

The impact of energy price shock on jobs - a structural approach

Ralf Martin¹ and Costanza Tomaselli²

¹Imperial College London, LSE-CEP, and World Bank – IFC

²Imperial College London

Abstract

What is the impact of energy price shocks on jobs? This paper examines how an increase in energy prices affects employment using the 2022 energy price crisis as a natural setting. While interesting in its own right it is also indicative of the employment effects of further carbon pricing which - like the 2022 fuel price shock - lead to an increase of carbon intensive fossil fuels such as oil and gas. While the sharp price increase of 2022 induced by the Russian attack on Ukraine was largely uniform across firms, we derive its impact by examining the differential employment response of firms with varying cross price elasticities between energy and employment. Thus we use a shift-share design where the energy price shock becomes the shift and cross price elasticities are the shares.

Using the energy crisis of 2022 as a natural setting and detailed administrative UK firm-level data, we exploit variation in firms' energy dependence by combining two measures of exposure: cross price elasticities between labor and energy, and energy cost shares. We estimate the heterogeneous impacts of rising energy costs on firms' employment decisions. Our results show that higher energy prices led to modest job losses, with less than one percent of jobs in our sample lost over 2022 and 2023 due to increased energy costs. However, the impact was far from uniform. The contraction in employment is concentrated in energy intensive sectors such as Electricity and Gas, Water and Waste, and Transportation, and is particularly evident in rural and peripheral regions where labor markets are less flexible and alternative job opportunities are limited. We also find that mid-sized firms bear a disproportionate share of the employment adjustment compared to both small and very large firms. These findings show how energy price volatility can generate uneven effects across sectors, regions, and firm sizes, highlighting the importance of targeted policy responses such as energy price stabilisation and support for workforce mobility to help reduce adverse labor market impacts during periods of energy price shocks.

Keywords: Energy, Price Shocks, Labor Market, Spatial Analysis

JEL Codes: E23, J2, L16, Q41, R23

1 Introduction

The surge in global energy prices in 2022 had profound economic repercussions, particularly for firms and households in Europe. The post-pandemic recovery and geopolitical disruptions (most notably the war in Ukraine) led to sharp increases in natural gas and electricity prices, creating substantial cost pressures for businesses reliant on energy-intensive production processes. While much attention has been given to the implications of rising energy costs for inflation and household consumption, less is known about how firms adjust their labor demand in response to energy price shocks. This paper investigates the extent to which higher energy costs translate into labor market adjustments, leveraging detailed firm administrative data from the UK. Our main contribution is to discover how the impact of an increase in energy prices is highly heterogeneous. We uncover that the contraction in employment is concentrated in energy intensive sectors such as Electricity and Gas, Water and Waste, and Transportation, and is particularly evident in rural and peripheral regions where labor markets are less flexible and alternative job opportunities are limited.

Energy is a critical input in the production process, and firms' ability to substitute away from energy towards other inputs varies significantly across industries, firm sizes, and locations. The degree of substitutability between energy and other production inputs has been widely studied in the context of firm cost minimization and production efficiency (Berndt and Wood, 1986; Hassler et al., 2012). We test whether firms with high cross price elasticities, those whose other inputs are more responsive to changes in energy prices, are more vulnerable to price fluctuations, with a specific focus on employment. These firms face a steeper trade-off between maintaining output and managing rising expenses, as higher energy price sensitivity implies greater adjustments in labor demand when energy costs increase.

In a standard Cobb-Douglas production function, input elasticity determines how firms adjust to cost shocks: firms with higher cross price elasticities should exhibit stronger labor market responses to energy price increases (Blanchard and Galí, 2009). Our empirical analysis confirms this hypothesis, demonstrating that employment declines are concentrated in firms with high energy dependencies, consistent with the literature on energy price pass-through and employment effects (Davis and Haltiwanger, 2001).

Using rich UK administrative firm-level data on firms' purchases and costs, we estimate the impact of an energy price spike on employment decisions. Our identification strategy exploits variation in firm-level energy intensity, while showing the results at a granular spatial level exploiting differences in spatial energy exposure. By leveraging fine geographic data, we account for local market conditions and infrastructure constraints which could influence firms' ability to adjust to energy price shocks (Rentschler and Kornejew, 2017).

We find that the labor demand contraction is particularly pronounced in energy-intensive industries, where higher operating costs necessitate reductions in labor input. Additionally, we document spatial heterogeneity, with firms in more rural areas having higher cross price elasticities than firms in large metropolitan areas. This finding is of particular relevance as labor markets in rural regions tend to be less flexible, with fewer alternative employment opportunities and lower worker mobility (Meghir et al., 2010). These results align with prior evidence that energy-intensive firms, typically large manufacturers, are more vulnerable to energy price shocks due to their reliance on fixed energy-intensive capital (Amaglobeli et al., 2024). Moreover, rural firms may face higher adjustment costs due to weaker infrastructure, limited access to credit, and smaller local labor pools, exacerbating employment losses in response to energy price shocks (Limão and Venables, 2001).

The policy implications of our findings are substantial. If energy price volatility persists, firms in energy-intensive sectors may continue to shed jobs or scale back operations, exacerbating sectoral labor market frictions. Understanding how firms respond to these shocks is crucial for designing policies that mitigate adverse employment effects. In particular, our results suggest that energy price stabilization measures or targeted support for energy-intensive firms could help sustain employment levels in vulnerable sectors.

Our study makes several key contributions to the literature on energy price shocks and firm behavior. First, we adopt a granular approach, leveraging firm-level administrative data to analyze the impact of energy price shocks. While much of the existing research has focused on macro-level effects, our granular data allow us to identify firm-specific responses and heterogeneity across firms of different sizes, energy intensities, and locations. This complements prior studies that have primarily examined the effects of energy price shocks on aggregate productivity and investment (Kilian, 2009).

Second, we focus explicitly on the substitutability between labor and energy inputs, whereas previous research has largely analyzed firm profitability, investment, and cost pass-through. The standard Cobb-Douglas production framework suggests that firms adjust labor and capital in response to changes in energy input prices (Thompson and Taylor, 1995). Our empirical findings confirm that firms with higher cross price elasticities are more likely to reduce employment, consistent with theoretical predictions. Importantly, we provide heterogeneous treatment effects, showing that firms in energy-intensive industries are particularly affected.

Third, we introduce a regional dimension to the analysis by assessing spatial variation in firms' energy exposure. Unlike previous research that has primarily examined sectoral differences, we provide evidence of how regional disparities in energy intensity, infrastructure, and labor market frictions could shape firm responses to energy price volatility. This aligns with broader work on regional labor market adjustments and

firm resilience to shocks (Limão and Venables, 2001; Meghir et al., 2010). Our results indicate that rural firms, in particular, experience greater employment losses, possibly due to weaker infrastructure, limited access to credit, and smaller local labor pools, which constrain their ability to adjust (Diodato and Weterings, 2014).

Finally, while several papers have examined the 2022 energy crisis (Fetzer et al., 2024; Alpino et al., 2024), they have primarily focused on energy share as a production cost or have restricted their analysis to the manufacturing sector, without considering broader employment and regional dimensions. Our study fills this gap by focussing on cross price elasticities as a way to more closely estimate a Cobb-Douglas production framework and by providing a comprehensive analysis that accounts for regional heterogeneity, sectoral differences, and cross-sectoral labor market effects. This is crucial for understanding the full impact of energy shocks on firms and workers beyond a narrow focus on production costs.

Our findings have important policy implications for labor market stability and economic resilience in the face of energy price volatility. Previous research suggests that temporary shocks to production costs can have long-lasting effects on employment, particularly in industries where re-hiring and training costs are high (Presidente et al., 2023). Understanding the channels through which energy price shocks propagate into labor markets is crucial for designing targeted interventions to support affected workers and firms.

The remainder of this paper is structured as follows. In Section 2, we present a simple theoretical framework that illustrates how energy price shocks can affect firms' input choices and employment levels. Section 3 provides institutional background on the UK energy crisis and discusses the main drivers of recent energy price increases. Section 4 describes the firm-level administrative data we use, the construction of our key variables, and summary statistics. In Section 5, we detail our empirical strategy for estimating the impact of energy shocks on employment, and present our main results, including difference-in-differences estimates and spatial patterns. Finally, Section 6 concludes with a discussion of the main findings and their implications for policy and future research.

2 The Model

2.1 Basic set-up

Consider a Cobb-Douglas production function with four production factors: labor (L), capital (K), energy (E), and other intermediates (M). As in Forlani et al. (2023), we assume that while labor, materials, and energy are flexible inputs whose quantities can vary in the short term, capital is a fixed input in the short run. We define \mathbb{V} as the set

of variable production factors and \mathbb{F} as the set of fixed factors, with $\mathbb{S} = \mathbb{F} \cup \mathbb{V}$.

The firm's Cobb-Douglas production function is given by:

$$Q = AK^{\alpha_K} L^{\alpha_L} M^{\alpha_M} E^{\alpha_E} = A \prod_{z \in \mathbb{S}} X_z^{\alpha_z},$$

where A represents total factor productivity (TFP), and z indexes the production inputs in the set $\mathbb{S} = \{L, M, E, K\}$.

Firms maximize their profit, given input prices for labor (W_L), energy (W_E), and other inputs (W_M). Since capital is fixed in the short run, the firm's short-run profit maximization problem is:

$$\max_{\mathbb{V}} \left(QP - \sum_{z \in \mathbb{V}} W_z X_z \right), \quad (1)$$

where P is the output price.

2.2 Impact of Energy Price Increases on Employment

We assume that firms face the following (log-linear) demand function:

$$Q = \Lambda^{\eta-1} P^{-\eta}, \quad (2)$$

where Λ is a firm- and time-specific demand shifter, and $\eta = \frac{\mu}{\mu-1}$ is the firm's demand elasticity. The corresponding markup is given by $\mu = \frac{\eta}{\eta-1}$. This implies:

$$PQ = (Q\Lambda)^{\frac{1}{\mu}}. \quad (3)$$

Now, considering the first-order conditions (FOCs) for labor and energy, we derive:

$$\frac{\partial Q}{\partial L} = \alpha_L Q/L = W_L/P, \quad (4)$$

$$\frac{\partial Q}{\partial E} = \alpha_E Q/E = W_E/P. \quad (5)$$

From these conditions, the ratio of labor to energy is:

$$\frac{L}{E} = \frac{\alpha_L}{\alpha_E} \times \frac{W_E}{W_L}. \quad (6)$$

This equation illustrates the elasticity of substitution between labor and energy: as the price of energy increases ($W_E \uparrow$), the firm reduces energy use and adjusts labor demand accordingly.

Given this structure, a positive shock to energy prices (e.g., an energy crisis) will affect employment in the following ways: - If labor and energy are complements (α_L/α_E is low), firms will reduce both labor and energy use, leading to larger employment losses. - If labor and energy are substitutes (α_L/α_E is high), firms can replace energy with labor to some extent, leading to less severe employment losses.

2.3 Quantifying the Impact on Employment

A change in energy prices between t and $t + 1$ will lead to a change in employment, $\Delta L = L_{t+1} - L_t$, which can be expressed as:

$$\Delta L = L_t \Phi_{LE,t}^{-1} \frac{\Delta W_E}{W_E}, \quad (7)$$

where $\Phi_{LE,t}^{-1}$ is the labor-energy substitution elasticity, determining the responsiveness of labor demand to energy price fluctuations.

2.4 Implications of the Model

This framework identifies key channels through which energy price increases lead to employment contractions. Firms with higher energy intensity (α_E large) are particularly vulnerable, experiencing greater reductions in labor demand as rising energy costs constrain production. When labor and energy are highly complementary, job losses tend to be more pronounced, as firms have limited ability to substitute between inputs. Moreover, labor market rigidity exacerbates regional disparities, with areas characterized by lower workforce mobility and fewer alternative employment opportunities facing the most severe employment declines. These insights are essential for understanding both sectoral and geographic heterogeneity in labor market responses to energy price shocks.

3 Institutional Background - The UK Energy Crisis

In recent years, the United Kingdom has witnessed a significant escalation in energy prices, profoundly impacting businesses across various sectors. This upward trajectory in energy costs is attributable to a confluence of domestic and international factors, including supply chain disruptions, geopolitical tensions, and structural transformations within energy markets. Between 2021 and 2022, the United Kingdom experienced significant increases in energy prices for industrial consumers, the average price (excluding

the Climate Change Levy¹) for electricity between July and September 2022 was 21.56 pence per kWh, up by 8.34 pence per kWh (63.1%) compared to the same period in 2021 (UK Government, 2022). Figures 1 and A1 in Appendix show how electricity and gas prices escalated drastically in 2022. These escalating costs have directly translated into higher operational expenses for businesses, placing considerable financial strain on firms, particularly those in energy-intensive industries.

Several pivotal factors have contributed to the surge in energy prices in the UK. Firstly, the post-pandemic economic recovery led to a sharp increase in global energy demand as industrial activities resumed, thereby exerting significant pressure on energy supplies. Secondly, geopolitical tensions, notably the Russian invasion of Ukraine in February 2022, exacerbated energy price volatility. Russia’s substantial reduction in gas exports to Europe compelled countries, including the UK, to seek alternative, often more expensive, energy sources. Thirdly, supply chain constraints, coupled with the UK’s limited natural gas storage capacity, amplified price fluctuations. The relatively small size of the UK’s gas storage facilities, compared to other European nations, offered minimal buffer against such shocks.

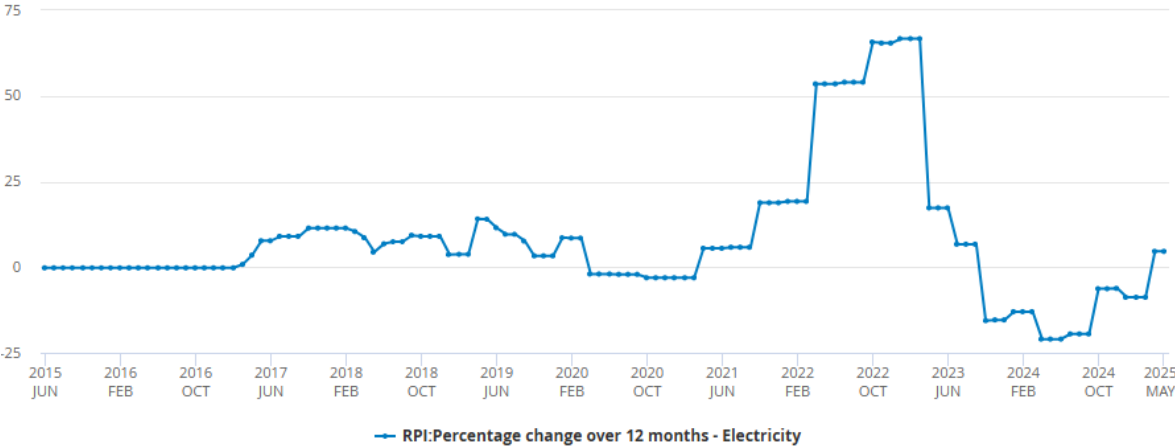


Figure 1: RPI: Percentage change - Electricity

Note: Data from Office for National Statistics (ONS)

¹The Climate Change Levy (CCL) is an environmental tax charged on the energy that businesses use. A means of encouraging businesses to be more energy efficient in how they operate, the CCL aims to reduce the overall emissions that businesses produce SEFE Energy UK (n.d.).

