV	-0.048	-0.041	-0.037	-0.038	-0.035			
	(0.080)	(0.080)	(0.080)	(0.080)	(0.080)			
PRICECAP	-0.559***	-0.847***	-1.355***	-0.346***	-0.201***	-0.337***	-0.197***	
	(0.064)	(0.064)	(0.066)	(0.065)	(0.063)	(0.064)	(0.063)	
FV x PRICECAP	-0.132**	-0.131**	-0.134**	-0.136**	-0.136**	-0.141**	-0.140**	-0.141**
	(0.065)	(0.065)	(0.065)	(0.064)	(0.064)	(0.065)	(0.065)	(0.065)
Regional effects	NO	YES	YES	YES	YES	-	-	-
Time effects	NO	NO	NO	NO	YES^	NO	YES^	YES^^
Linear trend	NO	YES	NO	NO	NO	NO	NO	NO
Polynomial trend	NO	NO	YES	YES	NO	YES	NO	YES
Temperature	NO	NO	NO	YES	YES	YES	YES	YES

*Notes: * p<0.10 ** p<0.05 ***p<0.01, individual-level cluster robust standard errors in the parentheses. Time effects include: ^monthly indicators and the interaction between day of month and day of week indicators; ^^ and further augmented with year and year by month indicators. Sample includes individuals observed for at least 2.5 years.* ***Electricity*** *– N=3,234,080, N(control)= 111,279, N(treated)= 3,122,801, N(individuals control) = 103, N(individuals treated)= 2,877.* ***Gas*** *– N=3,234,080, N(control)= 85,668, N(treated)=1,400,760, N(individuals control)=86, N(individuals control)= 1,297.*

Table 4. Robustness of the April 2022 price cap change on the inverse hyperbolic sine of energy consumption by control (FF) vs treatment group (FV).

	Pooled OLS		**Fixed Effects**					**Pooled Poisson**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Electricity								
FV x PRICECAP	-0.091***	-0.092***	-0.097***	-0.099***	-0.053***	-0.084***	-0.081***	-0.091***
	(0.022)	(0.022)	(0.021)	(0.020)	(0.016)	(0.018)	(0.026)	(0.022)
Panel B. Gas								
FV x PRICECAP	-0.141**	-0.150**	-0.145**	-0.140**	-0.107**	-0.117**	-	-0.062**
	(0.072)	(0.073)	(0.065)	(0.065)	(0.050)	(0.055)	-	(0.030)
Regional effects	YES	NO	-	-	-	-	-	YES
LSOA effects	NO	YES	-	-	-	-	-	NO
Household and housing controls	YES	YES	-	-	-	-	-	NO
Time effects	YES	YES	NO	YES	YES	YES	YES	YES
Regional specific polynomial trends	NO	NO	YES	NO	NO	NO	NO	NO
Temperature polynomial	NO	NO	NO	YES	NO	NO	NO	NO
Individuals observed > 1 year	NO	NO	NO	NO	YES	NO	NO	NO
Ln(consumption +1)	NO	NO	NO	NO	NO	YES	NO	NO
Exclude suspicious zeros (electricity only)	NO	NO	NO	NO	NO	NO	YES	NO
Observations: Electricity								
N (control)	102,001	102,001	111,279	111,279	235,812	111,279	111,279	111,279
N (treated)	2,780,451	2,780,451	3,122,801	3,122,801	3,783,174	3,122,801	3,122,801	3,122,801
N (individuals control)	94	94	103	103	295	103	103	103
N (individuals treated)	2,562	2,562	2,877	2,877	3,736	2,877	2,877	2,877
Observations: Gas								
N (control)	74,104	74,104	85,668	85,668	136,431	85,668	-	85,668
N (treated)	1,278,373	1,278,373	1,400,760	1,400,760	1,498,547	1,400,760		1,400,760
N (individuals control)	74	74	86	86	173	86		86
N (individuals treated)	1,184	1,184	1,297	1,297	1,435	1,297		1,297

*Notes: * p<0.10 ** p<0.05 ***p<0.01, individual-level cluster robust standard errors in the parentheses. Time effects include monthly indicators and the interaction between day of month and day of week indicators. Includes individuals observed for at least 2.5 years.*

Heterogeneous effects

In this sub-section we explore the existence of heterogeneous effects in our main results. Given the constraints in terms of the number of households that make up the control group, we make this analysis more tractable and efficient by using pooled OLS – controlling for region, time, and temperature effects – and ensuring that the sample is made up of households with at least one year of consumption data. As discussed before however, the choice of estimation method does not significantly affect the size and significance of the estimated ATEs.

We first investigate the extent to which the estimated ATEs remain comparable when we focus on the households who *state* that they engage in energy saving practices when initially recruited to participate in SERL. This analysis sheds light on whether the revealed energy reduction behaviour implied by our ATEs align (in sign and in magnitude) with the *stated* behaviour by households about their typical energy saving practices. Equation 1 is estimated separately using four sets of indicators: 1) a dichotomous variable that equals 1 if the household representative states that they put on extra clothing rather than turning the heating on or up 'quite often', 'very often' or 'always' (and 0 otherwise, i.e., 'not often' or 'never'); 2) a dichotomous variable that equals 1 if the household representative states that they turn off the lights in rooms that are not being used 'quite often', 'very often' or 'always' (and 0 otherwise, i.e., 'not often' or 'never'); 3) a dichotomous variable equal to 1 if the household representative states that *their household* puts 'some' or a 'great deal' of effort into limiting or reducing energy consumption (and 0 otherwise, i.e., 'little', 'none' or 'don't know') and 4) a set of dichotomous variables defined by specific cut-off points (18, 19, 20 or 21°C). Each indicator is set equal to 1 if the household stated that they set their thermostat at least to the level of the given threshold and equal to 0 otherwise, so that if I set my temperature at 20 or higher that dummy is non-zero.[35] We carry out the heterogeneous analysis using the "turning off lights" indicator for electricity consumption, and thermostat settings variables for gas consumption.

The results of the heterogeneous analysis are reported in Table 5 (Panel A) for electricity. At the 5% level of statistical significance, we find that the ATEs are indeed associated with the households who *state* that they regularly engage in energy saving behaviour. This is true for both the use of extra clothing (Column 2) and switching off lights (Column 4). Households who reported often turning the lights off, achieved reductions in electricity, as expected, given the households' keener than average attention to their energy use and/or environmental concerns.

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[35] In other words, they express the total, not the marginal effects, of behaviour at that setting. The norm in Britain is gas central heating. Air conditioning is unusual.

The interpretation of the results for the case of the third indicator is more complicated as it relies on the *subjective perception of the amount of effort* exerted to undertake energy saving action, which is likely to be different across the survey respondents and for different energy services. Our results suggest that respondents who stated that they typically exerted only a limited amount of effort were nonetheless able to achieve a reduction in their electricity consumption (Table 5, column 5), however this finding is only statistically significant at the 10% level.