4 Data

4.1 Office for National Statistics (ONS) firm-level databases

Our dataset consists of UK firm level data from the Office for National Statistics (ONS), we use mostly two business surveys the Annual Business Survey (ABS) and the Annual Purchase Survey (APS) from 2015 to 2018 and then from 2021 to 2022. The reason why we do not use 2019 and 2022 is because the ONS did not collect the APS during those two years due to reduced capacity during COVID19. The ABS is the main structural business survey, it contains financial information from businesses representing the UK non-financial business economy (about two-thirds of the UK economy). The financial variables covered include turnover, purchases, employment costs, capital expenditure and stocks. The ABS does not contain Northern Ireland as the Northern Ireland Statistics and Research Agency (NISRA) does not allow sharing of micro data to external researcher. ABS is essential in our analysis as it contains information on capital expenditures which allow us to compute the capital shares. The APS collects information about business' expenditure on energy, services, goods, and materials that are used up or transformed by the business activity. The survey includes raw materials, power and fuel, rental on buildings, and business services. We supplement the ABS and APS with data from the Business Structure Database (BSD) which provides a version for researchers of the quasi-exhaustive Inter-Departmental Business Register (IDBR) which covers 2.1 million businesses, representing nearly 99 per cent of UK economic activity.² We use this additional data for two reason (i) it helps us identifying where the firm is located (ii) at the time of the analysis the BSD had employment in 2023 while ABS and APS only to 2022.

APS and ABS are two independent surveys carried out at various time intervals, they are both sub-samples of the IDBR. Businesses are added to the IDBR if they are registered for Value Added Tax (VAT) with the UK tax authority His Majesty Revenue and Customs (HMRC), registered for a Pay As You Earn (PAYE) scheme with HMRC, the system British employers or pension providers use to take tax contributions before they pay wages or pension, and an incorporated business registered at Companies House, the UK register of firms.

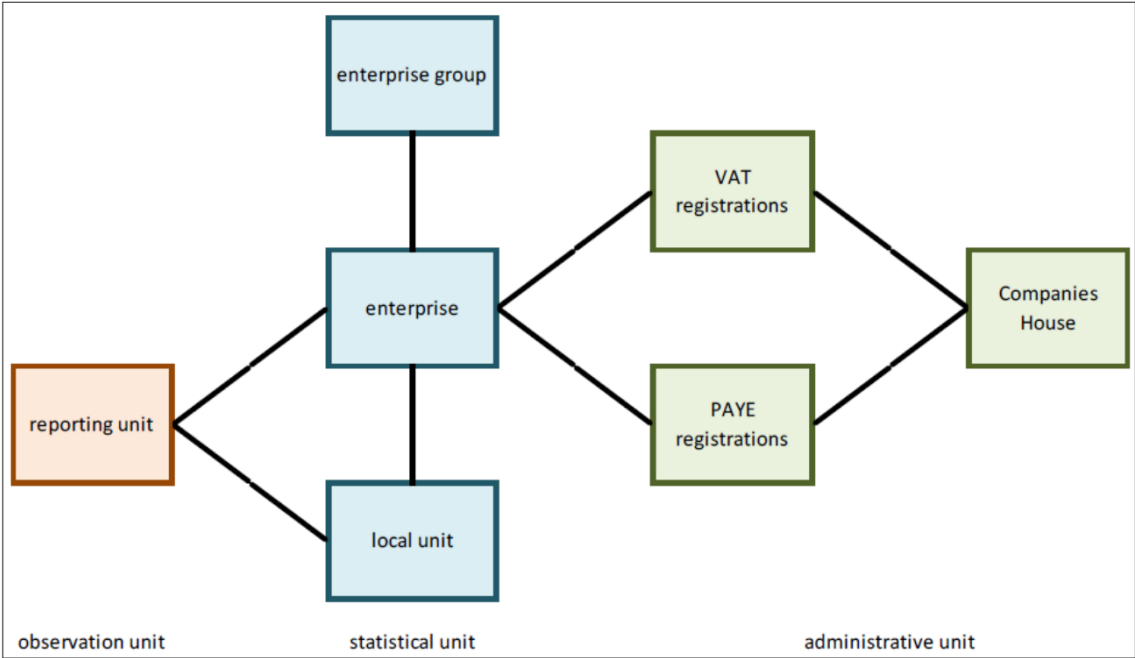
The APS samples covers approximately 33,000 businesses, sample selection is carried out using a stratified random sample design. Similar reporting units (businesses) are grouped into strata as defined by three variables employment size band, SIC, geographical region.

²Businesses are added to the IDBR if they are registered for Value Added Tax (VAT) with the UK tax authority His Majesty Revenue and Customs (HMRC), registered for a Pay As You Earn (PAYE) scheme with HMRC, the system British employers or pension providers use to take tax contributions before they pay wages or pension, and an incorporated business registered at Companies House, the UK register of firms (ONS).

Sample selection occurs independently for each stratum. All businesses with 250 or more in employment are selected every year. The APS also uses inclusion markers to select businesses with low employment but high turnover. APS also excludes certain SIC sectors: (i) part of agriculture, forestry and fishing (01.1 to 01.5), (ii) part of financial and insurance activities (64110 to 64290 and 65300), (iii) public administration and defence (section O), (iv) activities of households as employers (section T), and (v) activities of extraterritorial organisations and bodies (section U).

The ABS covers approximately 62,000 businesses each year and contains financial information from businesses representing the UK non-financial business economy (about two-thirds of the UK economy). The financial variables covered include turnover, purchases, employment costs, capital expenditure and stocks.

For both surveys the business unit to which questionnaires are sent is called the reporting unit, the response from the reporting unit can cover the enterprise as a whole, or parts of the enterprise identified by lists of local units, figure 2 shows the reporting hierarchy. For this reason we will consider the reporting unit the enterprise, which may consist of one or more sub-units (called local units), for example, the head office for a group of shops.



Source: ABS technical Guide

Figure 2: ONS Reporting Unit Hierarchy

Merging databases and sample representativeness To estimate the cross impacts of energy and employment we need information from both APS and ABS (and 2023 information from BSD). We thus have merged the databases by using the ruref (reporting unit reference) identifier and the year reported. At the moment to facilitate the computation of factor shares we have not included in our sample firms reporting zero turnover. Table 1 shows a comparison between the universe and our matched sample, in which the majority of firms (64.5%) have over 250 employees, unlike in the universe of firms sampled, this is to be expected due to how ONS sample firms and our need to have a balanced panel. Table B1 in the Appendix shows the distribution of our sample within sectors, the majority of our sample is in manufacturing and wholesale/retail trade.

Table 1: IDBR and sample used in the analysis comparison between 2021 and 2022 by company employees size

Employees	ABS APS Matched Sample		IDBR	
	n	Percent	n	Percent
0-9	1,042	0.05	4,410,953	0.893
10-19	1,026	0.049	285,543	0.058
20-49	1,442	0.069	153,511	0.031
50-99	1,662	0.079	48,862	0.010
100-249	2,260	0.108	26,106	0.005
250+	13,527	0.645	17,241	0.003

Note: The table shows the comparison between the IDBR and our sample for the years 2021-2022 by number of employees. Due to how ABS and APS are sampled and our need to have a balanced panel it is expected that our sample is skewed towards larger businesses.

5 Cross Price Elasticity of Demand between Labor and Energy and Energy Share

5.1 Estimation Cross Price Elasticities from Shares via CES Regression

In analyzing firm production decisions, it is important to distinguish between factor shares and cross price elasticities. In the context of energy and labor usage, the *energy share* s_E and the *labor share* s_L represent the proportions of a firm's turnover allocated to each input:

$$s_E = \frac{W_E E}{R}, \quad s_L = \frac{W_L L}{R}, \quad (8)$$

where W_E and W_L are the unit prices of energy and labor, E and L their respective quantities, and R total turnover³. Shares capture the static cost burden but not how firms substitute between inputs when relative prices change.

In order to estimate the cross price elasticity of demand between labor and energy⁴, rather than assuming a particular functional form for demand, we exploit the constant-elasticity-of-substitution (CES) relationship in its log-ratio form:

$$\ln \frac{s_L}{s_E} = \sigma \ln \frac{W_L L}{W_E E} = \sigma \ln \frac{W_L}{W_E} + \sigma \ln \frac{L}{E}.$$

Under constant returns to scale and fixed capital in the short run, one can show that this simplifies to

$$\ln \frac{s_L}{s_E} = \beta \ln \frac{W_L}{W_E},$$

where $\beta = 1 - \sigma$. We therefore estimate by OLS across firms:

$$\underbrace{\ln \frac{s_L}{s_E}}_{\text{log_ratio_shares}} = \beta \underbrace{\ln \frac{W_L L}{W_E E}}_{\text{log_ratio_prices}} + \varepsilon,$$

From the estimated slope $\hat{\beta}$, we recover the substitution parameter

$$\hat{\sigma} = 1 - \hat{\beta}.$$

Finally, the cross price elasticity of labor demand with respect to the energy price for firm i is

$$\eta_{L,PE}^{(i)} = \hat{\sigma} \times s_E^{(i)}.$$

Analogously,

$$\eta_{E,PL}^{(i)} = \hat{\sigma} \times s_L^{(i)}.$$

This two-step procedure ensures our estimated elasticities are consistent with the CES framework while leveraging easily observed expenditure shares. cross price elasticities provide dynamic insight into firms' substitution possibilities. Two firms with identical shares may exhibit very different $\eta_{L,PE}$ if one can more easily switch from energy to labor, for example by using more manual processes or labor-intensive technologies ([Labandeira](#)

³Energy costs by type (coal, electricity, gas, etc.) and labor costs are observed in our APS data.

⁴For simplicity in the rest of the paper we are going to refer to them as cross price elasticities.

et al., 2017; Pindyck, 1979). In the short run, fixed capital amplifies these substitution effects, making cross price elasticities a key metric for assessing the employment impacts of energy price shocks (Kilian, 2009).

5.2 Descriptive Statistics

This section provides evidence of the shares and elasticities in our sample, for better comprehension and ease of comparison across the two we have presented the results in absolute values but is worth noting that the shares are always positive and the elasticities are always negative⁵. Table 2 presents a comparison of energy, labor, and material elasticities alongside their respective factor shares. This comparison highlights differences in input responsiveness, where labor and material inputs exhibit higher average elasticities and shares compared to energy.

Table 2: Comparison of absolute values of shares and elasticities distribution

Metric	Energy Elasticity / Share	Labour Elasticity / Share	Material Elasticity / Share
Min	0.000 / 0.000	0.000 / 0.000	0.000 / 0.000
1st Quartile	0.005 / 0.002	0.336 / 0.135	0.202 / 0.065
Median	0.017 / 0.008	0.565 / 0.264	0.386 / 0.182
Mean	0.035 / 0.021	0.545 / 0.320	0.420 / 0.270
3rd Quartile	0.038 / 0.022	0.764 / 0.455	0.626 / 0.433
Max	1.000 / 1.000	1.000 / 1.000	1.000 / 1.000

Note: The Table shows the Energy, labor and Material Elasticities and Shares compared. For ease of comparison, we present the values in absolute terms.

Our descriptive analysis shows that in recent years, cross price elasticities have increased, albeit very modestly (Figures A2). Larger firms, measured by employment, tend to exhibit higher cross price elasticities and energy shares (Figure 3), but smaller companies tend to have more outliers. Additionally, sectors with the highest cross price elasticities and shares are primarily associated with electricity, oil and gas, and transportation (Table 3), this can be also seen in Figure A3, with the shape of SIC sections D (electricity and gas) and H (transportation and storage). Both Figure 3 and Table 3 demonstrate that, across firms, the energy cost share greatly exceeds the estimated cross-price elasticity of labor, this is because the CES substitution parameter $\hat{\sigma}$ typically lies well below unity, it follows that

$$\eta_{L,PE}^{(i)} = \hat{\sigma} s_E^{(i)} \ll s_E^{(i)} .$$

Hence, the observed responsiveness of labor to energy price changes is almost entirely a *scale effect*—firms with larger s_E incur greater alterations in total cost and therefore labor

⁵For the elasticities this is due to construction, while for the share this is because we have excluded firms with negative values.

expenditure—while the pure *substitution effect* (captured by $\hat{\sigma}$) plays a negligible role. In practical terms, energy price shocks translate predominantly into changes in firms’ overall cost burdens rather than inducing meaningful shifts in their capital-labor-energy input mix.

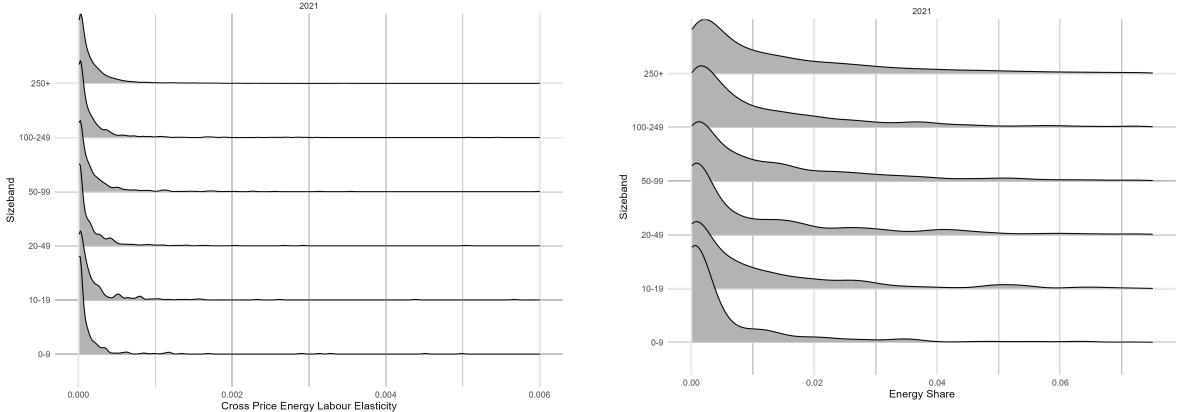


Figure 3: Cross Price Elasticities and Energy Shares by company employment in 2021
 Note: The graphs show a comparison between cross price elasticities and shares by firm employment size.

Table 3: Comparison of Highest Cross Price Elasticity and Energy Shares by SIC Sector at Six-Digit Level in 2021

Industry	Cross Price Elasticity	Industry	Energy Share
Mineral oil refining	0.004	Mineral oil refining	0.359
Production of electricity	0.003	Production of electricity	0.246
Manufacture of chemicals	0.002	Manufacture of chemicals	0.188
Trade of electricity	0.002	Manufacture of oils and fats	0.141
Manufacture of oils and fats	0.001	Trade of electricity	0.133
Passenger land transport	0.001	Passenger land transport	0.132
Freight transport by road	0.001	Freight transport by road	0.111
Other passenger land transport	0.001	Other passenger land transport	0.101
Distribution of gas	0.001	Distribution of gas	0.084
Electricity distribution	0.001	Passenger water transport	0.078

Note: The tables show the top ten energy cross price elasticities and shares in 2021 by SIC sector at the six-digit level. Due to ONS regulations, we cannot report statistics with fewer than 10 observations. Some sectors may thus have been excluded from this list.

5.3 Geographical distribution of elasticities and shares

5.3.1 Country level analysis

Cross price elasticities and energy shares are consistently higher in Wales and Scotland than in England (Figure 4). Sectors such as Electricity and Gas (SIC Section D), Water and Waste (Section E), and Transportation (Section H) tend to exhibit higher cross price elasticities and larger energy shares, as shown in Figures A4 and A5 in the Appendix. Table 4 presents the top ten SIC sectors by country in terms of cross price elasticity and energy share for 2021, confirming that Electricity and Gas, Water and Waste, and Transportation consistently rank among the most energy-intensive and price-sensitive sectors across countries. Table 5 extends this comparison to the six-digit SIC level, highlighting that electricity production and distribution, as well as passenger transport activities, account for a substantial share of the observed cross price elasticities and energy cost exposure in our sample.