The results of the analysis for gas are reported in Table 5 (Panel B) and Table 6. Like electricity, the ATEs are statistically significant for those typically using additional clothing as a way to control consumption. In contrast, those respondents that were able to achieve a statistically significant (at the 5% level) reduction in gas consumption also reported exerting a great deal of effort (Table 5, column 6), possibly as a result of their inability to provide a sufficiently comfortable environment for all the household members. This result is not only interesting from the perspective of the potential consistency between revealed and stated preferences, but also from a policy perspective, as the substantial increases in energy price during the crisis have led to behaviours associated with high levels of costly effort (e.g., cognition, time, and stress), at least as perceived by the survey respondents.

In Table 6 we observe an increasingly larger reduction in consumption for the households who were most able to adjust their consumption, initially setting their temperatures at relatively high levels at the time of completing the survey. This is reflected in the increasing size of the negative coefficients reported in column 1 (thermostat set at 18°C), column 3 (19°C), column 5 (20°C) and column 7 (21°C). This provides evidence that households who had stated having set higher temperatures on their thermostat (or smart controls) will have been the ones with the most scope to adjust in response to the crisis leading to lower levels of consumption.

We also attempt to explore the distributional effects of the energy price crisis by breaking down our sample by the Index of Multiple Deprivation (IMD). Equation 1 is therefore estimated separately for the first two quintiles (highest levels of deprivation), the third quintile (medium levels) and finally the fourth and fifth quintiles (lowest levels).

The results in Table 7 show an inverted U-shape in the ATEs across the IMD quintiles. More specifically, the results presented in Panel A imply that electricity consumption fell in response to the energy price crisis in the lowest two (column 1) and highest two (column 3) quintiles, suggesting that households in the middle of the distribution were relatively less responsive to price changes.

Panel B shows that the largest estimated changes in gas consumption are observed for the first two quintiles representing the greatest degree of multiple deprivation. While the inverted U-shape still exists, the ATE is only statistically significant at the 10% level for the upper IMD quintiles (column 3), while it is statistically significant at the 1% level for the first two quintiles. These results imply that the ATEs for the whole sample, discussed in the main findings, may be driven in large part by households living in areas with the highest levels of multiple deprivation. Indeed, the ATE point estimate for the first two IMD quintiles is numerically larger than in our main findings (22 per cent versus 13-14 per cent) which is concerning from the welfare perspective of the impact of the crisis on deprived households.

Expenditure ATEs

Having established that prices increased for the treatment group using a visual analysis and that their consumption decreased as a result, we aim to evaluate the extent to which the lower levels of consumption and the higher prices translated into changes in expenditure. Evaluating the changes in household expenditure illustrates how much the energy crisis impacted households' budgets and welfare.

The divergence in expenditure between the FV and FF group is marked at the start of the energy price crisis, when the FV group appears to have spent more than FF (see Figure A4 in Appendix A). To statistically corroborate this finding, Table 8 reports the pooled OLS and fixed effects regressions to assess the causal impact of the energy price crisis on electricity (Panel A) and gas (Panel B) expenditure.

The ATEs in the pooled and fixed effects regressions concord with the visual analysis and indicate that households spent £0.36 extra per day on electricity (columns 1 and 2), equivalent to around £131 per year. The ATEs in the pooled and fixed effects regressions in Table 8 (columns 3 and 4) imply that households spent £0.55 extra per day on gas, equivalent to around £201 per year. Hence on average the ATEs suggest that households spent an extra £332 per year on energy. The impact of energy price crisis on gas expenditure was more substantial than for electricity expenditure, even though gas is much cheaper than electricity, because households consume significantly more kilowatt hours of gas than electricity over the year.

Table 5: Heterogeneous (behavioural) impact of the April 2022 price cap change on the inverse hyperbolic sine of energy consumption by control (FF) vs treatment group (FV).

	Pooled OLS					
	No extra clothing (not often, never)	Extra clothing (quite or very often, always)	Lights off (not often, never)	Lights off (quite or very often, always)	Effort (little, no, DK)	Effort (some, great deal)
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Electricity						
FV x PRICECAP	-0.052	-0.072**	-0.039	-0.074**	-0.090*	-0.051
	(0.054)	(0.034)	(0.054)	(0.032)	(0.050)	(0.034)
Panel B. Gas						
FV x PRICECAP	-0.149	-0.147**	-	-	0.022	-0.179**
	(0.135)	(0.066)	-	-	(0.083)	(0.072)
Observations: Electricity						
N (control)	63,077	172,263	25,476	210,336	62,235	173,577
N (treated)	944,293	2,831,152	545,367	3,234,960	939,343	2,843,831
N (individuals control)	81	213	31	264	74	221
N (individuals treated)	934	2,974	532	3,201	925	2,811
Observations: Gas						
N (control)	31,074	104,823	-	-	28,884	107,547
N (treated)	335,344	1,161,439	-	-	356,016	1,142,531
N (individuals control)	42	130	-	-	36	137
N (individuals treated)	325	1,108	-	-	343	1,092

*Notes: * p<0.10 ** p<0.05 ***p<0.01, individual-level cluster robust standard errors in the parentheses. All regressions control for Geographical Office Region fixed effects, temperature, and time effects which include monthly indicators and the interaction between day of month and day of week indicators. Includes individuals observed for at least 1 year. DK denotes 'Don't know'.*

Table 6. Heterogeneous (behavioural, continued) impact of the April 2022 price cap change on the inverse hyperbolic sine of gas consumption by control (FF) vs treatment group (FV).

	Pooled OLS						
	Temperature Controlled (at least 18)	Temperature Controlled (below 19)	Temperature Controlled (at least 19)	Temperature Controlled (below 20)	Temperature Controlled (at least 20)	Temperature Controlled (below 21)	Temperature Controlled (at least 21)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FV x PRICECAP	-0.154**	-0.137	-0.156**	-0.146	-0.166**	-0.120	-0.222*
	(0.068)	(0.139)	(0.075)	(0.106)	(0.084)	(0.079)	(0.116)
N (control)	91,196	21,258	76,704	30,504	67,458	60,744	37,218
N (treated)	1,111,652	210,990	979,888	345,685	845,193	696,934	493,944
N (individuals control)	110	26	92	38	80	75	43
N (individuals treated)	1,063	202	936	329	809	668	470

*Notes: * p<0.10 ** p<0.05 ***p<0.01, cluster robust standard errors in the parentheses. All regressions control for Geographical Office Region fixed effects, temperature, and time effects which include monthly indicators and the interaction between day of month and day of week indicators. Includes individuals observed for at least 1 year. Temperature Controlled (below 18) is omitted due to fewer than 10 individuals in the control group.*

Table 7. Heterogeneous (IMD) impact of the April 2022 price cap change on the inverse hyperbolic sine of energy consumption by control (FF) vs treatment group (FV).

	Pooled OLS					
	IMD quintile 1-2	IMD quintile 3	IMD quintile 4-5	IMD quintile 1-2	IMD quintile 3	IMD quintile 4-5
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A. Electricity			Panel B. Gas		
FV x PRICECAP	-0.083**	0.005	-0.089**	-0.226***	0.106	-0.175*
	(0.040)	(0.087)	(0.045)	(0.084)	(0.132)	(0.103)
N (treated)	105,508	35,268	95,036	61,074	22,927	52,430
N (control)	1,704,567	704,504	1,374,103	622,815	282,116	593,616
N (individuals treated)	131	47	117	77	28	68
N (individuals control)	1,688	752	1,460	600	268	567

*Notes: * p<0.10 ** p<0.05 ***p<0.01, individual-level cluster robust standard errors in the parentheses. All regressions control for Geographical Office Region fixed effects, temperature, and time effects which include monthly indicators and the interaction between day of month and day of week indicators. Includes individuals observed for at least 1 year. DK denotes 'Don't know'. Includes individuals observed for at least 1 year.*

Table 8. Impact of the April 2022 price cap change on gas and electricity expenditure by control (FF) vs treatment group (FV).