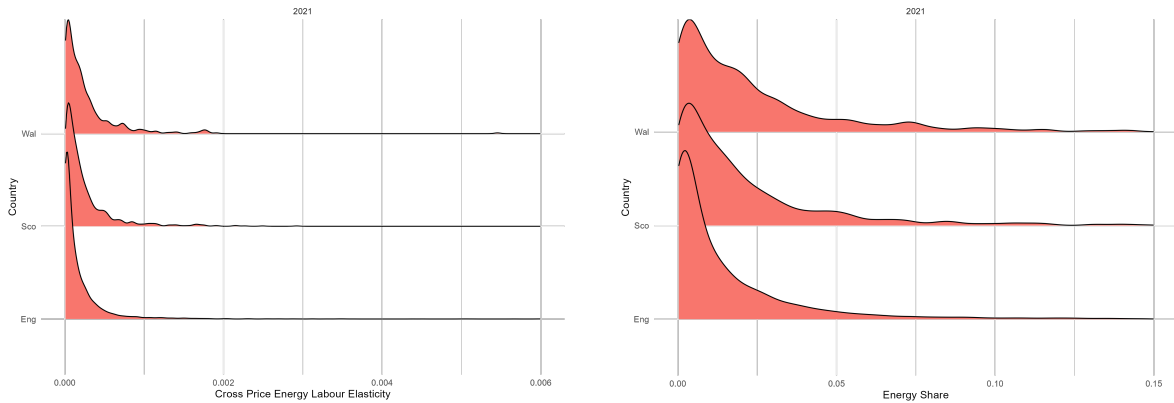


Figure 4: Cross Price Elasticities and Energy Shares by country in 2021

Note: The graphs show a comparison between Cross Price Elasticities and Energy Shares in 2021 by country. Northern Ireland is not included because the Northern Ireland Statistics and Research Agency (NISRA) does not allow sharing of micro data to external researcher.

5.3.2 Travel to Work level analysis

Conducting spatial analysis at the country level might not capture regional labor market and local industry conditions. For this reason in this paper we have conducted most of the spatial analysis at Travel to Work Areas (TTWAs). TTWAs are a geography created to approximate labor market areas. In other words, they are derived to reflect self-contained areas in which most people both live and work. TTWAs are useful for helping build an understanding of local labor markets, for framing local labor market analysis, and in particular for examining the spatial mismatch between labor supply and

Table 4: Comparison of Highest Cross Price Elasticities and Energy Shares by SIC Sector and Country in 2021

SIC Section	Country	Cross Price Elasticity	SIC Section	Country	Energy Share
Electricity and gas	England	0.0018	Electricity and gas	England	0.1574
Transport	Wales	0.0011	Electricity and gas	Scotland	0.1195
Transport	Scotland	0.0007	Transport	Wales	0.1016
Transport	England	0.0006	Transport	Scotland	0.0619
Water and Waste	England	0.0005	Transport	England	0.0581
Arts, entertainment and recreation	Scotland	0.0005	Water and Waste	England	0.0490
Water and Waste	Scotland	0.0005	Arts, entertainment and recreation	Scotland	0.0482
Accommodation and food	Wales	0.0004	Water and Waste	Scotland	0.0423
Arts, entertainment and recreation	Wales	0.0004	Accommodation and food	Wales	0.0412
Accommodation and food	Scotland	0.0004	Accommodation and food	Scotland	0.0374

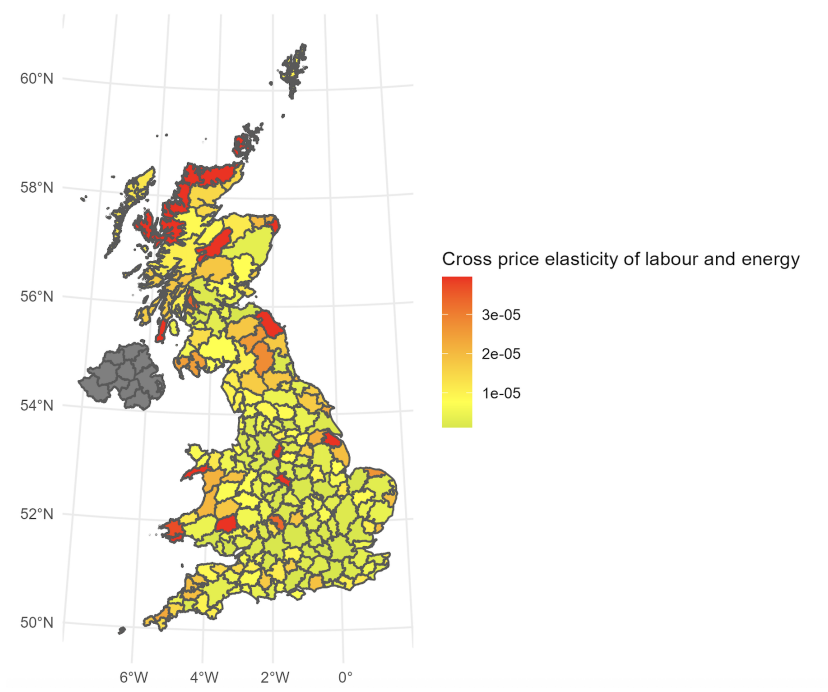
Note: The tables shows the ten highest cross price elasticities and energy shares in 2021 by country and SIC Sector. To note due to ONS regulations we are cannot report statistics with less than 10 observations so some sectors might have been excluded from this list.

Table 5: Comparison of Highest Cross Price Elasticities and Energy Shares by SIC Sector at six digit level and Country in 2021

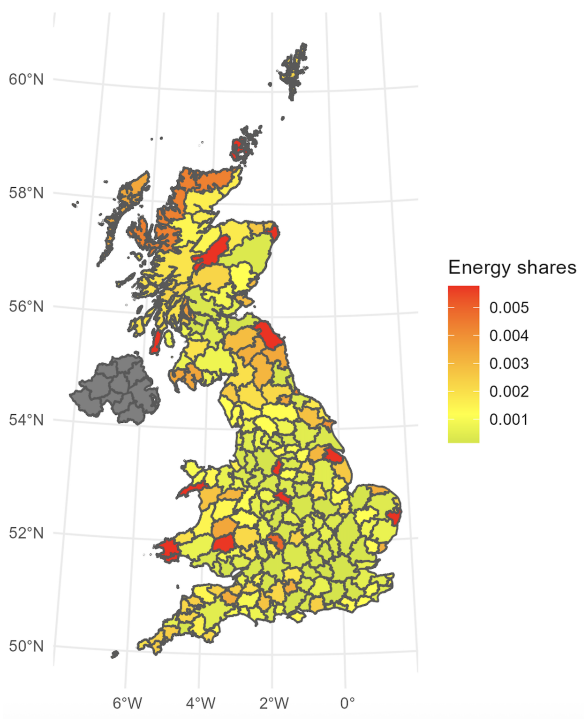
SIC Code	Country	Cross Price Elasticity	SIC Code	Country	Energy Share
Electricity production	Wales	0.0038	Electricity production	Wales	0.3371
Mineral oil refining	England	0.0037	Mineral oil refining	England	0.3360
Electricity production	England	0.0026	Electricity distribution	Scotland	0.2231
Electricity production	Scotland	0.0020	Electricity production	England	0.2117
Electricity distribution	Scotland	0.0018	Passenger land transport	Scotland	0.1842
Tour operator activities	Wales	0.0017	Freight transport by road	Wales	0.1828
Passenger land transport	Wales	0.0017	Tour operator activities	Wales	0.1761
Manufacture of chemicals	England	0.0017	Passenger land transport	Wales	0.1725
Electricity trade	England	0.0017	Freight transport by road	Scotland	0.1547
Passenger land transport	Scotland	0.0016	Electricity production	Scotland	0.1495

Note: The tables shows the ten highest cross price elasticities and energy shares in 2021 by country and SIC Sector at six digit level. To note due to ONS regulations we are cannot report statistics with less than 10 observations so some sectors might have been excluded from this list.

demand ([Office for National Statistics, 2016](#)). In Figure 5 we portray the cross price elasticities and energy shares by TTWA in 2021. Figure 5a shows that in London and South East of England cross price elasticities are lower, while in Scotland and part of Wales this seems to be the opposite. When comparing these findings with energy shares (Figure 5b) we notice a similar picture. These results would corroborate the hypothesis that any significant change in employment is mostly due to a scale effect rather than a substitution effect.



(a) Cross Price Elasticities by TTWA in 2021



(b) Energy shares by TTWA in 2021

Figure 5: Energy exposure measured by Cross Price Elasticity and Energy Share by TTWA in 2021

6 Empirical Methodology and Results

We estimate the impact of the energy price shock on employment using a difference-in-differences specification with firm fixed effects, where the intensity of treatment varies continuously with each firm’s ex-ante energy dependence, this specification is similar to Autor et al. (2013) and Hsiang (2010). The dependent variable is the logarithm of firm employment. We define a post-treatment indicator (*post*) that equals one for observations in 2022 and 2023, capturing the period after the energy shock. We then interact this post indicator with the firm’s cross price elasticity or energy share (*energy coefficient*) measured in 2021, or the earliest available year if 2021 data is missing.⁶

The resulting regression model is specified as:

$$\log(\text{Employment}_{it}) = \beta_1 \text{post}_t + \beta_2 (\text{post}_t \times \log(\text{energy coefficient}_i)) + \alpha_i + \varepsilon_{it}, \quad (9)$$

where α_i denotes firm fixed effects. The coefficient of interest, β_2 , identifies the differential employment response for firms with higher ex-ante energy exposure compared to less exposed firms. Standard errors are clustered at firm level.

Dependent Variable:	(1)	(2)
	log(Employment)	
<i>Variables</i>		
Post	−0.0506* (0.0284)	−0.0253 (0.0162)
Post × log(Cross Elasticity)	−0.0090*** (0.0031)	
Post × log(Energy Share)		−0.0120*** (0.0034)
Observations	16,738	16,717
Firm Fixed Effects	Yes	Yes
R^2	0.98556	0.98629

Table 6: Empirical Results: Impact of the interaction of Cross Price Elasticities and Energy Shares with the post period on Employment

Notes: Standard errors (in parentheses) are clustered at the firm level. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Column one measures the specification using cross elasticity, while column 2 uses energy share. The post period captures the years after 2021.

⁶If the cross price elasticity or energy share is unavailable for 2021, we use 2018 data; if not available in 2018, we use the closest preceding year. This is primarily relevant for smaller firms that are not surveyed annually.

Table 6 compares two specifications examining the effect of the period following the energy crisis and its interaction with firm-level characteristics on log employment. In column (1), the interaction between the post period and $\log(\text{Cross Elasticity})$ is negative and statistically significant, suggesting that firms with higher cross price elasticities tend to reduce employment more after the event. In column (2), the interaction between the post period and $\log(\text{Energy Share})$ is also negative and highly significant, indicating that firms with higher energy intensity similarly experience greater employment declines. The direct effect of the post period alone is negative in both specifications but only weakly significant or insignificant. Notably, the magnitude of the coefficient on the energy share interaction is larger in absolute terms than that of the cross price elasticity, suggesting that energy intensity is a stronger driver of post-period employment adjustments. Overall, the results imply that firms with higher energy dependence experience greater employment declines, and that this channel may dominate the input substitution effect captured by the cross elasticity.

6.1 Employment Impact under a No-Price-Change Scenario

To further quantify the effect of energy dependency on employment, we estimate the counterfactual change in employment for firms if energy prices had remained constant. Specifically, we define the employment change for firm i in 2022 as:

$$\Delta L_{i,post} = (\exp(-\beta_x \cdot \text{energy coefficient}_i) - 1) \cdot L_{i,post} \quad (10)$$

where $\Delta L_{i,post}$ represents the estimated change in employment for firm i following 2021 under a scenario where energy prices do not change, β_x is the estimated coefficient capturing the effect of energy dependency on employment, $\text{energy coefficient}_i$ is the firm's cross price elasticity or energy share, and $L_{i,post}$ is the observed employment level of firm i after 2021. When we use cross price elasticities, the results suggest that higher energy prices led to a reduction of about 0.3% of jobs in our sample in both 2022 and 2023. By contrast, when exposure is measured using energy shares, the estimated employment loss rises to approximately 0.6% per year.

Figure 6 presents a binned scatterplot comparing the employment loss estimates based on cross price elasticities (horizontal axis) and energy shares (vertical axis). Each hexagon's color intensity reflects the density of observations, with areas containing fewer than 10 observations obscured to preserve confidentiality. The fitted line indicates a strong positive relationship between the two measures: firms with higher estimated job losses under the cross price elasticity approach also tend to show higher losses when using energy shares. However, the slope above the 45-degree line suggests that the energy share estimates are systematically larger than those based on cross price elasticities,

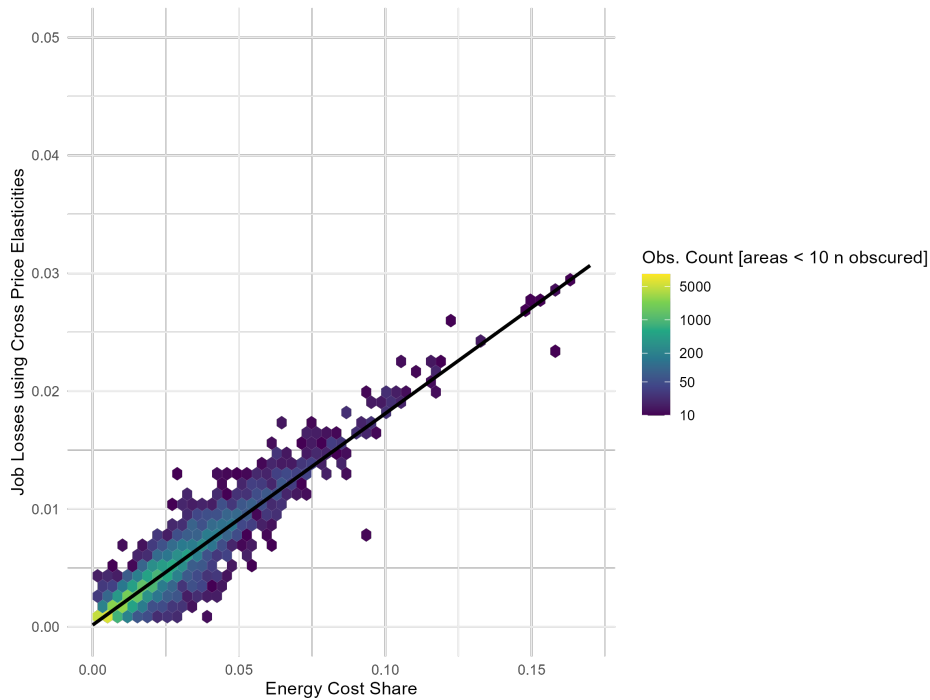


Figure 6: Scatterplot comparing Energy Shares with Jobs Lost by using Cross Price Elasticities

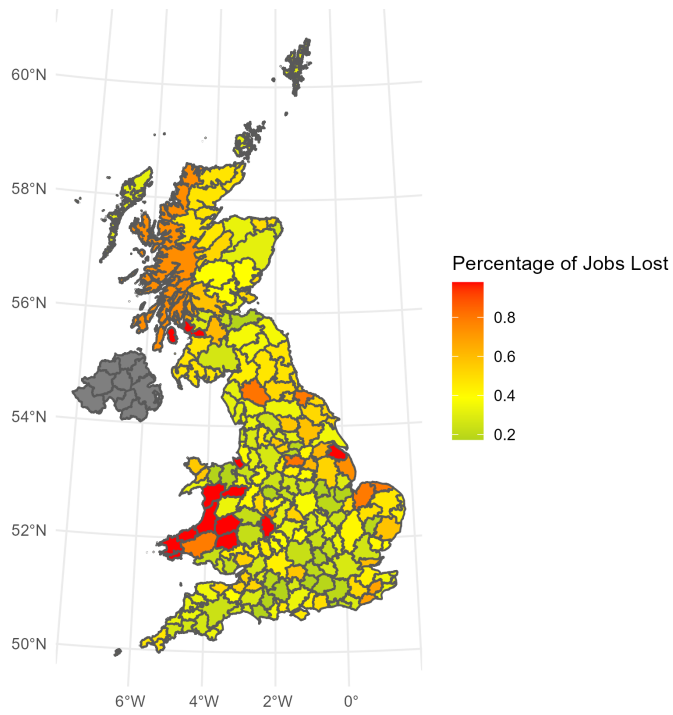
consistent with the descriptive results showing that the implied employment effect is roughly twice as large when using energy shares.