	Pooled OLS	**Fixed Effects**	**Pooled OLS**	**Fixed Effects**
	(1)	(2)	(3)	(4)
	Panel A. Electricity		**Panel B. Gas**	
FV x PRICECAP	0.356*** (0.052)	0.356*** (0.051)	0.548*** (0.078)	0.551*** (0.077)
Regional effects	YES	-	YES	-
Time effects	YES	YES	YES	YES
Temperature	YES	YES	YES	YES
N (treated)	111,279	111,279	85,668	85,668
N (control)	3,122,801	3,122,801	1,400,760	1,400,760
N (individuals treated)	103	103	86	86
N (individuals control)	2,877	2,877	1,297	1,297

*Notes: * p<0.10 ** p<0.05 ***p<0.01, individual-level cluster robust standard errors in the parentheses. Time effects include monthly indicators and the interaction between day of month and day of week indicators. Includes individuals observed for at least 2.5 years.*

Staggered treatment effects

The results presented thus far assume a single treatment time defined at the date of April 2022 – the time of the price cap change which followed the Ukraine-Russia conflict. However, as discussed earlier, households switched from a fixed to a variable tariff at various times between this date and the end of our sample likely due to their fixed price contract ending. As noted in Section 3, to consider these different treatment times in our analysis we aggregate our daily data at the monthly level to make the models more tractable. To show that there is no loss in generality, we re-estimate the baseline findings using a simple 2x2 approach, showing that our main results are robust to a higher level of aggregation before proceeding. We then estimate the simple, group-average, and group-specific ATEs using our staggered framework considering two periods during which some of the households switched to a variable rate, i.e., between April 2022 and March 2023 or between April 2023 and December 2023.

Our fixed effects models in Table 9 (columns 1 and 3) developed using aggregated data to estimate ATEs following the April 2022 price cap change show estimated effects that are *larger* than our main findings for electricity (14%) and gas consumption (26%) (columns 1 and 3, Panel A). By contrast, when employing two-way-fixed-effects models, we estimate ATEs that are *smaller* than our main findings for electricity (4%) and gas consumption (9%) (columns 2 and 4, Panel A). Hence, our main findings appear robust to monthly aggregation of consumption data, with ATEs that lie between these two sets of results for both electricity (10%) and gas (14%) consumption.

In the next step, we allow for staggered movements within two treatment timepoints, i.e., those switching either in April 2022-March 2023 or in April 2023-December 2023. Using doubly robust regression[36] (Sant'Anna and Zhao, 2020), which allows for flexibility in the timing of the treatment within these two time periods, we estimate the ATEs considering households as either *always treated* (i.e., post April 2022 or April 2023) or *not yet treated* (i.e., remaining untreated until the relevant period in which the households switch from fixed to a variable tariff). The results presented in Table 10, in the simple 2x2 case, suggest that our main findings slightly overestimated the ATEs for electricity (always treated: 9%; not yet treated: 6%) and gas consumption (always treated, 12%; not yet treated, 11%). The group average ATEs present a similar picture. Looking at the group-specific ATEs, it seems that the most important treatment time is April 2022 for electricity, whereas for gas there is limited evidence to support that a staggered approach is necessary when considering the group-specific effects. It is also worthwhile mentioning that we test for pre-trends using this framework and are unable to reject the null of parallel trends (pre-treatment), further supporting the potential existence of parallel trends in absence of the crisis (Table 10). All-in-all our main estimates are robust to this higher level of aggregation and to staggered treatment effects.

Table 9: Monthly (mean) (**Panel A**) IHS electricity and gas consumption and (**Panel B**) log of electricity and gas prices by control (FF) vs treatment group (FV) pre vs post April 2022 using fixed effects (FE) and two-way fixed effects (TWFE) regression clustered at individual level. Implied elasticity of demand calculated below.

	FE	TWFE	FE	TWFE
	Electricity		Gas	
	(1)	(2)	(3)	(4)
	Panel A. Consumption			
FV x PRICECAP	-0.137***	-0.0395**	-0.256***	-0.093*
	(0.004)	(0.017)	(0.011)	(0.054)
	Panel B. Prices			
FV x PRICECAP	0.292***	0.256***	0.484***	0.466***
	(0.0101)	(0.010)	(0.064)	(0.012)
Individual FE	Y	Y	Y	Y
Time FE	N	Y	N	Y
Temperature	Y	Y	Y	Y
Implied Price Elasticity of Demand	-0.404	-0.135	-0.411	-0.157

*Notes: * p<0.10 ** p<0.05 ***p<0.01, individual-level cluster robust standard errors in the parentheses. Time effects include year-month indicators. Sample includes individuals observed for at least 1 year.* ***Electricity*** *- N=136,052, N(control)=381, N(treated)=3,735.* ***Gas*** *- N= 53,629, N(control)=219, N(treated)=1,406.*

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[36] Given the smaller sample size, we are unable to reliably estimate the ATEs using a balanced panel at the monthly level of aggregation in the staggered framework. We therefore use a more flexible approach treating the panel as repeated cross-sections with clustered standard errors at the household level. As with the heterogeneity analysis to further circumvent the smaller sample, we allow households to enter the sample if they are observed for at least a year.

Table 10. Monthly (mean) IHS electricity and gas consumption by control (FF, always untreated and not yet treated) vs treatment group (FV) using doubly robust staggered diff-in-diff clustered at the individual level.

	Panel A. Electricity		**Panel B. Gas**	
	Always untreated	**Not yet treated**	**Always untreated**	**Not yet treated**
ATT (2x2)				
Simple	-0.086***	-0.060***	-0.124*	-0.106**
	(0.032)	(0.022)	(0.069)	(0.052)
By Group				
Average	-0.081***	-0.059***	-0.132**	-0.118**
	(0.028)	(0.021)	(0.063)	(0.056)
April ‘22-March ‘23	-0.092**	-0.061***	-0.113	-0.090
	(0.036)	(0.023)	(0.088)	(0.058)
April ’23-December 23’	-0.054*	-0.054*	-0.159	-0.159
	(0.030)	(0.030)	(0.103)	(0.103)
Pre-trend Chi^2 (40), p-value	47.04, 0.206	46.910, 0.210	40.263, 0.459	40.320, 0.456

*Notes: * p<0.10 ** p<0.05 ***p<0.01, doubly robust unbalanced estimator with individual-level cluster robust standard errors in the parentheses. Sample includes individuals observed for at least 1 year.* ***Electricity*** *– N=136,052, N(control)= 381, N(treated) =3,735.* ***Gas*** *– N=53,629, N(control)=219, N(treated)=1,406.*

Implied price elasticities of demand

We can examine the responsiveness of households to prices by calculating the implied unit price elasticity of demand for both gas and electricity. We focus on our aggregated monthly data for brevity[37], since these calculations are being used to further describe household behaviour during the energy crisis. Notice that we have already reported the percentage change in consumption using models with one and two-way-fixed-effects (see Table 10, Panel A), therefore we calculate the elasticity of demand as follows[38]:

$$\varepsilon_{ped} = \frac{\%\,\Delta\, consumption}{\%\,\Delta\, price} \tag{2}$$

We also estimated the additional percentage change in prices for the treatment (*FV*) group, compared to the control (*FF*) group. This is achieved by simply replacing the consumption-based outcomes with gas and electricity prices in our models (see Table 10, Panel B).