6.2 Heterogeneity Analysis of Employment Impact

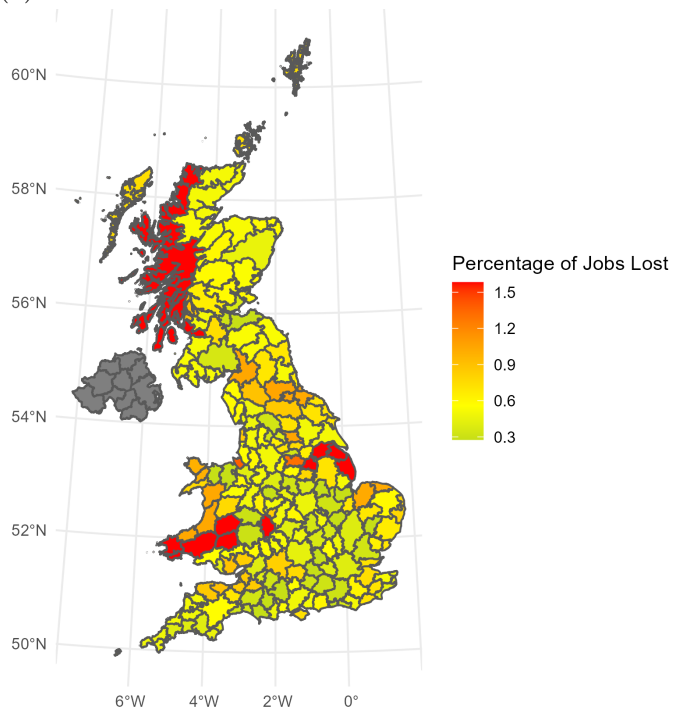
Geographical Analysis of Employment Impact To visualize the spatial dimension of the effects described above Figure 7 shows the counterfactual employment losses across Travel-to-Work Areas (TTWAs), aggregated from the firm-level estimates using Equation 10⁷. Due to data constraints in some TTWAs (i.e., fewer than ten observations), we merge geographically adjacent units using both the 2001 and 2011 TTWA classifications to ensure meaningful coverage⁸.

⁷For data readability we have windsorised the map results, full results are available at Table ??

⁸TTWA codes and sometimes confines are different when using the 2001 and 2011 nomenclature, we ensured consistency by manually comparing the results



(a) Job Losses Estimated with Cross Price Elasticities



(b) Job Losses Estimated with Energy Shares

Figure 7: Comparison of Percentage of Jobs Lost by TTWA Using Different Measures of Energy Exposure

Figure 7a shows the spatial pattern of job losses calculated with cross price elasticities, while Figure 7b displays the same outcome using energy shares. Both maps reveal clear regional disparities, with certain areas in Wales, Scotland, and parts of northern England experiencing the highest estimated employment impacts. However, the magnitudes differ substantially: under the cross price elasticity approach, job losses are lower than when using energy shares. These results have been winsorised at the 2nd and 98th percentiles to improve map readability.

In the Appendix, Table B3 and Table B4 report the corresponding un-winsorised estimates for the grouped TTWA areas, based on cross price elasticities and energy shares, respectively. Examining these results reveals that certain regions, particularly in Scotland and Wales, exhibit job losses of up to 4–5% under both measures of energy exposure. However, the estimates based on energy shares are consistently larger across areas compared to those based on cross price elasticities.

This comparisons highlight that when using energy shares, the estimated employment impact is both larger and more spatially concentrated in specific regions. Overall, these maps and tables illustrate that the choice of firm-level energy exposure measure has important implications for assessing the local labor market effects of energy price shocks.

Sectoral Analysis of Employment Impact In this subsection, we focus on sectoral heterogeneity in job losses by examining how the impact of rising energy costs varies across broad SIC sections. Tables 7 and 8 present the estimated percentage of jobs lost by SIC section using cross price elasticities and energy shares, respectively. While the overall ranking of sectors is broadly similar across both measures, the estimates based on energy shares tend to be slightly larger than those derived from cross price elasticities, particularly for sectors such as Electricity and Gas and Water and Waste. This reflects the fact that the energy share captures direct exposure more mechanically, whereas cross price elasticities account for firms’ substitution possibilities across inputs. However, regardless of the measure used, the sectors experiencing the highest proportional job losses are Electricity and Gas, Water and Waste, and Transportation. This is consistent with the earlier descriptive evidence highlighting these sectors as among the most energy-intensive in the economy.

Table 7: Percentage of Jobs Lost by SIC Section using Cross Price Elasticities

SIC Section	Description	Employment	Percentage Jobs Lost
C	Manufacturing	1,111,602	0.4951
D	Electricity and Gas	133,915	1.2351
E	Water and Waste	98,997	1.1320
F	Construction	260,144	0.2023
G	Wholesale and Retail Trade	1,928,039	0.2003
H	Transportation	546,041	1.0924
I	Accommodation and Food Services	780,390	0.5477
J	Information and Communication	391,077	0.1365
K	Financial and Insurance	120,860	0.0138
L	Real Estate	120,819	0.1912
M	Professional and Scientific Services	639,839	0.0706
N	Administrative Services	1,032,475	0.1406
P	Education	71,166	0.2580
Q	Health and Social Work	458,972	0.2674
R	Arts and Entertainment	207,434	0.6535
S	Other Services	41,937	0.4095

Notes: The table shows the percentage of jobs lost by SIC section using cross price elasticities. Companies that did not report their sector have been excluded from this analysis. It is important to note that these results rely on a balanced panel that requires firms to be observed repeatedly over time. Consequently, the sample may not be fully representative of the entire universe of firms within each SIC section.

Firm Size Analysis of Employment Impact In this subsection, we focus on firm size heterogeneity in job losses by examining how the impact of rising energy costs varies across firm sizes. Tables 9 and 10 summarise the percentage of jobs estimated to be lost across different firm size bands, using cross price elasticities and energy shares, respectively. While the underlying approach differs, both measures indicate that larger firms tend to experience a greater absolute number of job losses due to their scale, but the share of jobs lost relative to employment varies in important ways across size bands.

In both specifications, mid-sized firms (those employing between 50 and 249 workers) tend to show higher percentages of job losses compared to the smallest size bands (0–9 and 10–19 employees) and even compared to the largest firms (250+). This pattern may reflect that mid-sized firms are large enough to be significantly exposed to energy costs but not as diversified or resilient as the very largest employers. It is important to note that these estimates are based on balanced panel data, requiring consistent reporting over time, which likely results in a sample that over-represents larger, more stable firms relative to the wider business population.

Table 8: Percentage of Jobs Lost by SIC Section using Energy Shares

SIC Section	Description	Employment	Percentage Jobs Lost
C	Manufacturing	1,111,602	0.5942
D	Electricity and Gas	133,915	2.5467
E	Water and Waste	98,997	1.6773
F	Construction	260,144	0.2775
G	Wholesale and Retail Trade	1,928,039	0.2694
H	Transportation	546,041	1.6060
I	Accommodation and Food Services	780,390	0.6995
J	Information and Communication	391,077	0.1882
K	Financial and Insurance	120,860	0.0399
L	Real Estate	120,819	0.2626
M	Professional and Scientific Services	639,839	0.1047
N	Administrative Services	1,032,475	0.2039
P	Education	71,166	0.3732
Q	Health and Social Work	458,972	0.4165
R	Arts and Entertainment	207,434	0.9072
S	Other Services	41,937	0.6384

Notes: The table shows the percentage of jobs lost by SIC section using energy shares. Companies that did not report their sector have been excluded from this analysis. It is important to note that these results rely on a balanced panel that requires firms to be observed repeatedly over time. Consequently, the sample may not be fully representative of the entire universe of firms within each SIC section.

Table 9: Percentage of Jobs Lost by Firm Size using Cross Price Elasticities

Firm Size	Employment	Percentage Jobs Lost
0–9	1,639	0.2275
10–19	2,976	0.3614
20–49	32,252	0.2046
50–99	43,765	0.4006
100–249	185,538	0.4089
250+	7,677,537	0.3584

Notes: This table shows the percentage of jobs lost by firm size category, estimated using cross price elasticities. Companies that did not report firm size have been excluded. These results are based on a balanced panel requiring firms to be observed over multiple years. As a result, the sample may not fully represent the universe of firms and could be skewed towards larger, longer-surviving firms.

7 Conclusion

This paper provides new empirical evidence on how sharp energy price shocks affect employment, using rich administrative data and exploiting variation in firms' energy

Table 10: Percentage of Jobs Lost by Firm Size using Energy Shares

Firm Size	Employment	Percentage Jobs Lost
0–9	1,639	0.2664
10–19	2,976	0.6050
20–49	32,252	0.2668
50–99	43,765	0.5692
100–249	185,538	0.8393
250+	7,677,537	0.4964

Notes: This table shows the percentage of jobs lost by firm size category, estimated using energy shares. Companies that did not report firm size have been excluded. These results are based on a balanced panel requiring firms to be observed over multiple years. As a result, the sample may not fully represent the universe of firms and could be skewed towards larger, longer-surviving firms.

dependence. By comparing estimates based on both cross price elasticities and energy shares, we highlight that firms with higher energy intensity and lower substitution possibilities are particularly vulnerable to rising energy costs.

Our results indicate that the 2022 energy crisis led to a small contraction in employment, with less than 1% of jobs in our sample lost over 2022 and 2023 as a direct consequence of elevated energy prices. However the impact was not homogeneous across regions, sectors, or firm of different sizes. Sectors such as Electricity and Gas, Water and Waste, and Transportation show the highest proportional losses, reflecting their structural dependence on energy inputs. Moreover, we find clear spatial heterogeneity: rural and peripheral regions experience larger job losses, likely due to less flexible labor markets, weaker infrastructure, and fewer alternative employment opportunities. Our firm size analysis suggests that mid-sized firms (50–249 employees) face relatively larger percentage employment losses than both the smallest and largest firms. This likely reflects their greater exposure to energy costs, combined with more limited diversification and resilience compared to very large firms.

Taken together, our findings underscore the importance of considering both production structure and local labor market conditions when assessing the labor market impacts of energy shocks and formulating policy responses. From a policy perspective, targeted interventions—such as energy price stabilization, incentives for energy efficiency upgrades, and support for labor mobility—could help mitigate adverse employment effects, particularly in energy-intensive sectors and vulnerable regions.

Finally, this study demonstrates the value of using detailed firm-level elasticities and energy shares to better understand the channels through which energy price volatility translates into employment outcomes. Future research could build on these insights by

examining longer-term firm adaptation strategies, such as technological investments or shifts in production processes, and by comparing how institutional contexts shape firms' resilience to similar shocks.

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Appendix

A Model

What is the immediate impact of carbon pricing on firms? In particular how is employment in firms that face carbon pricing and/or higher energy prices affected? If we can model this well we can also easily provide evidence on the impact on sectors or regions. Here we develop a simple Cobb-Douglas production function framework. There are n factors in particular that we would want to allow to vary between firms that determine the impact of carbon pricing. These include:

1. The factor intensity of a firm in terms of carbon intensive inputs
2. The elasticity of substitution between such inputs and others (notably labour)
3. The ability of firms to pass through any cost increases to their customers

Framework to measure the impact of price changes We consider a production function comprising of a set of production factors, some fixed in the short run and some variable. We aim to anticipate what are the changes in the variable factors when faced with changes in prices of a factor.

B Notations

- For the sake of ease of reading, we drop all subscript X_{it} indicating sector/firm and time.
 - Note that the coefficients are the production functions are not time or firm specific. Prices, quantities and shares are both time and firm specific.
 - The mark-up rate μ is time and firm specific
- Lower letters indicate log transformation, such as $\forall X, x = \ln X$
- \mathbb{V} is the set of factors that are variable in the short term. \mathbb{F} is the set of factors that are *not* variable in the short term.
- The set of all factors is $\mathbb{S} = \mathbb{F} \cup \mathbb{V}$
 - Throughout this paper, we consider that only one factor is fixed in the short-run: capital K ($|\mathbb{F}| = 1$)
 - There are n factors in \mathbb{V} , hence $n + 1$ factors in total ($|\mathbb{S}| = n + 1$)

- We index price (W), quantity (X), cost share in revenues (S) and the coefficients of the productions functions (α) by the position of each factor on the production factors list. $\forall X, X_z$ stands for the z -th position on the list of production factors.
 - We use an abusive notation for \mathbb{F} since K is the only factor, we index price, quantity, share and coefficients by K and not $n + 1$ to avoid confusion with factors from \mathbb{V} .

C Set-up

Hypotheses

1. K is a fixed factor in the short run, $K \in \mathbb{V}$
2. Homogeneity of degree γ of the production function

We consider 4 inputs: K, L, M, E (Capital, Labour, Material, Energy).

Function The Cobb-Douglas production function is

$$Q = AK^{\alpha_K} L^{\alpha_L} M^{\alpha_M} E^{\alpha_E},$$

or in log form:

$$q = a + \alpha_L l + \alpha_M m + \alpha_E e.$$

To adopt a more general notation where z is the position of the factor in the set $\mathbb{S} = c(L, M, E, K)$, we write:

$$Q = A \prod_{z \in \mathbb{S}} X_z^{\alpha_z}.$$

Thus, in log, we write the Cobb-Douglas function as

$$q = a + \sum_{z \in \mathbb{S}} \alpha_z x_z, \tag{11}$$

where q is a function of all the inputs $x_i, \forall i$. We denote it as $q((x_i)_{i \in \mathbb{S}})$.

Homogeneity We impose the homogeneity of the production function.

In all generality, the homogeneity of degree γ of a production function F and its inputs $(X_i)_{i \in 1:n}$ means that for any $S \in \mathbb{R}$:

$$F(SX_1, SX_2, \dots, SX_n) = S^\gamma \cdot F(X_1, X_2, \dots, X_n)$$

In the case of the Cobb-Douglas in log form, it means that for any $s \in \mathbb{R}$,

$$q((x_i)_{i \in \mathbb{S}} + s) = q((x_i)_{i \in \mathbb{S}}) + \gamma s.$$

$$\begin{aligned} q((x_i)_{i \in \mathbb{S}} + s) &= a + \sum_{z \in \mathbb{S}} \alpha_z (s + x_z) \\ &= a + \sum_{z \in \mathbb{S}} \alpha_z x_z + \sum_{z \in \mathbb{S}} \alpha_z s. \end{aligned}$$

Hence, the Cobb-Douglas function is homogeneous of degree γ if and only if:

$$\sum_{z \in \mathbb{S}} \alpha_z = \gamma. \quad (12)$$

Marginal productivity From equation (11), it comes that:

$$\forall j \in \mathbb{V}, \frac{\partial q}{\partial x_j} = \alpha_j \quad (13)$$

Thus, we can rewrite eq. (11) as:

$$q = a + \sum_{z \in \mathbb{S}} \frac{\partial q}{\partial x_z} \cdot x_z. \quad (14)$$

Note that for fixed factors, ($K \in \mathbb{F}$),

$$\frac{\partial q}{\partial k} = \alpha_K = \gamma - \sum_{j \in \mathbb{V}} \alpha_j.$$

Hence, using homogeneity (12) and marginal productivity expression (13),

$$\frac{\partial q}{\partial k} = \gamma - \sum_{j \in \mathbb{V}} \frac{\partial q}{\partial x_j}. \quad (15)$$

Demand shifter We assume that a representative firms faces the following (log linear) demand:

$$Q = \Lambda^{\eta-1} P^{-\eta}, \quad (16)$$

where

- Λ is a firm and time specific demand shifter,
- P is the price of the final good (output),
- $\eta = \frac{\mu}{\mu-1}$ is the firm elasticity of demand (time and firm specific), and
- $\mu = \frac{\eta}{\eta-1}$ is the mark-up rate (dependant on the elasticity of demand). Note that $\frac{\eta-1}{\eta} = \frac{1}{\mu}$.

We can express the total revenues of the firm PQ :

$$\begin{aligned} Q = \Lambda^{\eta-1} P^{-\eta} &\iff Q^{-\frac{1}{\eta}} = \Lambda^{\frac{1-\eta}{\eta}} P \\ &\iff P = Q^{-\frac{1}{\eta}} \Lambda^{\frac{\eta-1}{\eta}} \\ &\iff PQ = Q^{1-\frac{1}{\eta}} \Lambda^{\frac{\eta-1}{\eta}} \\ &\iff PQ = (Q\Lambda)^{\frac{\eta-1}{\eta}}. \end{aligned}$$

Hence,

$$PQ = (Q\Lambda)^{\frac{1}{\mu}}. \quad (17)$$

Problem of the firm Assuming that capital is fixed, firms face the following short run problem where they maximise profit π only on variable factors. The optimal use of factor, $(X_i)_{i \in \mathbb{V}}^*$, is the argument of:

$$\begin{aligned} \max_{\mathbb{V}} \pi &= \max_{\mathbb{V}} \left(QP - \sum_{z \in \mathbb{V}} W_z X_z \right) \\ &= \max_{\mathbb{V}} \left((Q\Lambda)^{\frac{1}{\mu}} - \sum_{z \in \mathbb{V}} W_z X_z \right) \end{aligned} \quad (18)$$

This leads to the following short run first-order condition of the firm's profit maximisation problem:

$$\forall j \in \mathbb{V}, \frac{d}{dX_j} \left((Q\Lambda)^{\frac{1}{\mu}} - \sum_{z \in \mathbb{V}} W_z X_z \right) = 0. \quad (19)$$

To solve it, note that:

- $\frac{\partial x}{\partial X} = \frac{1}{X}$,
- $\frac{\partial \Lambda}{\partial X_z} = 0$,
- $Q = A \prod_{z \in \mathbb{V}} X_z^{\alpha_z}$,
- $\frac{\partial Q}{\partial X_j} = A \alpha_j X_j^{\alpha_j - 1} \prod_{z \neq j \in \mathbb{V}} X_z^{\alpha_z} = \alpha_j X_j^{\alpha_j - 1} \frac{1}{X_j^{\alpha_j}} Q$,
hence, $\frac{\partial Q}{\partial X_j} = \alpha_j \frac{1}{X_j} Q$, and
- $\frac{\partial q}{\partial x_j} = \alpha_j$.

Therefore,

$$\begin{aligned} \forall j \in \mathbb{V}, \frac{d}{dX_j} \left((Q\Lambda)^{\frac{1}{\mu}} - \sum_{z \in \mathbb{V}} W_z X_z \right) &= 0 \\ \iff \Lambda^{\frac{1}{\mu}} \frac{1}{\mu} \frac{\partial Q}{\partial X_j} Q^{\frac{1}{\mu} - 1} - W_j &= 0 \\ \iff \Lambda^{\frac{1}{\mu}} \frac{1}{\mu} Q^{\frac{1}{\mu} - 1} \alpha_j \frac{1}{X_j} Q &= W_j \\ \iff \Lambda^{\frac{1}{\mu}} \frac{1}{\mu} Q^{\frac{1}{\mu}} \frac{\partial q}{\partial x_j} \frac{1}{X_j} &= W_j. \end{aligned}$$

We can rewrite it as

$$\frac{\frac{\partial q}{\partial x_j}}{\mu} = \frac{X_j W_j}{\Lambda^{1/\mu} Q^{1/\mu}}. \quad (20)$$

And since $\Lambda^{1/\mu} Q^{1/\mu} = PQ$, we can interpret the right hand side ($X_j W_j / PQ$) as the cost share of input j , that we denote S_j for all j in \mathbb{V} .

Hence,

$$\frac{\frac{\partial q}{\partial x_j}}{\mu} = S_j, \quad (21)$$

i.e. the log derivative of the production function w.r.t to variable factors over markups is equal to the cost share in revenue of a factor.

Note that due to non-constant returns to scales ($\gamma \neq 1$), the sum of the shares does not necessarily sum up to 1.

$$\sum_{j \in \mathbb{V}} S_j = \sum_{j \in \mathbb{V}} \frac{a_j}{\mu} = \frac{\gamma - \alpha_K}{\mu} \neq 1$$

Passing equation (20) in log (Note that μ has no upper case):

$$\frac{1}{\mu}(\lambda + q) - \ln \mu + \ln \left(\frac{\partial q}{\partial x_j} \right) - x_j = w_j. \quad (22)$$

Then, by taking the total derivative with respect to all factor x_o in \mathbb{V} (and not \mathbb{F} since $\forall z \in \mathbb{F}, dx_z = 0$) we write:

$$dw_j = \frac{1}{\mu} \sum_{o \in \mathbb{V}} \frac{\partial q}{\partial x_o} dx_o - dx_j, \quad (23)$$

since $\frac{\partial q}{\partial x_j} = \alpha_j$ is a constant, it means that

$$\sum_{z \in \mathbb{V}} \frac{\partial \left(\frac{\partial q}{\partial x_j} \right)}{\partial x_z} dx_z = 0.$$

Using the factor share defined in equation (21), we have

$$dw_j = \sum_{z \in \mathbb{V}} S_z dx_z - dx_j, \quad (24)$$

which can be written in matrix form,

$$\mathbf{\Phi} \mathbf{dx} = \mathbf{dw}. \quad (25)$$

With

$$\Phi_{ij} = \begin{cases} S_j & \text{if } i \neq j \\ S_j - 1 & \text{if } i=j, \end{cases} \quad (26)$$

$$\mathbf{\Phi} = \begin{bmatrix} S_1 - 1 & \cdots & S_j & \cdots & S_n \\ \vdots & & \vdots & & \vdots \\ S_1 & \cdots & S_j - 1 & \cdots & S_n \\ \vdots & & \vdots & & \vdots \\ S_1 & \cdots & S_j & \cdots & S_n - 1 \end{bmatrix}.$$

Equation (26) defines a system of n equations (with $n = |\mathbb{V}|$). We can invert the matrix Φ to solve the system:

$$\begin{aligned}\Phi \mathbf{dx} &= \mathbf{dw} \\ \iff \mathbf{dx} &= \Phi^{-1} \mathbf{dw}.\end{aligned}\tag{27}$$

We have that (proof below):

$$|\Phi| = (-1)^n \left(1 - \sum_{o \in \mathbb{V}} S_o \right).\tag{28}$$

We rewrite it as

$$|\Phi| = (-1)^n \left(1 - \frac{\gamma - \alpha_K}{\mu} \right)$$

Hence, the matrix Φ fails to be invertible if and only if $\frac{\gamma - \alpha_K}{\mu} = 1$. Which is the case when

$$\sum_{j \in \mathbb{V}} S_j = 1,$$

that Φ is not invertible where there is no fixed factor ($\mathbb{V} = \mathbb{S}$), no mark-up ($\mu = 1$), and constant returns to scale ($\gamma = 1$). The matrix Φ is invertible if any of these three conditions is not true.

Determinant of Φ . Proof of equation (28)

Let's denote the determinant of the matrix Φ as \mathcal{D}_n , with

$$\Phi = \begin{bmatrix} S_1 - 1 & \cdots & S_j & \cdots & S_n \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ S_1 & \cdots & S_j - 1 & \cdots & S_n \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ S_1 & \cdots & S_j & \cdots & S_n - 1 \end{bmatrix}.\tag{29}$$

We use the properties of the determinant as a linear map between vectorial spaces, thus preserving linear combinations, i.e. adding to a column any linear combination of others columns does not change the value of the determinant. Since $\det(\mathcal{D}) = \det(\mathcal{D}^T)$, it also works with rows.

Let us prove by induction that:

$$\forall n \in \mathbb{N}^*, \mathcal{D}_n = (-1)^n \left(1 - \sum_{o \in \mathbb{V}} S_o \right).\tag{30}$$

For $n=1$, $\mathcal{D}_1 = -(S_1 - 1) = 1 - S_1$.

For $n=2$,

$$\begin{aligned}\mathcal{D}_2 &= \begin{vmatrix} S_1 - 1 & S_2 \\ S_1 & S_2 - 1 \end{vmatrix} \\ &= (S_1 - 1)(S_2 - 1) - S_1 S_2 \\ &= 1 - S_1 - S_2.\end{aligned}$$

Let us then assume that for any n ,

$$\mathcal{D}_{n-1} = \begin{vmatrix} S_1 - 1 & S_2 & \cdots & S_{n-1} \\ S_1 & S_2 - 1 & \cdots & S_{n-1} \\ \vdots & \vdots & \ddots & \vdots \\ S_1 & S_2 & \cdots & S_{n-1} \\ S_1 & S_2 & \cdots & S_{n-1} - 1 \end{vmatrix} = (-1)^{n-1} \left(1 - \sum_{o=1}^{n-1} S_o \right).$$

Let us consider \mathcal{D}_n the determinant of the matrix Φ defined in eq. (29). By adding the second row to the first, and adding to each row the following one, except of the last one gives us a simpler determinant for \mathcal{D}_n

$$\begin{aligned}\mathcal{D}_n &= \begin{vmatrix} S_1 - 1 & S_2 & \cdots & S_{n-1} & S_n \\ S_1 & S_2 - 1 & \cdots & S_{n-1} & S_n \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ S_1 & S_2 & \cdots & S_{n-1} & S_n \\ S_1 & S_2 & \cdots & S_{n-1} - 1 & S_n \\ S_1 & S_2 & \cdots & S_{n-1} & S_n - 1 \end{vmatrix} \\ &= \begin{vmatrix} -1 & 1 & \cdots & 0 & 0 \\ 0 & -1 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & 1 & 0 \\ 0 & 0 & \cdots & -1 & 1 \\ S_1 & S_2 & \cdots & S_{n-1} & S_n - 1 \end{vmatrix}.\end{aligned}\tag{31}$$

Developing by the first column (using Laplace expansion),

$$\mathcal{D}_n = (-1) \cdot \begin{vmatrix} -1 & \cdots & 0 & 0 \\ \vdots & \ddots & \vdots & \vdots \\ 0 & \cdots & 1 & 0 \\ 0 & \cdots & -1 & 1 \\ S_2 & \cdots & S_{n-1} & S_n - 1 \end{vmatrix} + (-1)^{n+1} S_1 \begin{vmatrix} 1 & 0 \cdots & 0 & 0 \\ -1 & 1 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & 1 & 0 \\ 0 & 0 & \cdots & -1 & 1 \end{vmatrix}. \quad (32)$$

The first of the two minors in (32) is simply \mathcal{D}_{n-1} with a change in indexing starting from S_2 to S_n . The second minor is triangular (no element above the diagonal), it's determinant is the product of the diagonal elements (all 1 in this case).

$$\begin{aligned} \mathcal{D}_n &= (-1)^n \left(1 - \sum_{o=2}^n S_o \right) + (-1)^{n+1} S_1 \\ &= (-1)^n \left(1 - \sum_{o=2}^n S_o - S_1 \right) \\ &= (-1)^n \left(1 - \sum_{o=1}^n S_o \right). \end{aligned}$$

A Appendix Figures

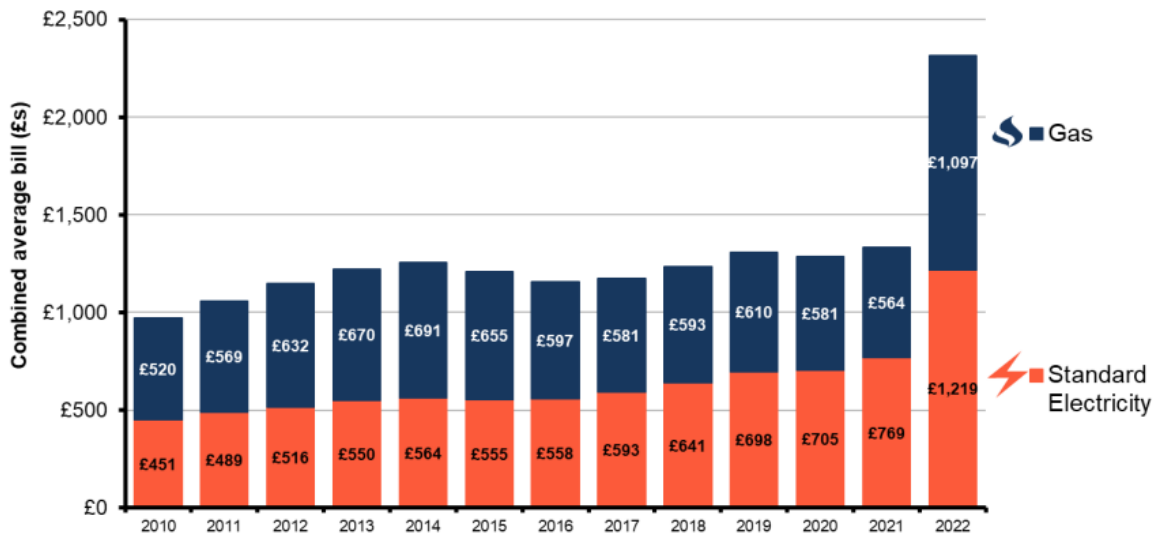


Figure A1: Average Standard Electricity and Gas bills - 2010 to 2022

Note: Data from *Department for Business, Energy & Industrial Strategy*

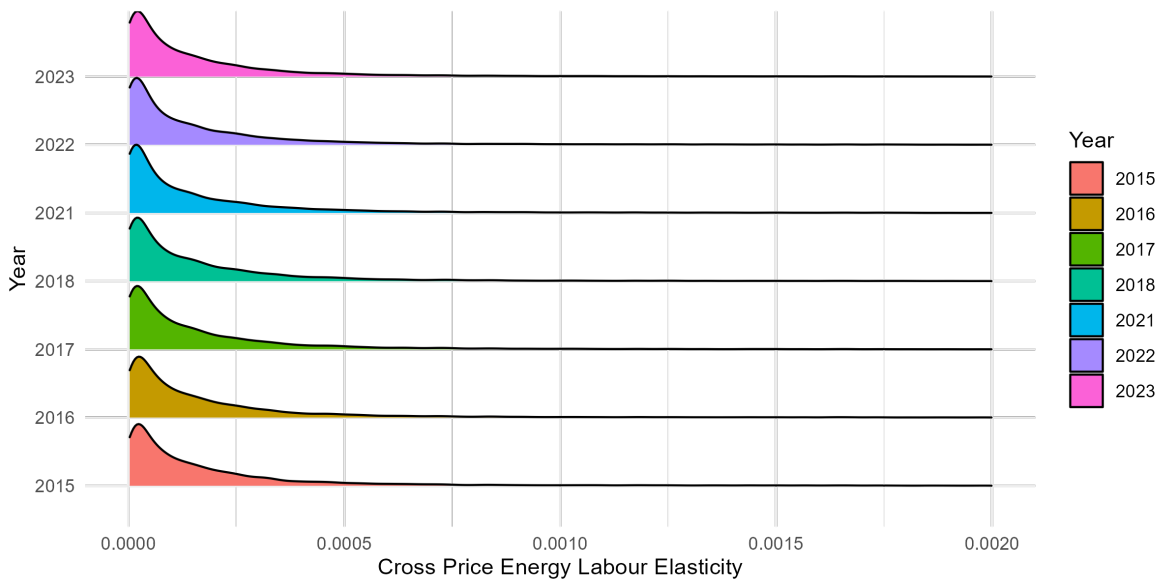


Figure A2: Cross-Price elasticities by year

Note: The graphs show cross-price elasticities between labor and energy 2015 to 2018 and from 2021 to 2023.