Using one and two-way fixed effects, our calculations reveal a price elasticity of demand for electricity equal to -0.404 and equal to -0.411 for gas using the former approach, and smaller elasticities

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[37] See Table A2 for the results using the daily level of disaggregation. The findings are qualitatively similar.

[38] As discussed above, the use of the inverse hyperbolic sine, with few zeros, should provide a good approximation of the exact proportionate change in consumption. With prices, however, we use a log-transformation given there are no zeros and apply the exact [exp ($\hat{\beta}$)-1] correction to calculate the proportionate change in prices given the coefficients are relatively large and would not serve as a good enough approximation.

(electricity, -0.135; gas, -0.157) using the latter approach. These results suggest households are inelastic to energy price changes, as expected (see e.g. Favero and Grossi, 2023). Our TWFE estimates fall broadly in line with the literature on the *short-term* price elasticity of demand which, according to the most recent meta-analysis on this topic by Labandeira and colleagues (2017), on average equal -0.126 for electricity and -0.180 for gas. Therefore, the estimates presented here provide robust (causally grounded) estimates of the *short-term* price elasticity of energy demand which are not only useful for theoretical and structural models of residential energy demand, but also for policymakers and regulators of energy markets who aim to mitigate the impact of energy prices shocks on households, as discussed in detail below.

5. Conclusions

The finding that energy price rises led to reductions in consumption is unsurprising. However, investigating causally the impact across different fuels and how unexpected and sustained increases in energy prices are experienced across socio-demographic groups provides the means for policymakers and energy companies to deal with the consequences of future geopolitical shocks to energy markets. The results can also guide households more generally through the transformations required to achieve energy affordability, energy security, and environmental objectives.

The analysis presented in this paper provides rigorous evidence on the effects of the recent energy price increases on households' behaviour using a diff-in-diff approach which exploits the exogenous shocks of the Ukraine war on energy markets and the forced transition of about 4 million households from their original suppliers that went bankrupt to a different supplier. The results are robust both to different specifications and placebo tests on the pre-treatment period (as discussed in Appendix B), reinforcing the validity of the causal links discussed in the paper, the latter by showing a statistically non-significant difference in consumption between our two groups of households during that earlier period.

Our analysis reveals significant reductions in gas and electricity consumption as a result of the steep and unexpected price increases from 2022, particularly for those households who were moved to a variable tariff. Although the elasticities are modest, they are in line with short-run price elasticities of energy demand. Despite being protected by a fixed tariff, even households on fixed contracts reduced their consumption during the energy crisis period. This interesting result is consistent with general trends in energy demand, technology adoption, and social norms in developed countries but also with the extensive media focus on the geopolitical situation as a source of energy price volatility (e.g. see Levell et al, 2024; Piao and Managi, 2023).

Arguably, the relatively larger impact of the energy crisis on gas consumption which emerges in our study could be ascribed to the differential sensitivity of households to gas prices and bills during the energy crisis. This is consistent with the results of the Frontier Economics study which revealed that the most common actions used to cope with the recent financial pressures included setting lower temperatures on their thermostats and heating fewer rooms in the house to reduce heating usage. Our results also reflect the fact that the reduction in consumption during the energy crisis has been achieved by those who indicated that they were already inclined to make an effort to reduce consumption through the implementation of various energy saving actions which might become established habits in future. However, we find some preliminary evidence that different actions were also adopted by households at different levels of social deprivation in response to the price increases. To investigate the overall impact of the price increases on energy expenditure, we also considered electricity and gas expenditure as our outcome variables finding that the overall impact of the price increases was a larger increase in gas expenditure than for electricity.

Data limitations have prevented us from undertaking a more detailed analysis of specific tariffs or long-term contracts held by the households in our sample, although the presence of binding price-caps during the period of analysis has mitigated the effects of these limitations. A more detailed assessment of price elasticities across the whole sample of GB households, with a focus on different sociodemographic categories, will be the focus of future work. This can potentially inform the economic, distributional and environmental policy interventions required for the transition to a net zero economy.

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Appendix A

Table A1. Control variable definitions and sample summary statistics.

Variable	Definition	Electricity	Gas
*Socio-economic characteristics**		Mean	
Age	Age >64 years; 0 otherwise	0.445	0.431
Female	1 if female; 0 otherwise	0.437	0.433
Employed FT	1 if employed full-time; 0 otherwise	0.358	0.368
Employed PT	1 if employed part-time; 0 otherwise	0.091	0.109
LTSD	1 if long-term illness or disability; 0 otherwise	0.040	0.028
Unemployed	1 if unemployed; 0 otherwise	0.021	0.019
Retired	1 if retired; 0 otherwise	0.466	0.458
Other status	1 if other economic activity; 0 otherwise	0.013	0.011
Owner-mortgager	1 if owns accommodation; 0 otherwise.	0.793	0.872
Rent	1 if renting accommodation; 0 otherwise	0.207	0.128
Household size	Household size	2.235	2.356
Electric vehicle	1 if household has an electric vehicle (plug-in); 0 otherwise	0.042	0.038
*Housing characteristics**			
Bedrooms	Number of bedrooms	2.894	3.097
Detached	1 if living in a detached house; 0 otherwise	0.593	0.655
Terraced	1 if living in a terraced house; 0 otherwise	0.226	0.269
Flat	1 if living in a flat; 0 otherwise	0.181	0.076
Property > 2003	1 if property built post-2003; 0 otherwise	0.093	0.066
Gas central heat	1 if property has gas central heating; 0 otherwise	0.838	0.972
Electric central heat	1 if property has electric central heating; 0 otherwise	0.071	0.006
Other central heat	1 if property has other central heating; 0 otherwise	0.092	0.022
*Index of multiple deprivation (IMD), temperature**and regional characteristics**			
IMD quintile 4-5	1 if classified as IMD quintile 4-5; 0 if IMD quintile 1-3.	0.390	0.405
Mean temperature	Mean temperature of the air at 2m above the surface since last record (K units).	284.158	284.191
East midlands	1 if living in the East Midlands; 0 otherwise	0.071	0.097
East	1 if living in the East of England; 0 otherwise	0.102	0.100
London	1 if living in London; 0 otherwise	0.152	0.127
NE	1 if living in the North East of England; 0 otherwise	0.025	0.020
NW	1 if living in the North West of England; 0 otherwise	0.097	0.114
Scotland	1 if living in the Scotland; 0 otherwise	0.082	0.048
SE	1 if living in South East of England; 0 otherwise	0.157	0.149
SW	1 if living in the South West of England; 0 otherwise	0.093	0.092
Wales	1 if living in the Wales; 0 otherwise	0.071	0.081
West midlands	1 if living in the West Midlands; 0 otherwise	0.091	0.108
Yorkshire	1 if living in Yorkshire; 0 otherwise	0.059	0.065
*Energy Performance Certificate (EPC)****			
No EPC	1 if the property does not have an EPC; 0 otherwise	0.416	0.422
A	1 if the property has an EPC rated A; 0 otherwise	0.001	0.000
B	1 if the property has an EPC rated B; 0 otherwise	0.041	0.030
C	1 if the property has an EPC rated C; 0 otherwise	0.210	0.179
D	1 if the property has an EPC rated D; 0 otherwise	0.235	0.286
E	1 if the property has an EPC rated E; 0 otherwise	0.078	0.073
F	1 if the property has an EPC rated F; 0 otherwise	0.014	0.008
G	1 if the property has an EPC rated G; 0 otherwise	0.005	0.002
*Additional household and housing controls*****			
No follow up	1 if did not respond to the follow up survey; 0 otherwise	0.516	0.470
Income below £10k	1 if household income < £10,000; 0 otherwise	0.035	0.030
Income £10-20k	1 if household income £10,000-20,000; 0 otherwise	0.091	0.086
Income £20-30k	1 if household income £20,000-30,000; 0 otherwise	0.088	0.093
Income £30-40k	1 if household income £30,000-40,000; 0 otherwise	0.056	0.060
Income £40-50k	1 if household income £40,000-50,000; 0 otherwise	0.055	0.061
Income £50-60k	1 if household income £50,000-60,000; 0 otherwise	0.028	0.036
Income £60-70k	1 if household income £60,000-70,000; 0 otherwise	0.019	0.021
Income £70-80k	1 if household income £70,000-80,000; 0 otherwise	0.029	0.037
Income £80-90k	1 if household income £80,000-90,000; 0 otherwise	0.011	0.014
Income £90-100k	1 if household income £90,000-100,000; 0 otherwise	0.001	0.001
Income over £100k	1 if household income > £100,000; 0 otherwise	0.030	0.044
Income (prefer not to say)	1 if household preferred not to declare income; 0 otherwise	0.041	0.047
Gas payment by direct debit	1 if household pays for gas by direct debit; 0 otherwise	0.378	0.510
Gas payment by receipt on bill	1 if household pays for gas on receipt of bill; 0 otherwise	0.022	0.011
Gas payment by prepayment	1 if household pays for gas by prepayment; 0 otherwise	0.005	0.001