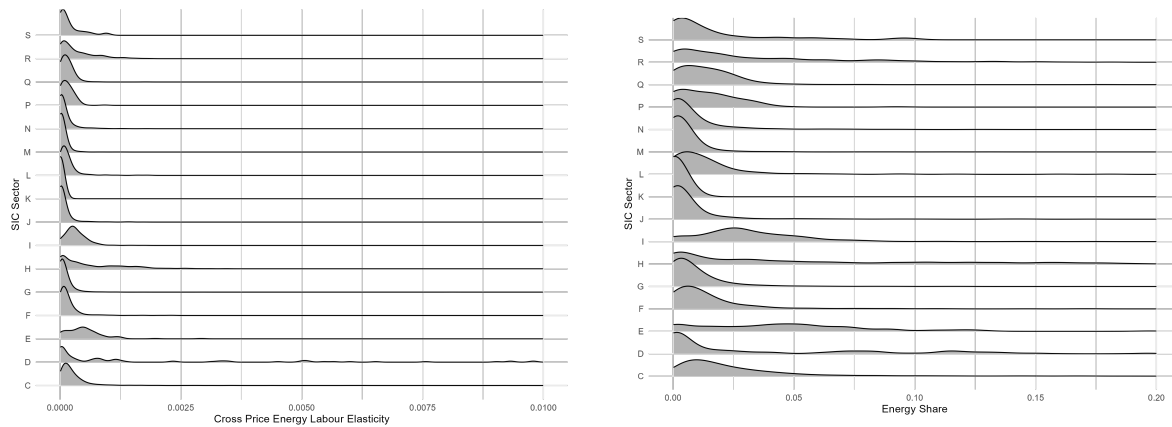


Figure A3: Cross price elasticities and energy shares by SIC sector in 2021
 Note: The graphs show a comparison between cross price elasticities and shares by SIC sector.

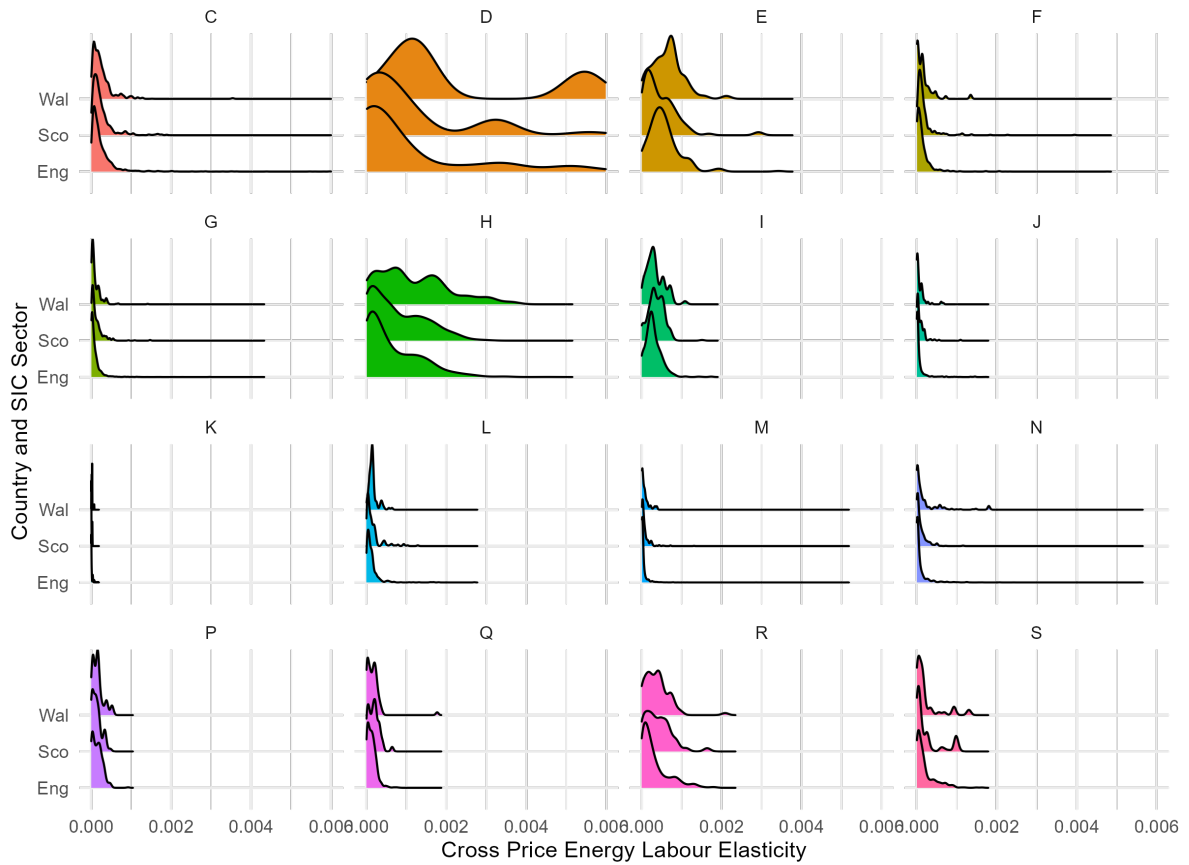


Figure A4: Cross Price Elasticities by sector and country in 2021

Note: The graphs show Cross Price Elasticities in 2021 by country and SIC sector. Northern Ireland is not included because the Northern Ireland Statistics and Research Agency (NISRA) does not allow sharing of micro data to external researcher.

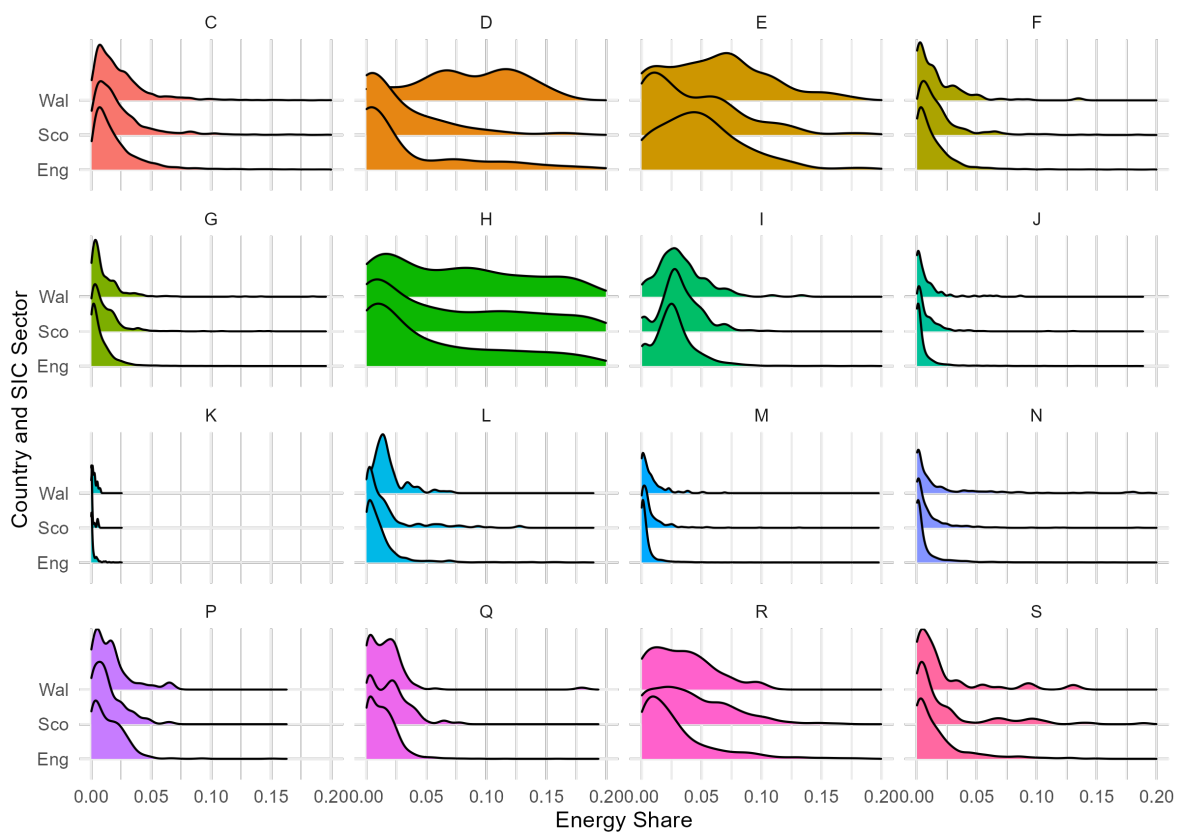


Figure A5: Energy Shares by country and sector in 2021

Note: The graphs show Energy Shares in 2021 by country and SIC sector. Northern Ireland is not included because the Northern Ireland Statistics and Research Agency (NISRA) does not allow sharing of micro data to external researcher.

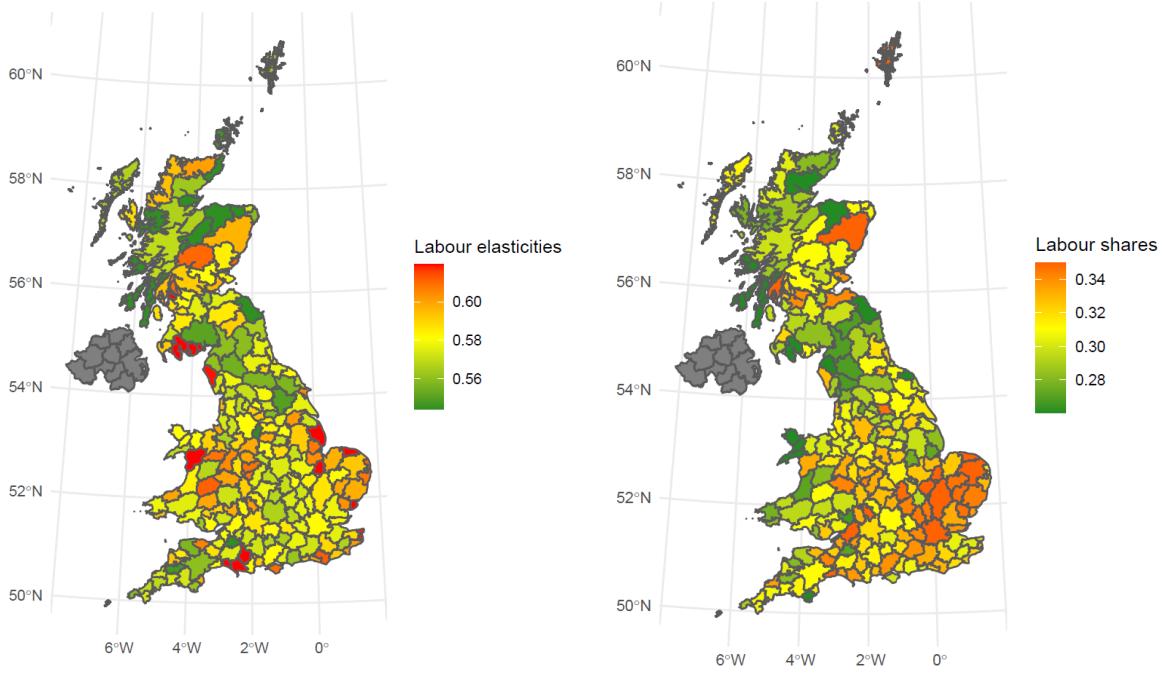


Figure A6: Labour elasticities and shares by TTWA in 2021

B Appendix Tables

Table B1: Sample by SIC section in 2021 and 2022

SIC Section	n	Percent
Agriculture, Forestry and Fishing	176	0.008
Mining and Quarrying	250	0.012
Manufacturing	4141	0.198
Electricity, gas, steam and air conditioning supply	262	0.013
Water supply, sewerage, waste management and remediation activities	289	0.014
Construction	1227	0.059
Wholesale and retail trade; repair of motor vehicles and motorcycles	4030	0.192
Transportation and storage	1028	0.049
Accommodation and food service activities	1220	0.058
Information and communication	1355	0.065
Financial and insurance activities	180	0.009
Real estate activities	498	0.024
Professional, scientific and technical activities	2142	0.102
Administrative and support service activities	2147	0.102
Education	287	0.014
Human health and social work activities	999	0.048
Arts, entertainment and recreation	545	0.026
Other service activities	183	0.009

Note: The table shows the sample sectors distribution for the years 2021-2022.

Table B2: Sample compared with ABS and APS 2018-2018 and 2021-2022

Year	Sample	ABS Universe	APS Universe
2015	8,290	45,652	22,500
2016	9,614	45,481	23,063
2017	10,071	46,725	24,410
2018	9,711	46,493	23,916
2021	9,789	44,304	19,541
2022	11,170	47,217	24,748

Note: The table shows the sample used in the analysis compared to the full sample of the APS and ABS from 2015 to 2018 and from 2021 to 2022.