Gas payment by other method	1 if household pays for gas using other methods; 0 otherwise	0.079	0.008
Electricity payment by direct debit	1 if household pays for electricity by direct debit; 0 otherwise	0.440	0.510
Electricity payment by receipt on bill	1 if household pays for electricity on receipt of bill; 0 otherwise	0.027	0.011
Electricity payment by prepayment	1 if household pays for electricity by prepayment; 0 otherwise	0.008	0.001
Electricity payment by other method	1 if household pays for electricity using other methods; 0 otherwise	0.009	0.008
Solar panel (no)	1 if household does not have solar panels; 0 otherwise	0.425	0.464
Solar panel (yes)	1 if household does have solar panels; 0 otherwise	0.059	0.066
Solar water (no)	1 if household does not have solar water heating; 0 otherwise	0.467	0.510
Solar water (yes)	1 if household does have solar water heating; 0 otherwise	0.017	0.019
Loft insulation (no)	1 if household does not have loft insulation; 0 otherwise	0.082	0.051
Loft insulation (yes)	1 if household does have loft insulation; 0 otherwise	0.402	0.479
Cavity insulation (no)	1 if household does not have cavity wall insulation; 0 otherwise	0.233	0.242
Cavity insulation (yes)	1 if household does have cavity wall insulation; 0 otherwise	0.251	0.287
Solid wall (no)	1 if household does not have solid wall insulation; 0 otherwise	0.443	0.491
Solid wall (yes)	1 if household does have solid wall insulation; 0 otherwise	0.041	0.038
Floor insulation (no)	1 if household does not have floor insulation; 0 otherwise	0.437	0.483
Floor insulation (yes)	1 if household does have floor insulation; 0 otherwise	0.047	0.047
Double glazed windows (no)	1 if household does not have double glazed windows; 0 otherwise	0.054	0.045
Double glazed windows (yes)	1 if household does have double glazed windows; 0 otherwise	0.430	0.484
Draught excluders (no)	1 if household does not have draught excluders; 0 otherwise	0.331	0.354
Draught excluders (yes)	1 if household does have draught excluders; 0 otherwise	0.153	0.176
N		2882452	1352477

*Notes: *Socio-economic, housing, and regional data extracted from SERL 6th Edition main survey. ** Temperature data originates from Copernicus/ECMWF ERA5 hourly reanalysis data. *** EPC data is extracted from the EPC API. **** Additional socio-economic and housing data extracted from SERL 6th Edition follow-up survey*

Table A2: Impact of April 2022 price cap on (**Panel A**) IHS energy consumption or (**Panel B**) log of energy prices by control (FF) vs treatment group (FV). Implied elasticity of demand calculated below.

	Pooled	**FE**	**Pooled**	**FE**
	Electricity		**Gas**	
	Panel A. Consumption			
FV x PRICECAP	-0.099***	-0.099***	-0.136**	-0.140**
	(0.021)	(0.020)	(0.064)	(0.065)
	Panel B. Prices			
FV x PRICECAP	0.409***	0.411***	0.506***	0.505***
	(0.011)	(0.011)	(0.012)	(0.014)
Regional effects	YES	-	YES	-
Time effects	YES	YES	YES	YES
Implied elasticity of demand	-0.196	-0.195	-0.207	-0.213
N (treated)	111,279	111,279	85,668	85,668
N (control)	3,122,801	3,122,801	1,400,760	1,400,760
N (individuals treated)	103	103	86	86
N (individuals control)	2,877	2,877	1,297	1,297

*Notes: * p<0.10 ** p<0.05 ***p<0.01, cluster robust standard errors in the parentheses. Time effects include monthly indicators and the interaction between day of month and day of week indicators. Includes individuals observed for at least 2.5 years.*

Figure A1. Number of GB domestic households switching supplier by fuel type (OFGEM, 2024b).

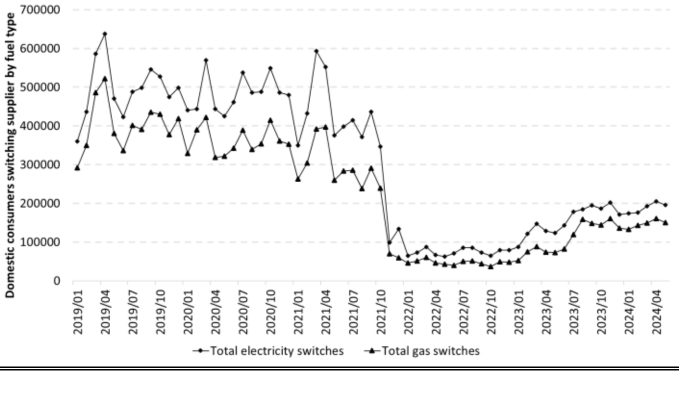


Figure A2. Average direct debit dual fuel bill (£) for typical GB households by supplier, tariff, and price cap level (OFGEM, 2024b).