Table B3: Jobs Lost by TTWA using Cross Price Elasticities

TTWA Code(s)	Employment	Percentage Jobs Lost
K01000002, W22000023, W22000011, W22000016, W22000009	3544	5.198679
S22000069, S22000023	18828	4.214910
E30000211, E30000056	12253	1.668892
E30000073, E30000289, E30000152	60565	1.421539
E30000168, E30000149	20189	1.265958
K01000007, K01000014	7229	1.114294
W22000025, W22000005, W22000021, W22000001, W22000033, W22000013	5725	0.978808
E30000121, E30000261	130386	0.813240
E30000106	19847	0.811146
E30000093	25099	0.798039
E30000198, E30000042, E30000074, E30000225	7413	0.794294
W22000006, W22000028	8844	0.790088
S22000073, S22000034, S22000011, S22000058, S22000030, S22000086, S22000062, S22000029, S22000032, S22000005	11841	0.741234
E30000264, E30000123, E30000083	13930	0.740261
E30000048, E30000202	45140	0.706235
E30000002, E30000160, E30000061	27385	0.684595
S22000085, S22000019, S22000054, S22000007	4852	0.664392
E30000154, E30000291, E30000119, E30000260	33593	0.618831
S22000071, S22000027	29467	0.614263
E30000126, E30000268	51155	0.605078
E30000158, E30000294	60092	0.585925
S22000061, S22000042, S22000014	23141	0.585214
E30000069, E30000222	36237	0.580694
E30000059, E30000214	13557	0.575303
E30000066, E30000219	18338	0.572123
E30000178, E30000263, E30000065, E30000021, E30000157, E30000293	6503	0.563032
E30000029	16553	0.561201
W22000002, W22000010, W22000022, W22000018	7847	0.560749
E30000097, E30000244	26212	0.556599
K01000006, K01000013	43254	0.533807
E30000116, E30000038, E30000195	77196	0.529264
E30000019, E30000176, E30000274, E30000146, E30000285	22162	0.526431
E30000080, E30000231	37505	0.525854
E30000134, E30000278	25057	0.518911
S22000041, S22000015, S22000051	6760	0.518549
E30000151, E30000095	22719	0.516860
E30000020, E30000177, E30000118, E30000259, E30000147, E30000088, E30000238	7728	0.510940
E30000043, E30000199, E30000215, E30000060, E30000012, E30000203	19804	0.510732
E30000140, E30000281	15992	0.508003
S22000084, S22000016, S22000004, S22000081	3415	0.497472
E30000035, E30000191	11479	0.497069
E30000150, E30000287, E30000135	7933	0.484258
E30000131, E30000275	38435	0.479233
E30000245, E30000098	189026	0.475587

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TTWA Code(s)	Employment	Percentage Jobs Lost
S22000044, S22000046, S22000080, S22000083, S22000066, S22000006, S22000021, S22000048	2995	0.472381
S22000072, S22000033, S22000043, S22000079, S22000053, S22000026, S22000051, S22000064, S22000002	9857	0.472254
E30000173, E30000096, E30000064	7431	0.470341
E30000017, E30000175	22177	0.467125
E30000107, E30000252, E30000139, E30000257, E30000051	7454	0.466903
E30000101, E30000248	47619	0.465955
S22000068, S22000022	12360	0.458632
E30000070	16283	0.456789
E30000170, E30000013	24655	0.453019
W22000029, W22000014, W22000008	10917	0.442288
E30000053, E30000209, K01000005	20395	0.441382
K01000003, K01000010	23411	0.435941
E30000254, E30000111	56363	0.434904
E30000276, E30000132	35295	0.433364
E30000185, E30000028, E30000092, E30000190, E30000034	43141	0.432664
E30000087, E30000242	92597	0.431637
E30000055, E30000210, E30000235, E30000084	29032	0.420813
E30000058, E30000030, E30000186	123480	0.413182
E30000045, E30000201	12255	0.411107
E30000037, E30000193	28715	0.403922
E30000090, E30000240	49137	0.398510
E30000122, E30000262	13813	0.396365
E30000161, E30000003	32120	0.394315
E30000041, E30000197	18061	0.391465
S22000009, S22000056	8039	0.388942
E30000192, E30000036, E30000277, E30000133	21412	0.387681
S22000076, S22000036, S22000074, S22000038	10984	0.385511
E30000205, E30000033, E30000189	25278	0.381003
E30000081, E30000233	96378	0.375126
E30000143, E30000288	36963	0.373100
E30000079, E30000230	157599	0.371696
K01000009, K01000001, S22000067, S22000020, S22000024, S22000063, S22000017	50814	0.358530
K01000008, W22000034	17570	0.356926
E30000110	48113	0.354777
E30000187, E30000031	23282	0.348281
E30000067, E30000220	83178	0.347798
E30000246, E30000114, E30000162, E30000099, E30000005	17739	0.342617
E30000223, E30000071, E30000076	34533	0.341698
E30000129, E30000272	46020	0.340307
E30000047, E30000208, E30000052	20662	0.338222
S22000057, S22000010, S22000025	21690	0.337149
E30000226, E30000075, E30000105, E30000279, E30000137	11027	0.336425
E30000227, E30000103, E30000125, E30000267	140950	0.335412
E30000145, E30000228	30760	0.334402
W22000030	6370	0.333792

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TTWA Code(s)	Employment	Percentage Jobs Lost
E30000009, E30000166	56975	0.328632
S22000060, S22000031	5676	0.328314
E30000024, E30000181, E30000010, E30000167, E30000224, E30000282, E30000141	5742	0.327027
E30000229, E30000078	222279	0.326424
E30000091, E30000241	6472	0.319443
E30000011, E30000169	206620	0.319016
S22000035, S22000013, S22000039	3360	0.317933
E30000144, E30000284	99413	0.316566
E30000148, E30000163, E30000286, E30000006, E30000290, E30000153	18330	0.314651
S22000047, S22000001	59654	0.314420
E30000018	35945	0.310650
E30000008, E30000165	10594	0.309260
S22000065, S22000018	210896	0.298184
E30000016, E30000174	17146	0.295106
W22000003	11601	0.293061
E30000204, E30000049	4366	0.284038
E30000194, E30000100, E30000247, E30000072	84637	0.281507
E30000112, E30000255	85347	0.281410
E30000182, E30000025	8502	0.280762
E30000266, E30000082, E30000234	1490429	0.276975
E30000001, E30000159	7068	0.276000
E30000015, E30000239, E30000089	355207	0.271069
E30000232, E30000180, E30000253, E30000270, E30000127, E30000109, E30000023	206764	0.268507
S22000037, S22000075	3754	0.267412
E30000044, E30000200	49934	0.267089
S22000008, S22000055	7202	0.264673
E30000014, E30000171	45865	0.262085
E30000102, E30000249	72049	0.258423
E30000039, E30000188, E30000032	32865	0.257476
E30000068, E30000221	12279	0.251904
E30000130, E30000273	52542	0.243922
S22000070, S22000028	25537	0.242029
E30000136, E30000050, E30000206	49047	0.238873
E30000094, E30000243	38565	0.236479
E30000183, E30000026	10186	0.235329
K01000004, K01000011	28706	0.234960
E30000179, E30000022	54270	0.234845
W22000032, W22000020	83076	0.227547
E30000104, E30000250	51688	0.226687
E30000086, E30000237	148674	0.224875
E30000085, E30000236, E30000063, E30000216	12485	0.220578
W22000024, W22000004	73699	0.220375
E30000004	46781	0.206600
E30000113, E30000256	111662	0.201658
E30000108	41154	0.195004
E30000138, E30000280	19962	0.194313
E30000040, E30000196	87516	0.193199
E30000184, E30000027	34224	0.191891
E30000142, E30000283	170268	0.188419
E30000057, E30000212	111653	0.183043

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TTWA Code(s)	Employment	Percentage Jobs Lost
E30000124, E30000054	49484	0.173093
W22000031, W22000019, W22000026, W22000012	18680	0.171739
S22000059, S22000012	116721	0.170219
E30000007, E30000164	30130	0.169728
E30000218, E30000156	73862	0.168670
E30000155, E30000292	18628	0.141943
E30000128, E30000271	9912	0.136854
E30000117, E30000258	6750	0.134489
E30000120, E30000172, E30000046	7723	0.124554

Notes: We calculated the jobs lost by TTWA (both 2001 and 2011 classification) for 2022 and 2023 by using cross price elasticities. For TTWAs with fewer than 10 observations (firms), we merged the analysis with neighboring TTWAs.

Table B4: Jobs Lost by TTWA using Energy Shares

TTWA Code(s)	Employment	Percentage Jobs Lost
S22000069, S22000023	18828	5.637081
K01000002, W22000023	3948	4.670149
E30000211, E30000056	12266	2.347716
E30000154, E30000291, E30000119, E30000260	33593	2.322247
E30000073, E30000289, E30000152	60565	2.070062
W22000006, W22000028	8844	1.937170
E30000264, E30000123, E30000083	13930	1.587568
S22000073, S22000034, S22000011, S22000058,	11841	1.581219
S22000030, S22000086, S22000062, S22000029,		
S22000032, S22000005		
E30000168, E30000149	20511	1.376713
E30000121, E30000261	130686	1.305750
E30000229, E30000078	222629	1.050057
E30000043, E30000199, E30000215, E30000060,	19806	1.049874
E30000012, E30000203		
K01000003, K01000010	23970	1.040294
W22000025, W22000005, W22000021, W22000001,	5725	1.035114
W22000033, W22000013		
E30000093	25252	1.028006
E30000198, E30000042, E30000074, E30000225	7419	1.025547
W22000002, W22000010, W22000022, W22000018	7847	0.990406
E30000151, E30000095	22719	0.904107
E30000106	19847	0.898655
W22000024, W22000004	74185	0.897521
S22000085, S22000019, S22000054, S22000007	4852	0.885168
E30000246, E30000114, E30000162, E30000099,	17739	0.858463
E30000005		
E30000014, E30000171	45910	0.852149
E30000019, E30000176, E30000274, E30000146,	22451	0.849222
E30000285		
K01000006, K01000013	43259	0.831821
E30000048, E30000202	45140	0.831141
E30000276, E30000132	35300	0.822955

Continued on next page

TTWA Code(s)	Employment	Percentage Jobs Lost
E30000178, E30000263, E30000065, E30000021, E30000157, E30000293	6503	0.794217
E30000090, E30000240	49137	0.790816
E30000055, E30000210, E30000235, E30000084 W22000015	29032	0.780735
W22000030	6370	0.765557
E30000066, E30000219	6370	0.765557
E30000142, E30000283	18338	0.760515
S22000071, S22000027	170268	0.754967
E30000087, E30000242	29534	0.743912
S22000035, S22000013, S22000039	92602	0.743497
E30000070	3360	0.742785
E30000126, E30000268	16283	0.734991
E30000059, E30000214	51254	0.725805
E30000002, E30000160, E30000061	13557	0.717830
E30000080, E30000231	27385	0.715055
E30000020, E30000177, E30000118, E30000259, E30000147, E30000088, E30000238	38222	0.710569
E30000192, E30000036, E30000277, E30000133	7728	0.708298
E30000173, E30000096, E30000064	21412	0.700140
E30000150, E30000287, E30000135	7444	0.695892
E30000069, E30000222	7933	0.694267
E30000131, E30000275	36606	0.665918
S22000061, S22000042, S22000014	38435	0.665168
E30000029	25467	0.655339
E30000134, E30000278	16553	0.651486
E30000045, E30000201	25057	0.640060
E30000037, E30000193	12255	0.637874
E30000097, E30000244	28715	0.625291
E30000140, E30000281	26235	0.625135
E30000035, E30000191	16102	0.617481
E30000144, E30000284	11586	0.611200
S22000041, S22000015, S22000051	101893	0.597253
E30000116, E30000038, E30000195	6760	0.597152
S22000084, S22000016, S22000004, S22000081	77199	0.595617
E30000101, E30000248	3415	0.585642
K01000008, W22000034	47887	0.585308
S22000037, S22000075	17570	0.585054
S22000076, S22000036, S22000074, S22000038	3754	0.581286
E30000185, E30000028, E30000092, E30000190, E30000034	10990	0.580944
E30000148, E30000163, E30000286, E30000006, E30000290, E30000153	43141	0.580078
E30000053, E30000209, K01000005	18330	0.576883
E30000136, E30000050, E30000206	20662	0.575847
E30000081, E30000233	49356	0.568143
E30000001, E30000159	98740	0.565303
E30000086, E30000237	7074	0.559803
E30000017, E30000175	151664	0.558263
W22000032, W22000020	21840	0.553759
E30000170, E30000013	83076	0.552212
W22000029, W22000014, W22000008	24993	0.548971
S22000009, S22000056	10917	0.547873
	8041	0.540664

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TTWA Code(s)	Employment	Percentage Jobs Lost
K01000007, K01000014	7234	0.534300
K01000009, K01000001, S22000067, S22000020, S22000024, S22000063, S22000017	50814	0.534190
S22000068, S22000022	12360	0.532425
S22000060, S22000031	5676	0.527622
E30000187, E30000031	23282	0.523051
E30000205, E30000033, E30000189	25286	0.522137
E30000016, E30000174	17146	0.520426
E30000245, E30000098	189542	0.520324
S22000072, S22000033, S22000043, S22000079, S22000053, S22000026, S22000051, S22000064, S22000002	10263	0.520014
E30000254, E30000111	56363	0.510748
S22000044, S22000046, S22000080, S22000083, S22000066, S22000006, S22000021, S22000048	2995	0.509241
E30000204, E30000049	4366	0.508526
E30000143, E30000288	36712	0.505522
S22000065, S22000018	212440	0.504124
E30000112, E30000255	86062	0.503022
E30000024, E30000181, E30000010, E30000167, E30000224, E30000282, E30000141	5742	0.502622
E30000067, E30000220	83193	0.501777
E30000011, E30000169	205659	0.497275
E30000158, E30000294	60127	0.493803
E30000015, E30000239, E30000089	361551	0.492322
E30000227, E30000103, E30000125, E30000267	141405	0.490925
E30000107, E30000252, E30000139, E30000257, E30000051	8893	0.489272
E30000122, E30000262	13813	0.489198
E30000129, E30000272	46020	0.487288
E30000110	48113	0.482276
E30000223, E30000071, E30000076	35630	0.479239
E30000161, E30000003	32246	0.478947
E30000091, E30000241	6526	0.469021
E30000041, E30000197	18061	0.464299
E30000079, E30000230	157897	0.461928
E30000183, E30000026	10186	0.457724
E30000226, E30000075, E30000105, E30000279, E30000137	11027	0.457582
S22000047, S22000001	62389	0.453407
E30000047, E30000208, E30000052	20662	0.445490
E30000104, E30000250	51799	0.435396
W22000003	11601	0.430147
E30000008, E30000165	10594	0.412677
E30000145, E30000228	31244	0.410537
K01000004, K01000011	28706	0.408044
E30000018	35978	0.402560
E30000266, E30000082, E30000234	1534372	0.401371
E30000232, E30000180, E30000253, E30000270, E30000127, E30000109, E30000023	215143	0.399529
E30000130, E30000273	52542	0.395566
E30000058, E30000030, E30000186	124056	0.391871
E30000102, E30000249	72590	0.387651

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TTWA Code(s)	Employment	Percentage Jobs Lost
S22000057, S22000010, S22000025	21690	0.365272
E30000094, E30000243	45214	0.362195
E30000179, E30000022	54270	0.358729
E30000009, E30000166	57256	0.357255
S22000008, S22000055	7202	0.352791
E30000004	46805	0.339665
E30000194, E30000100, E30000247, E30000072	85260	0.337381
E30000182, E30000025	8502	0.336183
E30000039, E30000188, E30000032	32868	0.332976
E30000007, E30000164	30275	0.326654
E30000138, E30000280	20728	0.326187
E30000044, E30000200	57376	0.322508
E30000108	41154	0.318588
S22000070, S22000028	25537	0.317096
E30000057, E30000212	116277	0.312921
E30000040, E30000196	88616	0.307895
E30000085, E30000236, E30000063, E30000216	12854	0.300443
E30000068, E30000221	12281	0.281363
S22000059, S22000012	117504	0.280301
E30000113, E30000256	115199	0.279146
E30000184, E30000027	34224	0.257280
E30000218, E30000156	73862	0.256032
E30000155, E30000292	18707	0.218827
W22000031, W22000019, W22000026, W22000012	18724	0.218081
E30000128, E30000271	9912	0.207840
E30000120, E30000172, E30000046	9047	0.193245
E30000117, E30000258	6750	0.164103
E30000124, E30000054	49484	0.103352

Notes: We calculated the jobs lost by TTWA (both 2001 and 2011 classification) for 2022 and 2023 by using energy shares. For TTWAs with fewer than 10 observations (firms), we merged the analysis with neighboring TTWAs.