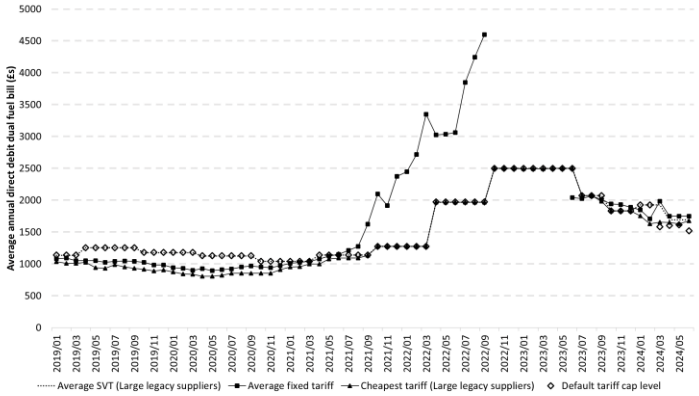
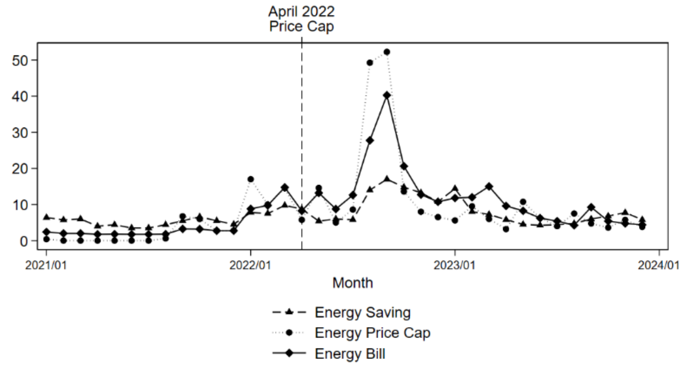
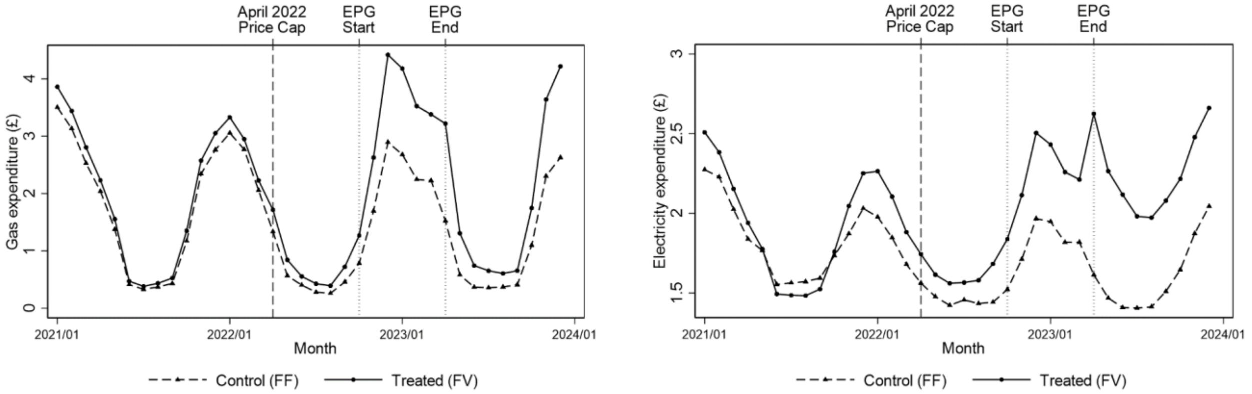


Figure A3. Average "Google Trends" in GB public interest in energy savings, price caps and bills.



Notes: Google Trend search results for terms "energy saving", "energy price cap" and "energy bill" between January 2021 and December 2023, monthly means. The vertical line represents the start of the energy price crisis, April 2022.

Figure A4. Monthly mean of daily energy expenditure (£/day) by FF and FV groups.



Panel A. Electricity

Panel B. Gas

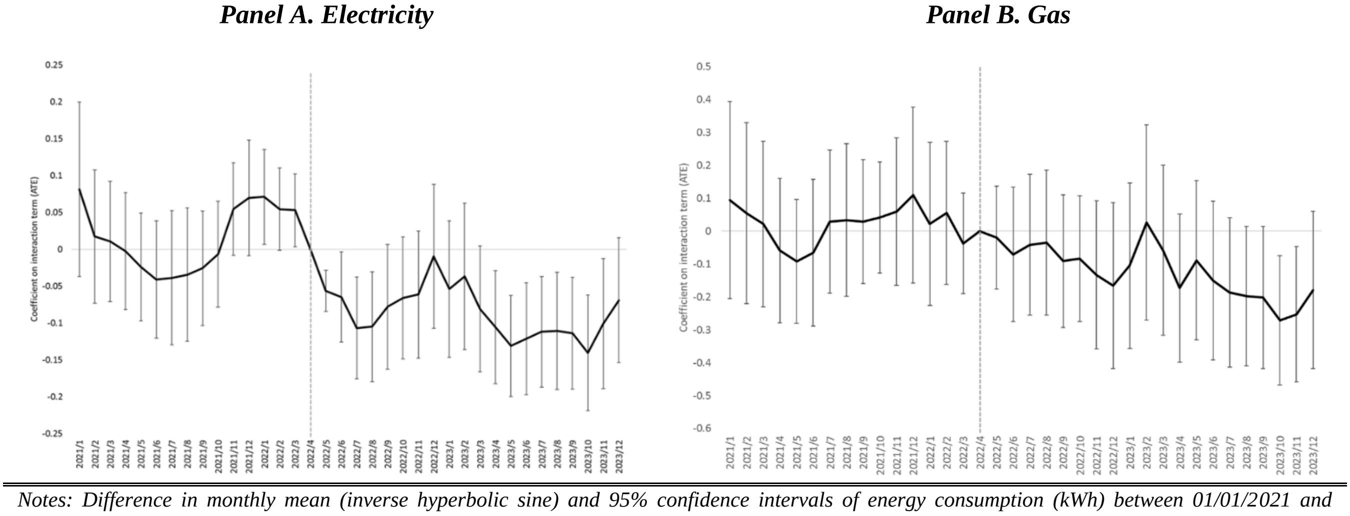
Notes: Monthly mean energy expenditure (£) between 01/01/2021 and 31/12/2023 by control group (households with fixed energy prices, ***FF****) and treated group (households with variable energy prices post-April 2022,* ***FV****).* ***Electricity*** *– N = 3,234,080 (N_{FF}=111,279; N_{FV}=3,122,801).* ***Gas –*** *N = 1,486,428 (N_{FF}=85,668; N_{FV}=1,400,760).*

Appendix B

Event study approach.