Table B5: TTWA codes and names according to the 2001 nomenclature

TTWA	Area	TTWA	Area
E30000001	Andover	E30000002	Ashford
E30000003	Banbury	E30000004	Barnsley
E30000005	Barnstaple	E30000006	Barrow-in-Furness
E30000007	Basingstoke	E30000008	Bath
E30000009	Bedford	E30000010	Bideford
E30000011	Birmingham	E30000012	Bishop Auckland and Barnard Castle
E30000013	Blackburn	E30000014	Blackpool
E30000015	Bolton	E30000016	Boston
E30000017	Bournemouth	E30000018	Bradford
E30000019	Bridgwater	E30000020	Bridlington and Driffield
E30000021	Bridport and Lyme Regis	E30000022	Brighton
E30000023	Bristol	E30000024	Bude and Holsworthy
E30000025	Burnley, Nelson and Colne	E30000026	Burton upon Trent
E30000027	Bury St Edmunds	E30000028	Buxton
E30000029	Calderdale	E30000030	Cambridge
E30000031	Canterbury	E30000032	Chelmsford and Brain- tree
E30000033	Cheltenham and Eve- sham	E30000034	Chesterfield
E30000035	Chichester and Bognor Regis	E30000036	Clacton
E30000037	Colchester	E30000038	Coventry
E30000039	Craven	E30000040	Crawley
E30000041	Crewe and Northwich	E30000042	Cromer and Shering- ham
E30000043	Darlington	E30000044	Derby
E30000045	Doncaster	E30000046	Dorchester and Wey- mouth
E30000047	Dover	E30000048	Dudley and Sandwell
E30000049	Eastbourne	E30000050	Exeter and Newton Abbot
E30000051	Falmouth and Helston	E30000052	Folkestone
E30000053	Gloucester	E30000054	Grantham
E30000055	Great Yarmouth	E30000056	Grimsby

TTWA	Area	TTWA	Area
E30000057	Guildford and Aldershot	E30000058	Harlow and Bishop's Stortford
E30000059	Harrogate and Ripon	E30000060	Hartlepool
E30000061	Hastings	E30000062	Hawes and Leyburn
E30000063	Hereford and Leominster	E30000064	Hexham and Haltwhistle
E30000065	Honiton and Axminster	E30000066	Huddersfield
E30000067	Hull	E30000068	Huntingdon
E30000069	Ipswich	E30000070	Isle of Wight
E30000071	Kendal	E30000072	Kettering and Corby
E30000073	Kidderminster	E30000074	King's Lynn and Fakenham
E30000075	Kingsbridge and Dartmouth	E30000076	Lancaster and Morecambe
E30000077	Launceston	E30000078	Leeds
E30000079	Leicester	E30000080	Lincoln
E30000081	Liverpool	E30000082	London
E30000083	Louth and Horncastle	E30000084	Lowestoft and Beccles
E30000085	Ludlow	E30000086	Luton and Watford
E30000087	Maidstone and North Kent	E30000088	Malton and Pickering
E30000089	Manchester	E30000090	Mansfield
E30000091	Margate, Ramsgate and Sandwich	E30000092	Matlock
E30000093	Middlesbrough and Stockton	E30000094	Milton Keynes and Aylesbury
E30000095	Minehead	E30000096	Morpeth, Ashington and Alnwick
E30000097	Newbury	E30000098	Newcastle and Durham
E30000099	Northallerton and Thirsk	E30000100	Northampton and Wellingborough
E30000101	Norwich	E30000102	Nottingham
E30000103	Okehampton	E30000104	Oxford
E30000105	Paignton and Totnes	E30000106	Penrith and Appleby
E30000107	Penzance and Isles of Scilly	E30000108	Peterborough
E30000109	Plymouth	E30000110	Poole
E30000111	Portsmouth	E30000112	Preston

TTWA	Area	TTWA	Area
E30000113	Reading and Bracknell	E30000114	Richmond and Catterick
E30000115	Rochdale and Oldham	E30000116	Rugby
E30000117	Salisbury	E30000118	Scarborough
E30000119	Scunthorpe	E30000120	Shaftesbury and Blandford Forum
E30000121	Sheffield and Rotherham	E30000122	Shrewsbury
E30000123	Skegness	E30000124	South Holland
E30000125	Southampton	E30000126	Southend and Brentwood
E30000127	St Austell	E30000128	Stafford
E30000129	Stevenage	E30000130	Stoke-on-Trent
E30000131	Sunderland	E30000132	Swindon
E30000133	Taunton	E30000134	Telford and Bridgnorth
E30000135	Thetford and Mildenhall	E30000136	Tiverton
E30000137	Torquay	E30000138	Trowbridge and Warminster
E30000139	Truro, Redruth and Camborne	E30000140	Tunbridge Wells
E30000141	Wadebridge	E30000142	Wakefield and Castleford
E30000143	Walsall and Cannock	E30000144	Warrington and Wigan
E30000145	Warwick and Stratford-upon-Avon	E30000146	Wells and Shepton Mallet
E30000147	Whitby	E30000148	Whitehaven
E30000149	Wirral and Ellesmere Port	E30000150	Wisbech
E30000151	Wolverhampton	E30000152	Worcester and Malvern
E30000153	Workington and Keswick	E30000154	Worksop and Retford
E30000155	Worthing	E30000156	Wycombe and Slough
E30000157	Yeovil and Chard	E30000158	York
K01000001	Berwick	K01000002	Brecon
K01000003	Carlisle	K01000004	Chester and Flint
K01000005	Monmouth and Cinderford	K01000006	Newport and Cwmbran

TTWA	Area	TTWA	Area
K01000007	Oswestry	K01000008	Wrexham and Whitchurch
S22000001	Aberdeen	S22000002	Ayr and Kilmarnock
S22000003	Badenoch	S22000004	Banff
S22000005	Campbeltown	S22000006	Dornoch and Lairg
S22000007	Dumbarton	S22000008	Dumfries and Annan
S22000009	Dundee	S22000010	Dunfermline
S22000011	Dunoon and Bute	S22000012	Edinburgh
S22000013	Eilean Siar	S22000014	Falkirk
S22000015	Forfar and Montrose	S22000016	Fraserburgh
S22000017	Galashiels and Peebles	S22000018	Glasgow
S22000019	Greenock	S22000020	Hawick
S22000021	Invergordon	S22000022	Inverness and Ding- wall
S22000023	Irvine and Arran	S22000024	Kelso and Jedburgh
S22000025	Kirkcaldy and Glen- rothes	S22000026	Kirkcudbright
S22000027	Lanarkshire	S22000028	Livingston and Bath- gate
S22000029	Lochaber	S22000030	Lochgilphead
S22000031	Moray	S22000032	Mull and Islay
S22000033	Newton Stewart and Wigtown	S22000034	Oban
S22000035	Orkney Islands	S22000036	Perth and Blairgowrie
S22000037	Peterhead	S22000038	Pitlochry
S22000039	Shetland Islands	S22000040	Skye and Lochalsh
S22000041	St Andrews and Cupar	S22000042	Stirling and Alloa
S22000043	Stranraer	S22000044	Thurso
S22000045	Ullapool and Gairloch	S22000046	Wick
W22000001	Aberystwyth and Lam- peter	W22000002	Bangor, Caernarfon and Llangefni
W22000003	Bridgend	W22000004	Cardiff
W22000005	Cardigan	W22000006	Carmarthen and Llan- doverly
W22000007	Dolgellau and Bar- mouth	W22000008	Ebbw Vale and Aber- gavenny
W22000009	Haverfordwest and Fishguard	W22000010	Holyhead
W22000011	Llandrindod Wells and Builth Wells	W22000012	Llandudno and Col- wyn Bay

TTWA	Area	TTWA	Area
W22000013	Machynlleth and Tywyn	W22000014	Merthyr Tydfil and Aberdare
W22000015	Newtown and Welshpool	W22000016	Pembroke and Tenby
W22000017	Porthmadog and Ffestiniog	W22000018	Pwllheli
W22000019	Rhyl and Denbigh	W22000020	Swansea Bay

Table B6: TTWA codes and names according to the 2011 nomenclature

TTWA	Area	TTWA	Area
E30000004	Barnsley	E30000018	Bradford
E30000029	Halifax	E30000039	Skipton
E30000046	Dorchester and Weymouth	E30000051	Falmouth
E30000054	Grantham	E30000061	Hastings
E30000064	Hexham	E30000070	Isle of Wight
E30000076	Lancaster and Morecambe	E30000093	Middlesbrough and Stockton
E30000095	Minehead	E30000106	Penrith
E30000108	Peterborough	E30000110	Poole
E30000124	Spalding	E30000135	Thetford and Mildenhall
E30000147	Whitby	E30000159	Andover
E30000160	Ashford	E30000161	Banbury
E30000162	Barnstaple	E30000163	Barrow-in-Furness
E30000164	Basingstoke	E30000165	Bath
E30000166	Bedford	E30000167	Bideford
E30000168	Birkenhead	E30000169	Birmingham
E30000170	Blackburn	E30000171	Blackpool
E30000172	Blandford Forum and Gillingham	E30000173	Blyth and Ashington
E30000174	Boston	E30000175	Bournemouth
E30000176	Bridgwater	E30000177	Bridlington
E30000178	Bridport	E30000179	Brighton
E30000180	Bristol	E30000181	Bude
E30000182	Burnley	E30000183	Burton upon Trent
E30000184	Bury St Edmunds	E30000185	Buxton
E30000186	Cambridge	E30000187	Canterbury
E30000188	Chelmsford	E30000189	Cheltenham
E30000190	Chesterfield	E30000191	Chichester and Bognor Regis
E30000192	Clacton	E30000193	Colchester
E30000194	Corby	E30000195	Coventry
E30000196	Crawley	E30000197	Crewe
E30000198	Cromer and Sheringham	E30000199	Darlington
E30000200	Derby	E30000201	Doncaster
E30000202	Dudley	E30000203	Durham and Bishop Auckland

TTWA	Area	TTWA	Area
E30000204	Eastbourne	E30000205	Evesham
E30000206	Exeter	E30000208	Folkestone and Dover
E30000209	Gloucester	E30000210	Great Yarmouth
E30000211	Grimsby	E30000212	Guildford and Alder- shot
E30000214	Harrogate	E30000215	Hartlepool
E30000216	Hereford	E30000218	High Wycombe and Aylesbury
E30000219	Huddersfield	E30000220	Hull
E30000221	Huntingdon	E30000222	Ipswich
E30000223	Kendal	E30000224	Kettering and Welling- borough
E30000225	King's Lynn	E30000226	Kingsbridge and Dart- mouth
E30000227	Launceston	E30000228	Leamington Spa
E30000229	Leeds	E30000230	Leicester
E30000231	Lincoln	E30000232	Liskeard
E30000233	Liverpool	E30000234	London
E30000235	Lowestoft	E30000236	Ludlow
E30000237	Luton	E30000238	Malton
E30000239	Manchester	E30000240	Mansfield
E30000241	Margate and Rams- gate	E30000242	Medway
E30000243	Milton Keynes	E30000244	Newbury
E30000245	Newcastle	E30000246	Northallerton
E30000247	Northampton	E30000248	Norwich
E30000249	Nottingham	E30000250	Oxford
E30000252	Penzance	E30000253	Plymouth
E30000254	Portsmouth	E30000255	Preston
E30000256	Reading	E30000257	Redruth and Truro
E30000258	Salisbury	E30000259	Scarborough
E30000260	Scunthorpe	E30000261	Sheffield
E30000262	Shrewsbury	E30000263	Sidmouth
E30000264	Skegness and Louth	E30000266	Slough and Heathrow
E30000267	Southampton	E30000268	Southend
E30000270	St Austell and Newquay	E30000271	Stafford
E30000272	Stevenage and Welwyn Garden City	E30000273	Stoke-on-Trent
E30000274	Street and Wells	E30000275	Sunderland
E30000276	Swindon	E30000277	Taunton

TTWA	Area	TTWA	Area
E30000278	Telford	E30000279	Torquay and Paignton
E30000280	Trowbridge	E30000281	Tunbridge Wells
E30000282	Wadebridge	E30000283	Wakefield and Castleford
E30000284	Warrington and Wigan	E30000285	Weston-super-Mare
E30000286	Whitehaven	E30000287	Wisbech
E30000288	Wolverhampton and Walsall	E30000289	Worcester and Kidderminster
E30000290	Workington	E30000291	Worksop and Retford
E30000292	Worthing	E30000293	Yeovil
E30000294	York	K01000005	Cinderford and Ross-on-Wye
K01000009	Berwick	K01000010	Carlisle
K01000011	Chester	K01000013	Newport
K01000014	Oswestry	N12000001	Ballymena
N12000002	Belfast	N12000003	Coleraine
N12000004	Cookstown and Magherafelt	N12000005	Craigavon
N12000006	Derry	N12000007	Dungannon
N12000008	Enniskillen	N12000009	Newry and Banbridge
N12000010	Omagh and Strabane	S22000005	Campbeltown
S22000013	Western Isles	S22000032	Mull and Islay
S22000035	Orkney Islands	S22000039	Shetland Islands
S22000047	Aberdeen	S22000048	Alness and Invergor-don
S22000049	Arbroath and Montrose	S22000050	Aviemore and Grantown-on-Spey
S22000051	Ayr	S22000052	Broadford and Kyle of Lochalsh
S22000053	Dalbeattie and Castle Douglas	S22000054	Dumbarton and Helensburgh
S22000055	Dumfries	S22000056	Dundee
S22000057	Dunfermline and Kirkcaldy	S22000058	Dunoon and Rothesay
S22000059	Edinburgh	S22000060	Elgin
S22000061	Falkirk and Stirling	S22000062	Fort William
S22000063	Galashiels and Peebles	S22000064	Girvan
S22000065	Glasgow	S22000066	Golspie and Brora
S22000067	Hawick and Kelso	S22000068	Inverness
S22000069	Kilmarnock and Irvine	S22000070	Livingston

TTWA	Area	TTWA	Area
S22000071	Motherwell and Air- drie	S22000072	Newton Stewart
S22000073	Oban	S22000074	Perth
S22000075	Peterhead	S22000076	Pitlochry and Aber- feldy
S22000077	Portree	S22000078	St Andrews and Cupar
S22000079	Stranraer	S22000080	Thurso
S22000081	Turriff and Banff	S22000082	Ullapool
S22000083	Wick	S22000084	Fraserburgh
S22000085	Greenock	S22000086	Lochgilphead
W22000003	Bridgend	W22000009	Haverfordwest and Milford Haven
W22000011	Llandrindod Wells and Builth Wells	W22000015	Newtown and Welsh- pool
W22000016	Pembroke and Tenby	W22000021	Aberystwyth
W22000022	Bangor and Holyhead	W22000023	Brecon
W22000024	Cardiff	W22000025	Cardigan
W22000026	Colwyn Bay	W22000028	Llanelli
W22000029	Merthyr Tydfil	W22000030	Pwllheli and Porth- madog
W22000031	Rhyl	W22000032	Swansea
W22000033	Tywyn and Dolgellau	W22000034	Wrexham