As a further robustness check, we return to the pre-treatment differences in electricity and gas consumption of the FV group relative to the FF group. Using an event study approach, we test empirically whether these differences were statistically significant prior to April 2022. This is achieved by including indicators for each year-month of the sample (replacing *PC* in equation 1) and interacting the indicators with the treatment indicator (*FV* in equation 1). The baseline is set to April 2022. Figure B1 presents the point estimates and their 95% confidence intervals for each year-month interaction, using electricity (Panel A) and gas (Panel B) consumption as the outcome of interest. Overall, the point estimates prior to April 2022 are clearly not statistically significantly different from zero at conventional levels, providing further support for parallel trends hypothesis up to (and therefore throughout) the treatment window.[39] In addition, this event study approach identifies the months of the energy price crisis which may have had the most impact (ATEs) on electricity and gas consumption. Figure B1 (Panel A) suggests that electricity consumption was mainly impacted by prices during summer 2022 and throughout the majority of 2023 (April to November). In contrast, Figure B1 (Panel B) suggests that the main impact of the energy price crisis is observed for gas in the winter of 2023, consistent with the end of the EPG scheme in June 2023. The results are consistent with the event study using our staggered diff-in-diff approach (Figure B2).

Figure B1. Event study ATEs



Panel A. Electricity

Panel B. Gas

Notes: Difference in monthly mean (inverse hyperbolic sine) and 95% confidence intervals of energy consumption (kWh) between 01/01/2021 and 31/12/2023 by control group (households with fixed energy prices, ***FF****) and treated group (households with variable electricity prices post-April 2022,* ***FV****). Coefficients and standard errors are estimated using linear regression (diff-in-diff) analysis interacting the treatment with year-month indicators. Standard errors are clustered at the individual level.* ***Electricity*** *– N = 3,234,080 (N_{FF}=111,279; N_{FV}=3,122,801).* ***Gas*** *- N = 1,486,428 (N_{FF}=85,668; N_{FV}=1,400,760).*

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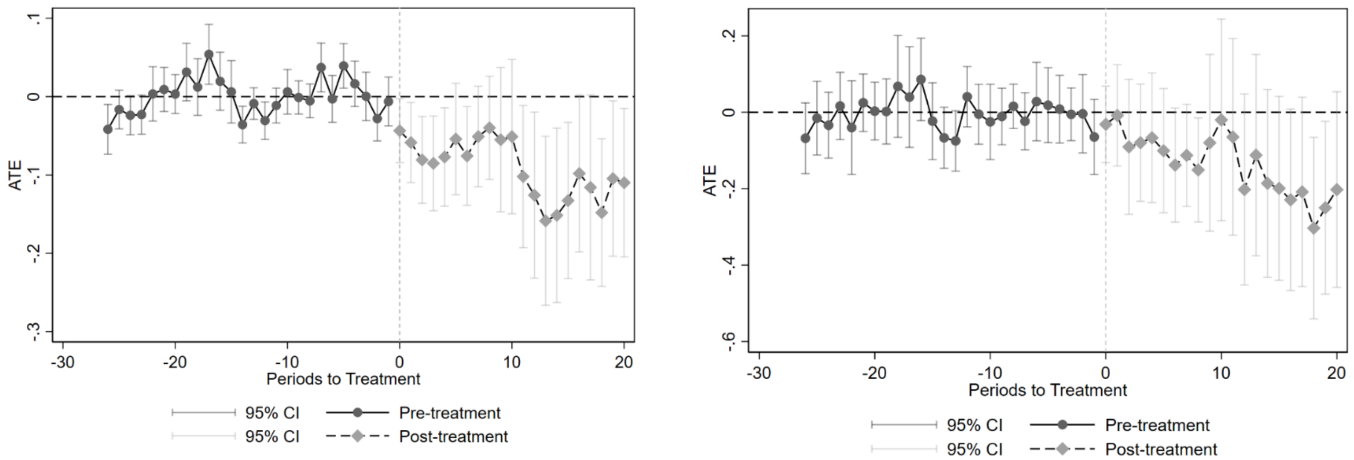
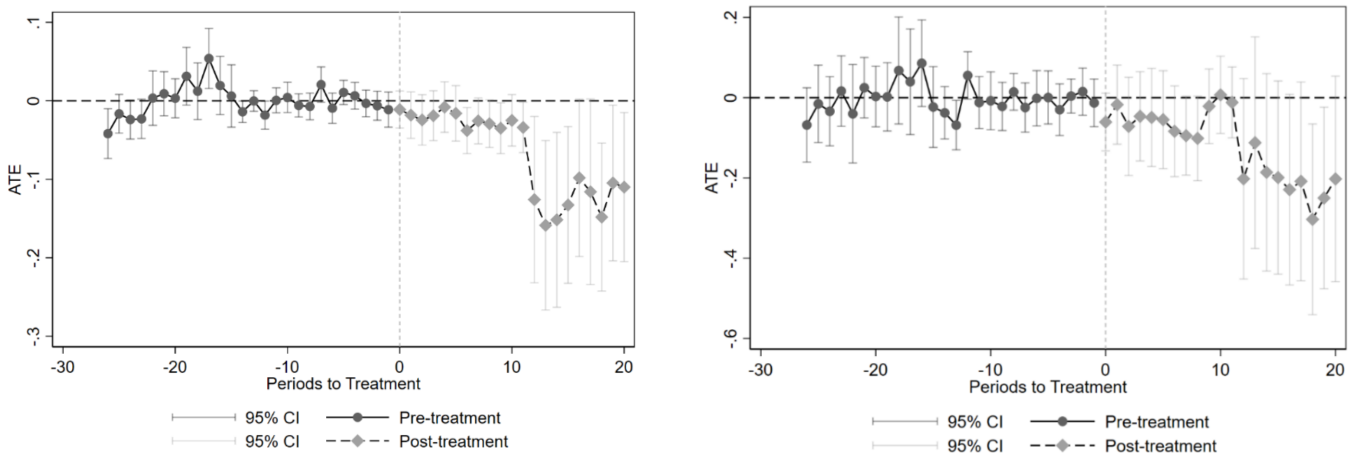
[39] There are a couple of point estimates in Figure B1, i.e., January and March 2022, which are statistically significant at the 5% level, overall however it is clear that the trends are parallel prior to April 2022.

Figure B2. Event study ATEs using staggered diff-in-diff

Electricity: always treated ***Gas: always treated***



Electricity: not yet treated ***Gas: not yet treated***



Notes: Monthly mean (inverse hyperbolic sine) electricity and gas consumption aggregated data, using doubly robust staggered diff-in-diff allowing for the groups (April 2022-March 2023 and April 2023-December 2023) to be considered as either always treated or not yet treated.

Placebo analysis

A placebo (falsification) analysis is conducted to further alleviate identification concerns in the context of our diff-in-diff framework. The concept behind the placebo analysis is that the arbitrarily assigned treatment groups should yield a placebo effect with a point estimate not statistically different from zero when re-estimating the main results using an arbitrary sample period. To carry out this test we restricted the sample period to the years 2020 and 2021. We then reset the control group (FF) as those households with fixed tariffs throughout this period and the treatment group (FV) to those whose tariffs were fixed prior to April 2021 and varied thereafter.

Using the placebo framework, we re-estimate the key results of Table 3 reported in the main body of the document. We anticipate a non-statistically significant effect on energy consumption for the placebo treatment coefficient (i.e., the interaction term) due to the quasi-randomisation process discussed above.

A non-significant effect for the placebo treatment provides further evidence in support of our identification strategy. Table B1 shows the placebo tests for the main results in which electricity consumption (Panel A) and gas consumption (Panel B) are dependent variables, respectively. Across the columns we provide the ATEs from the different specifications analogous to our main results. Crucially, we find no statistically significant effects during the placebo period across all specifications, which reinforces the existence of a causal effect in our main set of results.

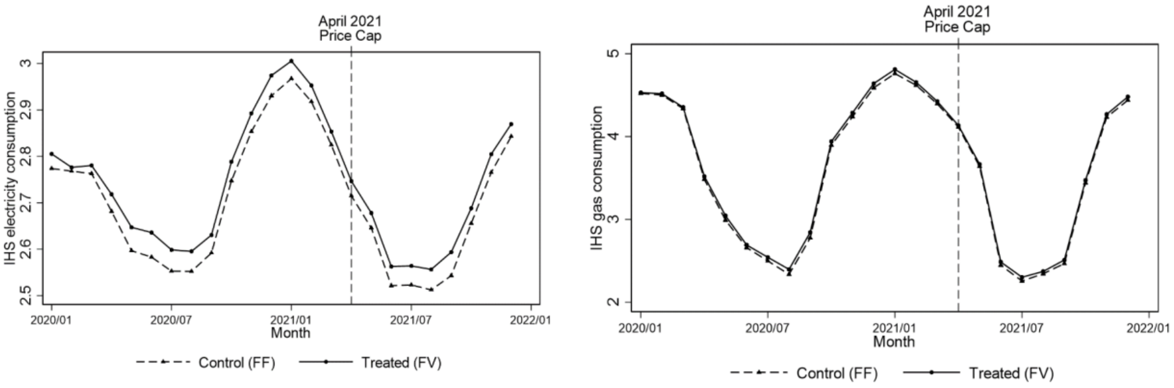
Table B1. Placebo impact of April 2021 price cap change on the inverse hyperbolic sine of electricity consumption by control (FF) vs treatment group (FV) (2020-2021).

	Pooled OLS		**Fixed Effects**		**Pooled OLS**		**Fixed Effects**	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A. Electricity				**Panel B. Gas**			
FV	0.038***	0.047***			0.033	0.038		
	(0.014)	(0.014)			(0.024)	(0.024)		
PRICECAP	-0.102***	-0.048***	-0.196***	-0.047***	-0.462***	-0.047***	-0.650***	-0.051***
	(0.004)	(0.004)	(0.005)	(0.004)	(0.012)	(0.012)	(0.015)	(0.011)
FV x PRICECAP	-0.000	0.001	-0.003	-0.002	0.002	-0.009	0.005	-0.006
	(0.006)	(0.006)	(0.006)	(0.006)	(0.014)	(0.014)	(0.013)	(0.013)
Regional effects	NO	YES	-	-	NO	YES	-	-
Time effects	NO	YES	NO	YES	NO	YES	NO	YES
Temperature	NO	YES	YES	YES	NO	YES	YES	YES
N (treated)	2,279,219	2,279,219	2,279,219	2,279,219	2,184,734	2,184,734	2,184,734	2,184,734
N (control)	2,252,438	2,252,438	2,252,438	2,252,438	1,111,372	1,111,372	1,111,372	1,111,372
N (individuals treated)	3,313	3,313	3,313	3,313	3,206	3,206	3,206	3,206
N (individuals control)	3,284	3,284	3,284	3,284	1,627	1,627	1,627	1,627

*Notes: * p<0.10 ** p<0.05 ***p<0.01, individual-level cluster robust standard errors in the parentheses. Time effects include monthly indicators and the interaction between day of month and day of week indicators. Includes individuals observed for at least 1.5 years.*

The placebo framework is also utilised to assess the possibility of parallel trends using visual analysis and of selection bias via balancing tests. Figure B3 (Panel A and Panel B) shows that while the trends of the two groups average daily and monthly consumption move in parallel, they do not deviate from these trends after April 2021. In addition, Table B2 reports on the balance of socio-demographic and housing characteristics. Compared with our main results in Table 3, the difference-in-means tests show that the socio-demographic and housing characteristics do not balance overall, neither for electricity nor gas consumption. Overall, these results suggest that despite a clear parallel trend there is no apparent (placebo) treatment effect. Moreover, there is selection into the (placebo) treatment in this period (2020-21) as highlighted by the statistically significant coefficient on FV (Table B1, Panel A). This clearly contrasts with the quasi-natural experiment utilised in the main analysis which appears to be effective during the period of the energy price crisis (2022-23).

Figure B3. Placebo monthly mean of (inverse hyperbolic sine) daily energy consumption by FF and FV



Panel A. Electricity | ***Panel B. Gas***

Notes: Monthly mean (inverse hyperbolic sine) energy consumption (kWh) between 01/01/2020 and 31/12/2021 by control group (households with fixed energy prices, ***FF****) and treated group (households with variable energy prices post-April 2021,* ***FV****).* ***Electricity*** *- N = 4,531,657 (N_{FV}=2,279,219; N_{FF}=2,252,438).* ***Gas*** *- N = 3,296,106 (N_{FV}=2,184,734; N_{FF}=1,111,372).*

Table B2. Placebo balancing statistics of the difference in socio-demographic means between FV and FV groups (2020-2021)

	Electricity			**Gas**		
Variable	FV Mean (1)	FF Mean (2)	Difference (3) = (1)-(2)	FV Mean (1)	FF Mean (2)	Difference: (3) = (1)-(2)
Female	0.422	0.443	-0.021	0.450	0.427	0.023
Age >65	0.388	0.459	-0.071***	0.392	0.432	-0.041***
Employed FT	0.402	0.348	0.054***	0.399	0.367	0.032**
Employed PT	0.111	0.091	0.020**	0.106	0.107	-0.001
LTSD	0.026	0.031	-0.005	0.031	0.026	0.005
Unemployed	0.014	0.018	-0.004	0.016	0.017	-0.002
Retired	0.423	0.490	-0.067***	0.427	0.461	-0.035**
Other status	0.016	0.016	-0.001	0.016	0.014	0.002
Own-mortgage	0.851	0.818	0.032***	0.849	0.870	-0.021*
Rent	0.149	0.182	-0.032***	0.151	0.130	0.021*
Household size	2.360	2.238	0.122***	2.378	2.319	0.059
Bedrooms	3.036	2.921	0.115***	3.077	3.049	0.028
Detached	0.631	0.609	0.022*	0.643	0.645	-0.001
Terraced	0.243	0.239	0.004	0.263	0.271	-0.008
Flat	0.125	0.151	-0.026***	0.094	0.084	0.010
Property > 2003	0.083	0.092	-0.010	0.079	0.064	0.014*
Gas central heat	0.879	0.862	0.017*	0.979	0.968	0.011**
Electric central heat	0.040	0.057	-0.017***	0.006	0.005	0.000
Other central heat	0.081	0.081	0.000	0.015	0.026	-0.011**
London	0.113	0.136	-0.023***	0.122	0.127	-0.005
IMD45	0.400	0.381	0.019	0.416	0.403	0.013
Mean temperature	283.964	284.075	-0.112***	284.048	284.088	-0.040*
N	2072727	2030931		1990166	1012038	

*Note: * p<0.10 ** p<0.05 ***p<0.01. Number of observations observed for at least 1.5 years. Tests use bivariate regressions clustered standard errors at the individual level.*